Calculate the Rate of Natural Radioactivity in the Soil of Some Schools Using the NaI(Tl) Detector in the City of Hilla-Iraq

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ABSTRACT

Activities and risk markers in 15-20 cm soil samples from Hilla City schools were thoroughly examined. This was made possible by the NaI(Tl) detector. The results indicated that the specific activity values for ^{238}U from 2.244±0.06 Bqkg^{-1} to 23.637±0.60 Bqkg^{-1}, with an average value of 11.70±0.39 Bqkg^{-1}. Similar to ^{232}Th, the average specific activity level was 8.53±0.31 Bqkg^{-1}, ranging between 1.603±0.09 Bqkg^{-1} and 21.503±0.56 Bqkg^{-1}. For ^{40}K, its specific activity range was 222.96±2.72 to 441.824±2.78 Bqkg^{-1}, with an average of 375.32±2.71 Bqkg^{-1}. The average radiative forcing of the radium equivalent (Ra_{eq}) was calculated to be 52.80 Bqkg^{-1}. The external risk index (H_{ex}) was 0.14, and the internal risk index (H_{in}) was 0.17. The gamma risk index (Iγ) was determined to be 0.41. Also, the average outdoor absorbed dose level D_{out} is 26.35 nGyh^{-1}, while the average indoor absorbed dose level D_{in} is 50.54 nGyh^{-1}. The average annual values of effective dose equivalents (internal and external) are 0.03 and 0.25 nGyh^{-1}. The additional lifetime cancer risk $ELCR_{(t)}$ due to natural radioactivity in the models was 0.93x10^{-3}. Note that the global average permissible nuclide concentration was 30, 32, and 420, and the danger index values were 1, 1, 6, 59, 84, 0.4, 0.07, and 1.45, respectively, based on the report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). After carefully comparing the study results with permissible global averages, they fit well within the recommended range.

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1. Introduction

Radiation is a complex and multifaceted phenomenon that encompasses both natural and man-made sources. Natural background radiation comes from space, the sun, and radioactive elements in the Earth's crust. Human activities such as medical X-rays, nuclear power plants, and specific industrial processes can contribute to radiation exposure. Various forms of radiation possess different levels of penetration and tissue-damaging capabilities[1,2]. Scientists meticulously examine natural radioactive in geological formations to understand the quantity and impact of radioactivity, particularly focusing on decay byproducts. These byproducts also can be radioactive, and their production and spread in the environment are big topics to consider. It is possible to detect the presence of naturally existing radionuclides like U-238, Th-232, and K-40. Interpretation of environmental pollution in rocks and soil will be the next discussion[3]. Humans may constantly be exposed to naturally occurring radiation from cosmic rays and the elements, but the exposure to artificially created rays from medical tests such as X-rays is simply limited. The natural radioactivity on Earth arises from radioactive isotopes usually present in the Earth's crust and decay products of naturally occurring radioactive materials. Rocks and soil are composed of Uranium-238 (U-238), Thorium-232 (Th-232), and Potassium-40 (K-40) which are the background radiation sources. These naturally occurring radionuclides, while being radioactive the contaminants may also be toxic and harmful to the environment[4]. Ingesting or breathing in radioactive materials, whether naturally occurring or man-made, can negatively impact health. Local geological circumstances can cause variations in environmental radiation levels and external exposure to gamma radiation, contributing to the average gamma radiation dosage people receive[5]. This dose is a cumulative statistical model. The amount of natural radioactivity in soil is gauged using essential methods for calculating the level of natural background radiation and identifying any potential leaks or timely releases of radioactive materials. This information is highly valuable. In the past two decades, a multitude of national surveys have been conducted by researchers across the globe The reason for investigating the activity of natural nuclides in school soil is the lack of field research covering such a study in the soil of schools located in the study area, in addition to the absence of a radiological map of the city of Hilla and the absence of national values at the permissible levels for Iraq, such as those available in the Arab world and the world. Therefore, this study aims to evaluate the natural radioactivity of ^{238}U, ^{232}Th, and ^{40}K as well as to

evaluate the risks of radioactive effects resulting from exposure to radioactivity in soil samples collected from different schools in the city of Hilla using gamma-ray spectroscopy.

2. Materials and Methods

2.1 Getting the samples ready

Twenty schools were selected in the city center of Hilla, and soil samples were collected for this study. The purpose of the study was to assess the radiation levels in these soil samples, focusing on radionuclides such as uranium-238, thorium-232, and potassium-40. The research had been done in the Research Laboratory for Advanced Studies, which is part of the Physics Department, College of Sciences at the University of Babylon. The laboratory experiments were performed on the basis of the agency manual and the IAEA's guidelines. Once the samples were gathered from the designated site, the collected soil samples were comprehensively cleaned in order to exclude the presence of extraneous materials; thereafter, the samples were stored in nylon bags. Having receiving them from the field, our task was to glue labels on them and date them. The purification process is the threshold for discarding unnecessary contaminants, including gravel and plant roots, from the species[6,7]. The electric oven was utilized as the apparatus in this laboratory test to remove moisture from the study samples through exposure of the samples to a 90-degree Celsius thermal condition for 90 minutes. Therefore, to get consistent sample particles of the same size, a 1 kg electric grinder was used for grinding the samples, which ran for 15 minutes. Further on, impurities were strained out with the help of screening. Samples saved in 1-L Marnell beakers before screening and analysis for one month were the safeguard mechanism to also ensure the presence of radioactive secular balance. These studies were conducted beforehand to determine the amount of radioactivity in the natural radiological traces that were used for the test[8].

2.2 The system of nuclear detectors

A digital technique was employed to ascertain the level of nuclear radiation caused by naturally occurring radionuclides in the samples under investigation. The system comprises a NaI (TI) detector and a 4096 multi-channel analyzer (MCA). The analog-to-digital converter links to the detector crystal to convert the radiation-induced pulse into digital data. The computer application MAESTRO-23 analyzes all these processes[9,10]. The spectrophotometer system was correctly calibrated thanks to the calibration process, which took into account both power response and counting efficiency. The energy peaks for thorium-208 (2614 keV), beryllium-214 (1763 keV),

and kalium-40 (1460 keV) were identified during the investigation of the soil samples[12]. For each of the aforementioned decay series, the resolution of the crystal detector, a critical component for obtaining accurate measurements, was determined. For thorium-232, uranium-238, and potassium-40, accuracy values of 0.0444, 0.0555, and 0.066 were achieved correspondingly. By publishing standard gamma emission elements with known energy values, energy response calibration validation was performed[11,12]. In order to ensure consistent and accurate power calibration, these calibration sources were placed above the detector with geometric uniformity in shape and distance from the sample, as shown in **Fig. 1**.

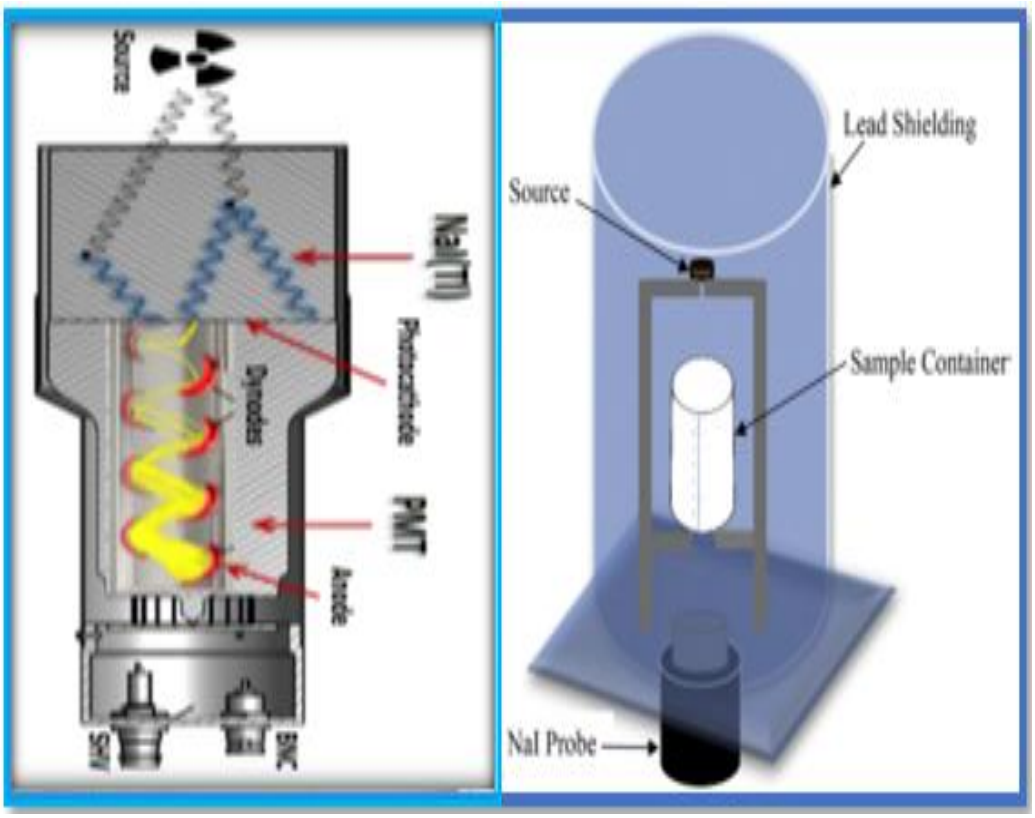

Figure 1: Schematic diagram and photograph of the shielding chamber[4].

3. Radioactivity measurements of samples

Following the radiation background assessment calculating energy and efficiency detector, intensity of activity, and danger the following formulae calculate the indicators.

3.1 Specific Activity

The specific activity of a given model acquires utmost importance in the field of radioactivity analysis since it gives a measurement of its intrinsic radioactivity on a per-unit-mass basis, denoted as Bq kg^{-1} or Ci g^{-1}. This crucial parameter, which quantifies the sample's radiological potency, is used to determine the specific activity (A) of a given sample[5,13]:

$$A(BqKg^{-1}) = \frac{N}{t \times \varepsilon \times I_\gamma \times m} \quad (1)$$

Where: N is the area under the photo peak, t is the counting time in seconds, I_γ is the probability of gamma emission, m is the sample weight in kilograms, and Ɛ is the detector's efficiency at a certain gamma energy. The aforementioned formula contains a thorough process for determining a sample's particular activity and provides a quantitative understanding of its radioactivity per unit mass. Underscoring the accuracy and dependability built into radiological investigations of this kind is this rigorous approach to measurement, which is rooted in the interaction of physical and temporal characteristics.

3.2 Evaluation of Outdoor and Indoor External Doses

Absorption of radioactive gamma rays, either directly or indirectly from natural or artificial sources, by the human body leads to the formation of accumulated radiation and if this radiation is not dissipated on time, it could lead to more serious negative effects on the health of the body and individual. Therefore, that can be a cancer risk and a possibility of getting genetic mutations over time as a result. Generally, it is known for the dose rate adsorbed on the planet's atmosphere, mainly at one meter above the surface. The radiation doses on the inside and outside must also be taken into account to avoid excessive radiation exposure. Consisting of radioactive dose equivalents from the naturally composed radioisotopes, namely, ^{238}U, ^{232}Th, and ^{40}K[14]. Equation (2) enables the computation of the external dose at a distance of 1 meter from the ground, and it is expressed as: Equation (2) enables the computation of the external dose at a vertical distance of 1 meter from the ground, and it is expressed as:

$$D_{out}\ (nGyh^{-1}) = 0.4620A_U + 0.6210A_{Th} + 0.04170A_K \quad (2)$$

Additionally, equation (3), which is defined as follows, is used to estimate the indoor external dose (D_{in}) caused by the presence of ^{238}U, ^{232}Th, and ^{40}K in indoor environments[15].

$$D_{in}\ (nGyh^{-1}) = 0.920A_U + 1.10A_{Th} + 0.0810A_K \quad (3)$$

These equations entail a methodical approach for finding the dose of external rays that the decay of ^{238}U, ^{232}Th and ^{40}K isotopes can bring resulting from the distribution of those elements in both indoor and outdoor conditions. Specifying for each isotope the characteristics of a new kind of radioactivity explains the overall uncertainty together with the other factors, contributing to the emergence of a full understanding of the radiation dynamics.

3.3 Radium Equivalent Activity (Ra_{eq}) for Assessing Radioactive Hazards

Having a radium equivalent activity (Ra_{eq}) index as a key indicator of the activities of the three specific natural radionuclides, i.e., ^{232}Th, ^{238}U, and ^{40}K, assimilated within the given substance, is an important step for assessing the extent of radiation hazards in a particular area. Such an indicator is a useful property for the risk assessment of the materials containing those radionuclides, the values being measured in $Bqkg^{-1}$ units. The Ra_{eq} index computes the cumulated exposure to the alpha and beta-radiation emissions of ^{232}Th, ^{238}U, and ^{40}K; this comprehensive result is useful for a comprehensive assessment of the basic health risk of radiation exposure. The mathematical equation for setting Ra_{eq} is given by[16]:

$$Ra_{eq}\ (Bqkg^{-1}) = A_U + 1.430A_{Th} + 0.0770A_K \quad (4)$$

The Ra_{eq} index, which is based on this mathematical framework, provides a useful and efficient way to understand and evaluate the cumulative radioactivity risk posed by materials containing ^{232}Th, ^{238}U, and ^{40}K.

3.4 Radiation Hazard Indices Calculation

To examine the health risks that are induced by the external gamma radiation and by the radioactive sources, which are soil-derived, measuring critical indicators of radiation hazards in radiation risk assessment is of significant importance. This will be helpful to set forth the facts and to see whether the health aspect is unavoidable. The outward risk index (H_{ex}) and inward risk index (H_{in}) are the key elements that determine the general risk index. The grouping of these indicators depends on the nature of the specific algorithms. Thus, the data processed reflects the radiation safety of the item or any remarks. The priority of danger is managed by the integral of the external radiation absorbed by the body (H_{ex}) and the H_{in} index, which is a measure of the internal hazard of radioactivity[17]. The original one is connected to the gamma-ray exposure, while the next one

has the radioisotope intake connection. The evaluation of these indicators is performed by applying the following equations:

$$H_{ex}= \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (5)$$

$$H_{in}= \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (6)$$

3.5 The Representative Level Index (I_γ) calculation

The index of radiological equivalent for gamma parameters (Iγ) is an important parameter while analyzing the potential hazards of gamma radiation from naturally occurring radioactive nuclides found in soils. The index is a useful tool not only for assessing the extent of bombardment of the population but also for linking the corresponding radionuclides that lead to a hazardous situation. The evaluated level of danger from radiation (the danger level of these nuclides) can be determined by using this formula[18,19]:

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (7)$$

The isotropic level index (I_γ) is a quantitative method applied for the purposes of measuring exposure to high dose gamma radiation resulting from the process of accumulation of radiotoxicity in soil. The human body experiences gamma radiation emitted by radionuclides. An I_γ value of less than one indicates that the risk of health problems will be minimal and that it will remain within acceptable radiation levels set by safety guidelines. Using this indicator, we will step by step monitor and manage the effect of radiation on the detection of soil samples and eventually.

3.6 Annual Effective Dose Equivalence (AEDE) Evaluation

The annual effective dose equivalent (AEDE) is the preferred method for assessing the nuclear radiation activity impact on human health over a one-year span. The radiation dose inside and outside the body of an individual is determined by adding the doses of radioactive materials into the individual's body and the corresponding multifarious conversion factors. While doing the AEDE assessment, it considers both indoor and outdoor exposure, offering a detailed overview of the health risks involved[20,21].

$$AEDE_{out} = \left[D_{out}\left(\frac{nGy}{h}\right) \times 8766\left(\frac{h}{y}\right) \times 0.2 \times 0.70\left(\frac{10^3 mSv}{10^9 nGy}\right)\right] = D_{out} \times 1.226 * 10^{-3} (mSvy^{-1}) \quad (8)$$

$$AEDE_{in} = \left[D_{in}\left(\frac{nGy}{h}\right) \times 8766\left(\frac{h}{y}\right) \times 0.80 \times 0.70\left(\frac{10^3 mSv}{10^9 nGy}\right)\right] = D_{in} \times 4.905 * 10^{-3} (mSvy^{-1}) \quad (9)$$

The AEDE Parameter, a parameter that monitors annual dosage in effective units expressed in milliseconds of sievert (mSv), is a paramount, indispensable tool for the assessment of possible health effects related to ionizing radiation. Besides that, a detailed approach for the assessment of the exposure to radiation helps health authorities determine the responsible steps to be taken and the decisions of the legislators to keep people safe and healthy. Individuals belonging to the general public should be allotted a total amount of radiation that is lower than the minimum standard amount that is set by the International Commission on Radiological Protection. As for the computation of the annual radiation dose, all possible ways of exposure are being taken into account. So, together with both normal and excessive usage of consumer goods containing NORM(s), this dose is the cumulative one. Consequently, the total radiation dose can be attributed to the sum of different fractions of radiation dose caused by all likely exposure routes (referred to as D_{total} in millisieverts per year, $mSvy^{-1}$). Such routes of reaction include an internal one, characterized by the inhalation and ingestion of radionuclides that lead to deep-tissue penetration, and an external one, characterized by the ability of gamma rays to travel through tissue and interfere directly with cells. The calculation of D_{total} is explained by this mathematical formula[2]:

$$D_{total}(mSvy^{-1}) = D_{ext.} + D_{int(inh)} + D_{int(ing)} \quad (10)$$

Where: The total radiation dose, D_{total}, is measured in $mSvy^{-1}$. $D_{ext.}$ is the annual external dosage from direct gamma radiation. Annual internal dose ($D_{int(inh)}$) owing to inhalation route in $mSvy^{-1}$. Annual internal dosage of $D_{int(ing)}$ owing to ingestion pathway in $mSvy^{-1}$.

3.7 Exceeding Lifetime Cost Risk (ELCR) Calculation

In the context of radiological health risk assessment, ELCR (excess lifetime cancer risk) estimation is of major importance since it allows for the prediction of the potential long-term health damage-causing effects of ionizing radiation exposure. This treat contains a set of formulas that significantly minimize exposure variables. The definition of ELCR focuses on sources of both outdoor and indoor radiation, along with a number of other considerations that improve the overall

image of the risk from these sources[22,23]. The following is a description of the ELCR calculation formula:

$$(ELCR)_{out} = E \times RF \times LE \quad (11)$$

$$(ELCR)_{in} = E \times RF \times LE \quad (12)$$

The ELCR parameter serves as a basic perception of the possibility of this increased risk of cancer by drawing on an individual's experience that lasts a lifetime of exposure to ionizing radiation. Similarly, this computational procedure allows for developing data-driven risk assessments and evidence-based decision-making approaches that consider various exposure factors and advantage public health.

4. Results and discussion

4.1 Specific Activity and $Ra_{(eq)}$

In the research conducted, the activity concentrations of ^{40}K, ^{238}U, ^{232}Th, and radium equivalents were measured for 20 soil samples collected from different schools in Al-Hilla city. These values fall within the acceptable range when compared to the average values around the world reported by the United Nations Scientific Committee on the Effects of Radiation. (UNSCEAR 2000)[24]. In Table 1, activity concentrations recorded range from 222.96±2.72 $Bqkg^{-1}$ (sample HS_8) to 419.824±2.78 $Bqkg^{-1}$ (HS_7) for ^{40} K, with a calculated mean of 375.32±2.71 $Bqkg^{-1}$. Similarly, for ^{238}U the range extends from 2.244±0.06 $Bqkg^{-1}$ for (HS_{11}) to 23.637±0.60 $Bqkg^{-1}$ for (HS_{19}), with an average of 11.70±0.39 $Bqkg^{-1}$. Activity concentrations of ^{232}Th include a range from 1.603±0.09 $Bqkg^{-1}$ (sample HS_4) to 21.503±0.56$Bqkg^{-1}$ (sample HS_7), resulting in an average of 8.53±0.31 $Bqkg^{-1}$. As for radium equivalent (Ra_{eq}), the range extends from 34.25±5.986 $Bqkg^{-1}$ for (HS_{20}) to 74.40±12.40 $Bqkg^{-1}$ (Model HS_1), with a calculated mean of 52.80±8.55 $Bqkg^{-1}$. These observations capture clear contrasts amid the specific activity values for the aforementioned radionuclides in the search area, and the average specific activity for ^{40}K, ^{232}Th, and ^{238}U obtained in this study was compared with other similar local studies, as shown in Table 2.

Table 1: Radioactive concentrations of naturally occurring nuclides and radium equivalents in models of the research area.

No.	S. C.	Activity Concentration [Bqkg^{-1}]			(Ra_{eq}) [Bqkg^{-1}]
		^{40}K	^{238}U	^{232}Th	
1	HS_1	308.860±2.67	21.478±0.59	20.380±0.55	74.40±12.40
2	HS_2	295.433±2.66	27.493±0.67	9.107±0.34	63.26±10.88
3	HS_3	435.674±2.76	20.807±0.58	5.944±0.31	62.85±9.655
4	HS_4	366.387±2.53	3.858±0.24	1.603±0.09	34.36±5.249
5	HS_5	315.811±2.70	11.614±0.40	19.230±0.53	63.43±11.05
6	HS_6	415.480±2.72	2.879±0.21	2.417±0.14	38.94±5.504
7	HS_7	419.824±2.78	6.146±0.31	21.503±0.56	70.92±10.73
8	HS_8	222.956±2.72	10.690±0.40	7.706 ±0.31	38.88±8.389
9	HS_9	346.366±2.79	6.756±0.32	5.111±0.24	40.73±7.265
10	HS_{10}	366.737±2.53	3.355±0.23	6.800±0.33	41.32±7.035
11	HS_{11}	400.874±2.65	2.244±0.06	3.217±0.18	37.71±5.605
12	HS_{12}	418.134±2.70	2.693±0.16	18.809±0.53	61.79±9.417
13	HS_{13}	395.528±2.63	18.101±0.53	11.963±0.43	65.66±10.73
14	HS_{14}	378.479±3.02	11.590±0.47	1.701±0.11	43.17±6.767
15	HS_{15}	435.797±2.76	18.238±0.53	12.201±0.43	69.24±10.87
16	HS_{16}	392.554±2.72	17.781±0.52	4.481±0.22	54.42±8.769
17	HS_{17}	407.652±2.67	16.515±0.50	9.957±0.39	62.14±10.13
18	HS_{18}	398.637±2.64	2.943±0.21	3.455±0.19	38.58±5.911
19	HS_{19}	426.048±2.73	23.637±0.60	2.385±0.18	59.85±8.66
20	HS_{20}	329.053±2.74	5.139±0.28	2.638±0.20	34.25±5.986
Av. ±S. D.		375.32±2.71	11.70±0.39	8.53±0.31	52.80±8.55
P. L.[24]		420	32	30	370

Table 2: Comparison of the results of the current study of soil samples from different locations in Iraq.

NO.	**Local sites**	**Specific activity in Bq/kg**			**Ref.**
		^{238}U	**^{232}Th**	**^{40}K**	
1	Kurdistan	83.33	19.147	284.86	[25]
2	Najaf	77.33	9.36	426.31	
3	Najaf	69.78	125.63	1165.29	
4	Babylon	14.07	12.32	416.65	
5	Maysan	21.19	9.72	453.91	
6	Karbala	19.45	24.47	245.1	
7	Babylon	15.485	15.505	170.206	
8	Baghdad	14.09	11.53	402	
Current study models		11.70	8.53	375.32	Present Study

Figure 2 illustrates the discrepancies graphically. The different geological structure that characterizes the sites of the research area is the cause of the resulting inherent variations in the activity values determined across all samples, as shown in the graphical representation. In conclusion, our analytical approach provides a comprehensive comparative examination of the individual activity levels of those radionuclides under study in soil samples from the study area. Comparing these values with international standards and graphical imaging provides important new perspectives on the geological and human processes that contribute to the observed disparities.

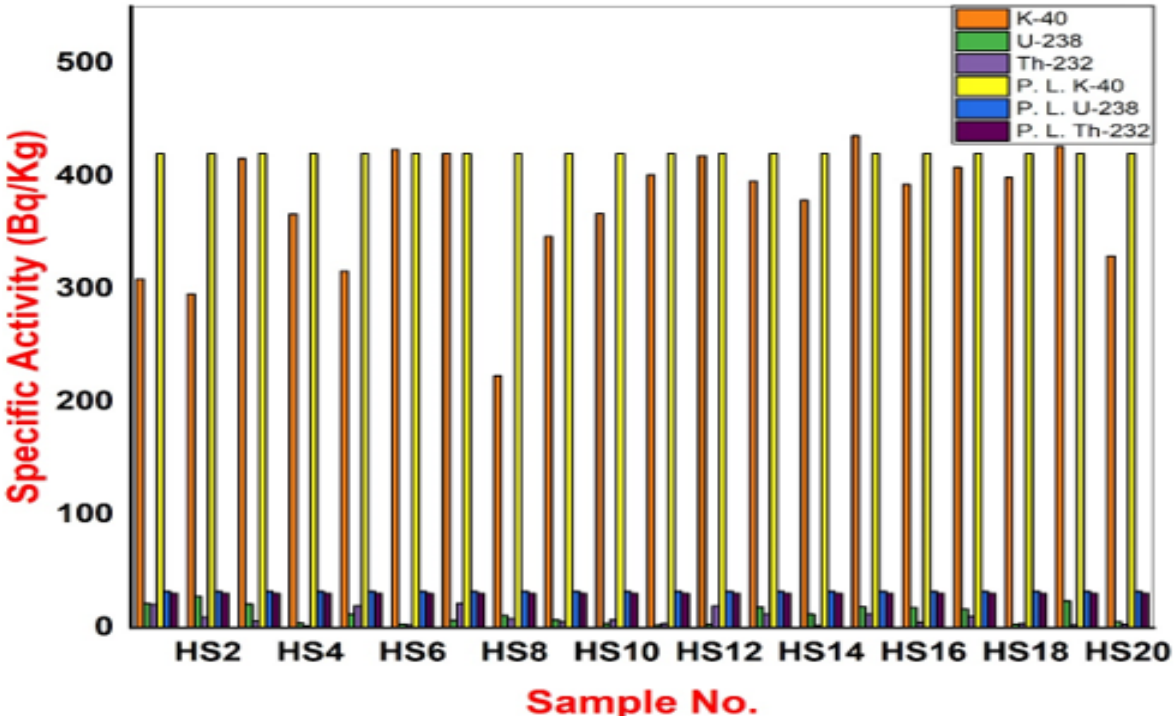

Figure 2: Activity concentrations of ^{40}K, ^{238}U, and ^{232}Th for schools' soil samples.

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

The radiological effects on all of the study area's samples were calculated in Table 3 using the following formulas: regression level index (I_γ) ranged from 0.28; HS_{20} to 0.56; HS_1 with an average of 0.41±0.06, external risk indicators (H_{ex}) ranged from 0.09; HS_{20} to 0.20; HS_1 with an average of 0.14±0.02 and internal hazard index (H_{in}) ranged from 0.1; HS_{20} to 0.26; HS_1. Table 2 shows that while the values of indoor absorbed dose rate D_{in} vary between 34.28; HS_{20} and 67.2; HS_1 $nGyh^{-1}$ and average (50.54±7.48) $nGyh^{-1}$, the values associated with outdoor absorbed dose rate D_{out} differ between 17.73; HS_{20} and 35.46; HS_{18}) $nGyh^{-1}$. We observed that the table's results fell short of what the Scientific Committee of the United Nations had advised.

Table 3: Results H_{ex}, H_{in}, I_{γ}, D_{out} and D_{in} of soil samples taken from the schools.

No.	S.C.	Hazard Index		Activity Concentration Index (I_{γ})	Observed dose	
		External ($H_{ex} \leq 1$)	Internal ($H_{in} \leq 1$)		D_{out} ($nGyh^{-1}$)	D_{in} ($nGyh^{-1}$)
1	HS_1	0.20±0.03	0.26±0.046	0.56±0.09	35.46±5.68	67.2±10.70
2	HS_2	0.17±0.03	0.25±0.044	0.47±0.08	30.68±5.01	59.24±9.54
3	HS_3	0.17±0.03	0.23±0.038	0.49±0.07	31.47±4.49	60.97±8.57
4	HS_4	0.09±0.01	0.12±0.019	0.29±0.04	18.06±2.49	34.99±4.75
5	HS_5	0.17±0.03	0.2±0.039	0.48±0.08	30.48±5.04	57.42±9.40
6	HS_6	0.11±0.01	0.11±0.019	0.33±0.04	20.49±2.61	39.61±5.94
7	HS_7	0.19±0.03	0.21±0.036	0.55±0.08	34.62±4.9	65.1±9.08
8	HS_8	0.10±0.02	0.13±0.031	0.30±0.06	19.02±0.86	36.37±7.27
9	HS_9	0.11±0.02	0.13±0.027	0.33±0.05	20.74±3.38	39.89±6.39
10	HS_{10}	0.11±0.02	0.12±0.024	0.33±0.05	21.07±3.26	40.27±6.10
11	HS_{11}	0.10±0.02	0.11±0.019	0.31±0.04	19.75±2.64	38.07±4.97
12	HS_{12}	0.17±0.03	0.17±0.03	0.48±0.07	30.36±4.3	57.04±7.94
13	HS_{13}	0.18±0.03	0.23±0.04	0.50±0.08	32.29±2.94	61.85±9.33
14	HS_{14}	0.12±0.02	0.15±0.027	0.35±0.05	22.19±3.19	43.19±6.14
15	HS_{15}	0.19±0.03	0.24±0.041	0.53±0.08	34.18±5.01	65.5±9.46
16	HS_{16}	0.15±0.02	0.20±0.035	0.43±0.06	27.37±4.09	53.08±7.81
17	HS_{17}	0.17±0.03	0.21±0.038	0.48±0.07	30.81±4.68	59.17±8.85
18	HS_{18}	0.10±0.02	0.11±0.021	0.32±0.04	20.13±2.78	38.8±5.24
19	HS_{19}	0.16±0.02	0.23±0.037	0.47±0.06	30.17±4.07	58.88±7.84
20	HS_{20}	0.09±0.02	0.11±0.022	0.28±0.04	17.73±2.81	34.28±5.34
Av.± S.D.		0.14±0.02	0.17±.0.03	0.41±0.06	26.35±3.9	50.54±7.48
P. L. [24]		1	1	6	59	84

4.3 The Results of Annual Effective Dose Equivalent and Lifetime Cancer Risk

Table 4 shows radiation effects such as absorption rate ($AEDE_{(outdoor)}$ and $AEDE_{(indoor)}$) and lifetime risk of cancer ($ELCR_{(out)}$ and $ELCR_{(in)}$) for soil samples collected from the study area. The values of the outdoor samples' effective doses range from (0.022; HS_{20} to 0.043; HS_1) $mSvy^{-1}$ with an average of (0.03±0.006) $mSvy^{-1}$, the samples' values for the indoor effective dosage rate range from (0.168; HS_{20} to 0.33; HS_1) $mSvy^{-1}$ with an average of (0.25±0.03) $mSvy^{-1}$. As shown in Table 3, Therefore, all table results fall within the limit. The (ELCR) for outdoor exposure, given in Table 3, ranged from ($0.11x10^{-3}$; HS_{20}) to ($0.144x10^{-3}$; HS_1) with an average value of (0.11±0.59) $x10^{-3}$. For indoor exposure, it is from ($0.555x10^{-3}$; HS_{20}) to ($1.088x10^{-3}$; HS_1) with an average of (0.82±1.63) $x10^{-3}$. The total (ELCR) ranges from ($0.627x10^{-3}$; HS_{20} to $1.231x10^{-3}$; HS_1)

with an average value of (0.93±1.22) x10^{-3}. Therefore, the results of this table fall within the limit recommended by the United Nations Commission on the Effects of Atomic Radiation.

Table 4: Results AEDE $_{(indoor)}$, AEDE $_{(outdoor)}$, ELCR $_{(out)}$, ELCR $_{(in)}$ and ELCR $_{(total)}$ in soil samples.

No.	S. C.	AEDE $_{(out)}$ ($mSvy^{-1}$)	AEDE $_{(in)}$ ($mSvy^{-1}$)	$ELCR_{(out)}$ x10^{-3}	$ELCR_{(in)}$ x10^{-3}	$ELCR_{(t)}$ x10^{-3}
1	HS_1	0.043±0.007	0.33±0.04	0.144±0.69	1.088±1.89	1.231±1.42
2	HS_2	0.038±0.007	0.291±0.04	0.124±0.64	0.959±1.78	1.083±1.33
3	HS_3	0.039±0.007	0.299±0.04	0.127±0.65	0.987±1.8	1.114±1.35
4	HS_4	0.022±0.005	0.172±0.03	0.073±0.49	0.566±1.37	0.64±1.02
5	HS_5	0.037±0.007	0.282±0.04	0.123±0.64	0.93±1.75	1.053±1.32
6	HS_6	0.025±0.006	0.194±0.03	0.083±0.52	0.641±1.45	0.724±1.09
7	HS_7	0.042±0.007	0.319±0.04	0.14±0.68	1.054±1.86	1.194±1.40
8	HS_8	0.023±0.005	0.178±0.03	0.077±0.5	0.589±1.39	0.666±.04
9	HS_9	0.025±0.006	0.196±0.03	0.084±0.53	0.646±1.46	0.73±1.09
10	HS_{10}	0.026±0.006	0.198±0.03	0.085±0.53	0.652±1.47	0.737±1.1
11	HS_{11}	0.024±0.005	0.187±0.03	0.08±0.51	0.616±1.43	0.696±1.07
12	HS_{12}	0.037±0.007	0.28±0.04	0.123±0.64	0.923±1.75	1.046±1.31
13	HS_{13}	0.04±0.007	0.303±0.04	0.131±0.66	1.001±1.82	1.132±1.36
14	HS_{14}	0.027±0.006	0.212±0.03	0.09±0.54	0.699±1.52	0.789±1.14
15	HS_{15}	0.042±0.007	0.321±0.04	0.138±0.68	1.06±1.87	1.199±1.4
16	HS_{16}	0.034±0.006	0.26±0.04	0.111±0.6	0.859±1.68	0.97±1.26
17	HS_{17}	0.038±0.007	0.29±0.04	0.125±0.64	0.958±1.78	1.083±1.33
18	HS_{18}	0.025±0.006	0.19±0.03	0.081±0.52	0.628±1.44	0.71±1.08
19	HS_{19}	0.037±0.007	0.289±0.04	0.122±0.63	0.953±1.77	1.075±1.33
20	HS_{20}	0.022±0.005	0.168±0.03	0.072±0.49	0.555±1.35	0.627±1.01
Av. ±S.D.		0.03±0.006	0.25±0.03	0.11±0.59	0.82±1.63	0.93±1.22
P. L. [24]		0.07	0.4	0.3	1.2	1.45

Figure 3 shows the ELCR profile across samples, highlighting the consistency of the estimated ELCR values within the specified bounds. This thorough analysis captures the radiological implications of the soil sample, offering insightful information on possible health hazards related to radiation exposure.

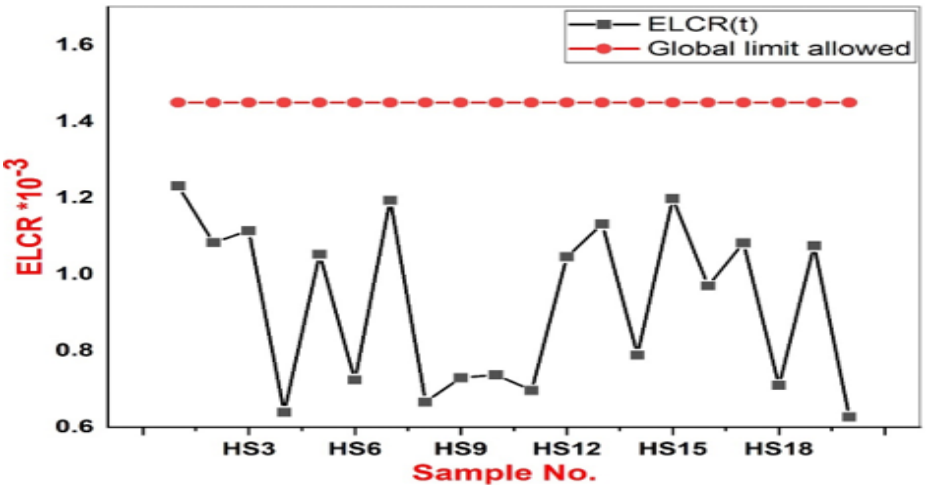

Figure 3: Total excess lifetime cancer risk (ELCR $_{(total)}$) against world.

5. Discussion of Study Results

The investigation's findings show significant patterns in the radionuclides' individual activities in the soil samples under study. However, the activity of ^{40}K is more specific compared to that of ^{232}Th and ^{238}U, as shown. This exceptional discovery is mainly due to the rare condition of the research site, which contains muddy ground and no rocks attributed to sedimentary or igneous rock composition. The results of the studies showed that the levels of radionuclide radiation that were the targets of the survey generally respected standards considered acceptable. However, surprisingly, the calculations in this study show that the actual rates for many of the specific activities monitored in soil models are lower compared to the values proposed by the United Nations Scientific Committee. Measuring radiation levels in the soil samples being studied is safe. By using (Ra_{eq}), as well as external and internal dose ratios (D_{out} and D_{in}), risk indices (H_{ex} and H_{in}), isotype index (I_{γ}), annual effective dose, and lifetime cancer risk ELCR $_{(total)}$, it was determined that the specific activity of Th-232 was significantly greater than that of ^{238}U. These results are consistent with global standards and guidelines, which are supported by UNSCEAR 2017 and ICRP 1993. As a result, all concerns about radiation effects on staff, students, and teachers in the school setting were dismissed and ignored. In conclusion, a comprehensive examination of the research data demonstrates that, in terms of radiation levels and associated health risks, the investigated environment is generally safe. The results are consistent with permissible international standards, highlighting the safety of radioactivity in the area and ensuring the safety of stakeholders and local residents.

6. Conclusion

The survey on natural radiation in the schools' soil around Hilla has shown that public health is generally safe. The observed prevalence of natural radionuclides, namely Uranium-238, Thorium-232, and Potassium-40, are within the safe limit and correspond to the natural background levels of radioactivity. This fact is also demonstrated by the data about radium equivalent, yearly effective dose equivalent and Hex index, which all point to no radiation risk. The determined research not only increases our knowledge of radiation surroundings in Hilla's schools but also gives us the best evidence to make a well-judged public health decision. This information will provide us with a reference to which we will compare the other data and, in this way, will decide the allocation of resources for monitoring the environment and assurance of students' and staff's well-being.

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حساب معدل النشاط الإشعاعي الطبيعي في تربة بعض المدارس باستخدام كاشف NaI(Tl) في مدينة الحلة – العراق

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المستخلص

تم إجراء تحقيق شامل للأنشطة المحددة ومؤشرات المخاطر الموجودة في عينات التربة المأخوذة من المدارس من بعض مناطق مدينة الحلة على عمق 15-20 سم. تم تحقيق ذلك باستخدام طريقة طيفية مخصصة باستخدام كاشف NaI(Tl). أشارت النتائج إلى أن قيم النشاط النوعي لليورانيوم 238 تتراوح من 2.244±0.06 $Bqkg^{-1}$ إلى 23.637± 0.60 $Bqkg^{-1}$، بمتوسط قيمة 11.70 ± 0.39 $Bqkg^{-1}$، كان متوسط مستوى النشاط النوعي للثوريوم 8.53 ± 0.31 $Bqkg^{-1}$، ويتراوح نشاطه بين 0.5281.603 ± 0.09 $Bqkg^{-1}$ و21.503 ± 0.56 $Bqkg^{-1}$بالنسبة للبوتاسيوم، كان نطاق نشاطها المحدد هو 0.373±11.109 إلى 152.15±1.381 $Bqkg^{-1}$ ، بمتوسط 60.507±0.838 $Bqkg^{-1}$. تم حساب متوسط التأثير الإشعاعي لمكافئ الراديوم ليكون 52.80 $Bqkg^{-1}$. وكان مؤشر المخاطر الخارجية (H_{ex}) 0.14، وكان مؤشر المخاطر الداخلية 0.17 (H_{in})تم تحديد مؤشر مخاطر جاما (Iγ) ليكون 0.41. أيضًا، متوسط مستوى الجرعة الممتصة في الهواء الطلق D_{out} هو 26.35 $nGyh^{-1}$، في حين أن متوسط مستوى الجرعة الممتصة في الداخل D_{in} هو 50.54 $nGyh^{-1}$. ويبلغ متوسط القيم السنوية لمكافئات الجرعة الفعالة (الداخلية والخارجية) 0.03 و0.25 $nGyh^{-1}$. كان الخطر للإصابة بالسرطان مدى الحياة $ELCR_{(t)}$ بسبب النشاط الإشعاعي الطبيعي في النماذج هو $0.93*10^{-3}$ علماً أن المتوسط العالمي لتركيز النويدات المسموح به هو (30 ,420 ,32)، وقيم مؤشر الخطر هي (1 ,1 ,6 ,59 ,84 ,0.4 ,0.07 و1.45) على التوالي، بناءً على تقرير لجنة الأمم المتحدة العنيه بآثار الإشعاع الذري (UNSCEAR). وبعد مقارنة نتائج الدراسة بعناية مع المتوسطات العالمية المسموح بها، فإنها تتناسب جيدًا مع النطاق الموصي به.