RADIOACTIVITY ASSESSMENT WITH DIFFERENT SAMPLES (SOIL, SEDIMENT) SELECTED FROM AL-BASRA GOVERNORATE, IRAQ

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Abstract

In this study it was evaluated the levels of natural radioactivity of some nuclei in different samples from Basra Governorate, which included two types of models (soil, sediments). Spectroscopic measurements were performed using NaI (Tl activated sodium iodide detector system (Tl) which is (3×3). Where the nuclei (^{238}U, ^{232}Th, ^{226}Ra and ^{40}K) were obtained with an average radioactive efficacy are (46.548±0.684), (40.325±1.151), (57.816±1.153) and (233.514±2.106) respectively. Also was identified measurements of hazard indices. All measured results ultimately yielded excellent results, Some are within the permissible limits, while others have gone beyond that.

Keywords : Radioactivity, NaI(Tl) detector, Background radiation, soil sample, radiation doses.

Introduction

Radioactive pollution is considered one of the most important and serious environmental problems, as it represents an increasing threat to life. Human, animal and plant due to the widespread use of radioactive materials In different fields of life. The phenomenon of radioactivity is defined as the release of different types of radiation (such as alpha, beta, and gamma rays) from the isotopes, so some isotopes either naturally (natural radioactivity) or by induction of these nuclei industrially (industrial radioactivity). The soil contains many naturally occurring radioisotopes such as uranium, thorium, radium, potassium, and others. It also contains many industrial radioactive isotopes produced by humans, and in quantities that exceed natural isotopes in some countries of the world. This is due to the expansion of applications that use these radioactive materials, including military, medical, agricultural, research, and other applications. The resulting pollutants from this applications that have the property of radiation (radioactive pollutants) require special treatment for safe disposal. Radioactive materials are diffuse in the soil solution and absorbed by the plant and accumulation in branches, walls, leaves and fruits or radioactive materials in the dust may fall directly on the leaves of the plant and its fruits, so the plant absorbs part of it and remains part of it attached to it. The humans are affected by 20% by absorbing the soil to radioactive materials and 80% by direct pollution of the plant.

Materials and Methods

Nuclear detection system

The specific efficacy of the gamma ray emitting nuclides was measured based on the high penetration strength of the gamma ray in the materials by using NaI (Tl) sodium iodide crystal detector with size (3 "x 3") cm, the equipped by a company (Spectrum Tachniques LLC) with a multi-channel analyzer containing 4096 channales, the nuclear measurements and analysis were done by a computer program called UCS_30. Figure 1: shows Nuclear counting system NaI(Tl) in present study.
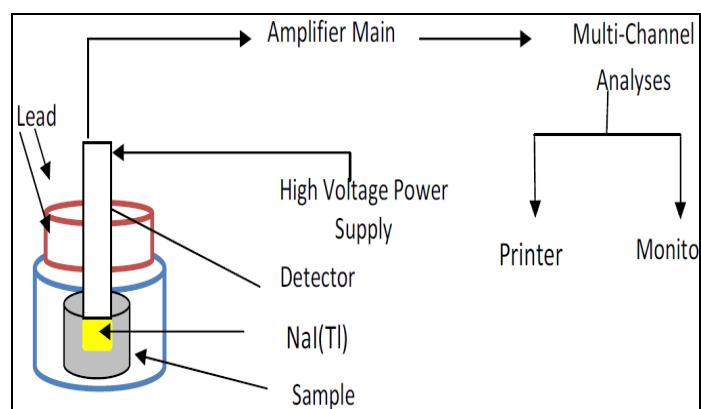

Fig. 1: Nuclear detection system: NaI(Tl)

Energy calibration

The energy calibration process is intended to determine the location of the energy of the incident photon for each channel. This is done using standard sources that contain well-known peaks of energies. When selecting these sources for calibration purposes, it takes into account a wide range of energies of the elements of the model spectrum to be detected. For energy calibration, the following standard sources were used: ^{133}Ba, ^{22}Na, ^{137}Cs, ^{60}Co, Figure 2: It represents the relationship between the energy of the standard sources and the corresponding channel number for each power value.
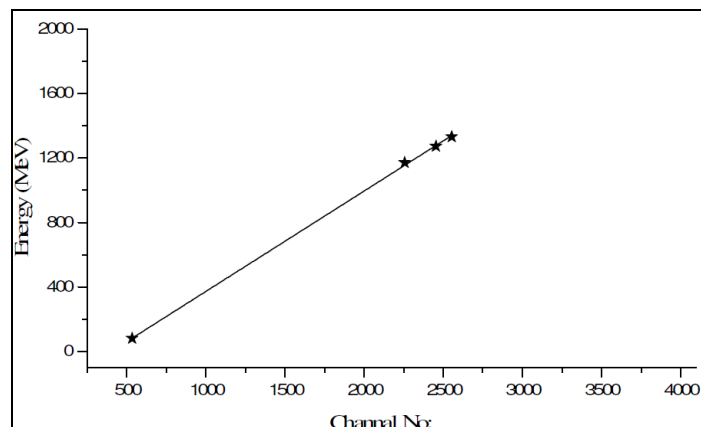

Fig. 2: The relationship between energy and photo peak position (Channel No.)

To calibrate the efficiency of the NaI (Tl) activated sodium iodide detector, standard sources with known energies were used. The decay equation 1: was used to measure the final radioactivity of the radioactive sources, And as follows[1].

$$A = A_0 e^{-\lambda t} \qquad \text{...(1)}$$

A : The Activity when performing a measurement in Bq Unit

A_0: The Activity of the radioactive source in Bq Unit

λ : decay constant in s-1

t: transmitted time.

So, the radioactivity recorded by the detector was measured for each energy of the radioactive sources for a duration (100 Sec). Finally, efficiency was calculated from equation 2:[2].

$$\xi = \frac{N-T}{A \times I_Y} \qquad \text{...(2)}$$

N: counting under the optical top.

T: measurement time.

A: radioactive source activity used for calibration.

I_Y: relative intensity of each energy of the radiated source.

After performing the steps mentioned above, it was observed that The detector efficiency is at its highest value at 81 Kev. This is due to the total absorption of the fallen photon and the occurrence of the photoelectric phenomenon. We also note the gradual decrease of this efficiency by increasing energy values, and the reason is the less influence of the photoelectric phenomenon and the advent of the Compton effect, which led to a lack of absorption of the energy of the falling photon due to its dispersion, figure 3: shows the relationship between them.
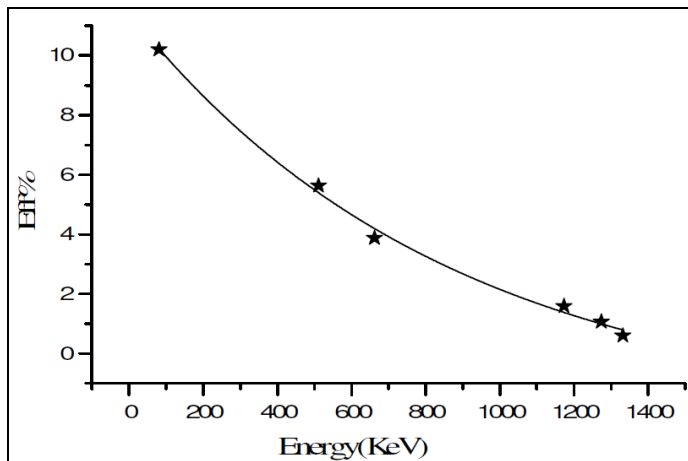

Fig. 3: The relationship between the efficiency and photon energy

Radionuclides were identified in soil samples taken in this study   through emission peaks results from the dissolution of uranium ^{238}U and thorium ^{232}Th and single ^{40}K potassium nuclei, and the detection efficiency of radionuclide energy was calculated by exponential equation 3:

$$y = y_0 + A * e^{(R0 \to x)} \qquad \text{...(3)}$$

Where the y_0, A and R_0 are the constant values

X : is the energy values for isotope in soil samples

Table 1: illustrates the energy and efficiency   for radionuclides in the studied samples. As well as, the value of the Energy Resolution   was calculated using the standard radioactive source (cobalt-60), and found it equals 6.936 MeV

Table 1 :   energy and efficiency for radionuclides in all the studied samples.

Eff%	Energy(Kev)	Nucleus
10.70	49.556	^{238}U
9.405	140.86	^{232}Th
8.819	186.21	^{226}Ra
0.406	1460.1	^{40}K

Area of study and Collation of Samples

Basra governorate was chosen to study the radiation levels for different samples (soil, sediment) . The eighteen samples were collected and determined by GPS device as shown in table (2), after collection from different regions with Taking into account the geographical distribution of study region and with Depth of 10 cm, these samples were placed in 1Kg plastic bags, the information's of the sample was fixed on these bags and prepared as follows:

- The samples were dried by exposing them to sunlight for 72 hours to obtain models free of moisture.

- The soil samples were then milled and screened using a clip with very small holes to remove gravel and the roots of suspended plants.

- The samples were stored after collection and preparation for a period of time before the process of radiological examination.

- Take 1 kg of dried soil sample and put in Measuring container with capacity of 1 liter to measure the specific radioactivity.

Table 2 : Shows the Sample code, Coordinates, Sampling Regions and Sample Type

latitudes	Meridians	Sampling Regions and Sample Type	Sample code	latitudes	Meridians	Sampling Regions and Sample Type	Sample code
		Al- Hartha (soil)	S10			Al-Barjasia (oil field)	S1
		Al-madaynah (soil)	S11			Shuaiba (oil field(	S2
		Rumaila North (soil)	S12			Hmar Musharraf (oil field)	S3
		Al-Zubair (soil)	S13			Al-Zubair (oil field)	S4
		Rumaila South (soil)	S14			Gas compressor (oil field)	S5

Safwan (soil)	S15	Rumaila North (oil field)	S6
Al- Qurna (soil)	S16	Al-Eaz marshe(sediment)	S7
Abu Al-Khaseeb (soil)	S17	Al- Qurna (sediment)	S8
Al-Barjasia (soil)	S18	Al- Faw (soil)	S9

Theoretical Concept

✓ **The background radiation (B.G)** was calculated by the following equation [3].

$$B.G(Bq) = \frac{N}{I_\gamma\%\xi\%T} \dots\dots(4)$$

✓ **The specific radioactivity** (**Specific Activity**) of the samples was measured with a time of accumulation (18000 Sec) and calculated   through the following equation [4].

$$\text{Specific Activity} = \frac{\frac{N}{T} - B.G}{I_\gamma\%\xi\% \, m} \dots\dots(5)$$

m: mass of the sample in (kg) units.

✓ **Measurement of Hazard Indices**

Depending on the specific efficacy of radium, thorium and potassium, several risk factors were measured, including:

✓ **Radium Equivalent (Ra$_{(eq)}$)**

The distribution of radium, thorium and potassium isotopes in a different way according to the different types of soils, and it can be standardized according to the resulting radiation exposure, which is known as the (**Ra$_{(eq)}$**) equivalent, according to the following equation:[5]

$$Raeq\left(\frac{Bq}{Kg}\right) = A_{Ra} + 1.43A_{Th} + 0.077A_K \dots\dots(6)$$

Whereas, A_{Ra}, A_{Th} and A_K,   the specific activity of the uranium and thorium series and the potassium chain respectively, and the highest value of Ra(eq) should be less than the internationally allowed limit (370 Bq \ Kg).

✓ **Absorbed Dose Rate in Air (AD)**

The total dose of the dose absorbed in air can be calculated in terms of the concentrations of terrestrial cores by the following equation [6]:

$$D(nGy\,h^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417\,A_K \dots\dots(7)$$

✓ **External Hazard Index (Hex)**

The external risk index is an evaluation of the natural gamma radiation risk, calculated from the following equation [7]:

$$Hex = \left(A_{Ra}/370 + A_{Th}/259 + A_K/4810\right) \le 1 \dots\dots(8)$$

✓ **Internal Hazard Index (Hin)**

The internal exposure is due to radon gas inhalation and its offspring, which can be expressed in terms of the internal risk factor [59], and is calculated by the following equation [8]:

$$Hex = \left(A_{Ra}/185 + A_{Th}/259 + A_K/4810\right) \le 1 \dots\dots(9)$$

This parameter must be less than one to be within the permissible limits globally.

✓ **Activity Concentration Index (Iγ)**

It is a coefficient used to calculate the risk arising from the gamma radiation associated with natural radionuclides, A_{Ra}, A_{Th} and A_K in the studied samples. The efficacy concentration factor (Iγ) is defined by the following equation:[9]

$$I_\gamma = \left(A_{Ra}/150 + A_{Th}/100 + A_K/1500\right) \le 1 \dots\dots(10)$$

If the effectiveness concentration value is (1) or less, then similar materials may be used, but if the value exceeds (1), similar materials cannot be used in building materials.

✓ **The Annual Effective Dose Equivalent (AEDE)**

In order to calculate the effective annual dose, we must consider the following:

• Coefficient of conversion from absorbed dose to effective dose

• Internal Preoccupation Factor.

Factor 0.7Sv was used as a factor to convert from the air-absorbed dose to the annual effective dose received by adults and used 0.8 as the internal occupation factor, which is the ratio of time spent inside and 0.2 is the ratio of time spent abroad, and from these data it was found that the annual effective dose calculated As follows [10]:

$$AEDE_{indoor}\,(mSv\backslash y) = AD\left(\frac{nGy}{h}\right) \times 8760\,h \times 0.8 \times 0.7\left(\frac{Sv}{Gy}\right) \times 10^{-6} \dots(1$$

$$AEDE_{outdor}\,(mSv\backslash y) = AD\left(\frac{nGy}{h}\right) \times 8760h \times 0.2 \times 0.7\frac{Sv}{Gy} \times 10^{-6} \dots(1$$

Whereas, 8760 indicates the number of hours of the year, and the global average annual effective dose is 0.48 mSv [11,12].

✓ **Excess Lifetime Cancer Risk**

The calculated value of the risk of increasing time life for cancer risk (ELCR) was calculated using the following equation
Accord calculated

$$(ELCR)_{outdoor} = E_{out} \times L_E \times R_F \dots\dots(13)$$
$$(ELCR)_{indoor} = E_{in} \times L_E \times R_F \dots\dots(14)$$

ELCR : increased lifetime of cancer risk

E_{in}, E_{out} :: Internal and external annual effective dose

L_E :is the average life expectancy (60 years) ,

R_F : is a risk factor 0.05 (Sv^{-1}) [64].

Results and Discussion

Results of natural radioactivity

The specific activity concentrations for ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K were calculated by using equation (5), also by relying on equation (2, 3). Table (3) shows the specific radioactivity of each of the nuclei obtained In our current work.

Table 3 : Results of natural radioactivity.

Specific Activity (Bq/Kg)				Code sample
^{40}K	^{226}Ra	^{232}Th	^{238}U	
244.771±1.986	29.348±0.853	34.017±1.099	35.973±0.608	S1
306.390±2.312	63.496±1.213	42.387±1.185	65.372±0.793	S2
184.222±1.974	33.679±0.931	14.692±0.735	28.599±0.553	S3
186.662±1.984	34.323±0.940	52.068±1.385	52.185±0.792	S4
268.282±2.184	96.797±1.50	26.811±0.943	49.902±0.693	S5
275.295±2.286	23.091±0.757	61.252±1.475	42.515±0.662	S6
203.995±1.963	114.311±1.638	69.160±1.524	59.980±0.764	S7
255.890±2.394	39.830±1.074	12.386±0.716	46.969±0.751	S8
263.259±2.243	53.556±1.153	37.248±1.150	48.799±0.709	S9
231.662±2.054	127.178±1.717	71.949±1.544	86.237±0.910	S10
222.955±2.022	24.517±0.754	12.991±0.656	27.018±0.510	S11
263.545±2.168	34.529±0.894	54.683±1.346	30.883±0.545	S12
243.521±2.171	48.193±1.094	35.260±1.119	50.736±0.723	S13
165.599±1.860	54.326±1.161	24.465±0.932	21.345±0.469	S14
268.044±2.260	47.920±1.091	36.325±1.136	61.409±0.795	S15
190.705±2.001	64.372±1.287	27.912±1.014	51.765±0.789	S16
240.411±2.159	67.386±1.294	68.602±1.561	44.071±0.674	S17
188.035±1.888	83.843±1.394	43.647±1.203	34.114±0.573	S18
233.514±2.106	57.816±1.153	40.325±1.151	46.548±0.684	Average ±SD
306.390±2.312	127.178±1.717	71.949±1.544	86.237±0.910	Max. ±SD
165.599±1.860	23.091±0.757	12.386±0.716	21.345±0.469	Min. ±SD

The highest specific activity value of ^{40}K potassium was (306.390±2.312) Bq/Kg in sample No. 2, which is due to the presence of phosphate fertilizers in this region, while the lowest value for it was (165.599 ± 1.860) Bq/Kg in sample No. 14. It was found that the average of these values is (233.514 ± 2.106) Bq/Kg. As for uranium ^{238}U, the highest specific efficacy value was (86.237±0.910) Bq/Kg in Sample No. 10, and the lowest value was (21.345±0.469) Bq/Kg in Sample No.14, and the average of these values was (46.548±0.684) Bq/Kg. The highest specific efficacy value for thorium 232Th was (71.949 ± 1.544) Bq/Kg in Sample No. (10), while its lowest value was (12.386 ± 0.716) Bq/Kg in Sample No. (8), and the average of these values was (40.325 ± 1.151) Bq/Kg, finally, the radium nucleus ^{226}Ra, the highest specific activity value was (127.178 ± 1.717) Bq/Kg in sample No. 10, and the lowest value was (23.091 ± 0.757) in Bq/Kg in sample No. 6, and the average of these values was (57.816 ± 1.153) Bq/Kg. Table No. (4) shows the results of some studies for Arab and international countries and compared them to the current study.

Table 4: the results of some studies of Arab and international countries [13,14,15] and compare with current study.

Specific Activity (Bq/Kg)			Country
K-40	Th-232	U-238	
165.8	7.7	25.5	Qatar
213.05	45.00	67.66	Thailand
384.47	11.27	3.82	Kuwait
481±78	53±9	48±9	Bangladesh
131±40	58±20	44±6	Brazil
1278	60.7	48.2	Egypt
638.7	64.5	191.1	India
225±63	11.2±3	14.5±3.9	Saudi Arabia
270±9.8	9.5±1.5	10.5±1.5	Libya
296±184	353±143	178±95	Malaysia
342	37	21	Turkey Istanbul)
346	31	19.6	Vietnam
379±108	49.1±18.5	60.4±26.2	West Siberia
822.7±31	58.2±5.1	44.4±4.5	To whom
420	33	45	World
165.599±1.860	40.325±1.151	46.548±0.684	Iraq / Basra

By comparing the results of radiometric measurements for some countries and referred to in the above table it is observed that, The highest value of the specific efficacy of potassium 40 equivalent in Egypt was (1278) Bq/kg and the lowest value recorded in Brazil was (131±40) Bq/kg As for the current study, the rate of specific effectiveness was (165.599±1.860) Bq/kg. The highest value of the specific efficacy of uranium-238 equivalent in India was (191.1) Bq / kg and the lowest value was in Kuwait and it reached (3.82) Bq/kg. 89.4) Bq/kg. As for the current study, the specific activity was within (46.548±0.684) Bq / kg. As for thorium-232 equivalents, the highest value was recorded in Malaysia,

which amounted to (353 ± 143) Bq / kg and the lowest value was (7.7) Bq / kg in Qatar [14]. As for the current study, the specific activity was within (40.325±1.151) Bq/kg. Thus, the results of the comparison show that all values of qualitative effectiveness of the current study are within the permissible limits internationally. For the purpose of identifying the variance in the distribution of concentrations of nuclei defined in our study and for the eighteen samples, Figure (4) show the values of potency concentrations for uranium, thorium, radium and potassium, respectively.
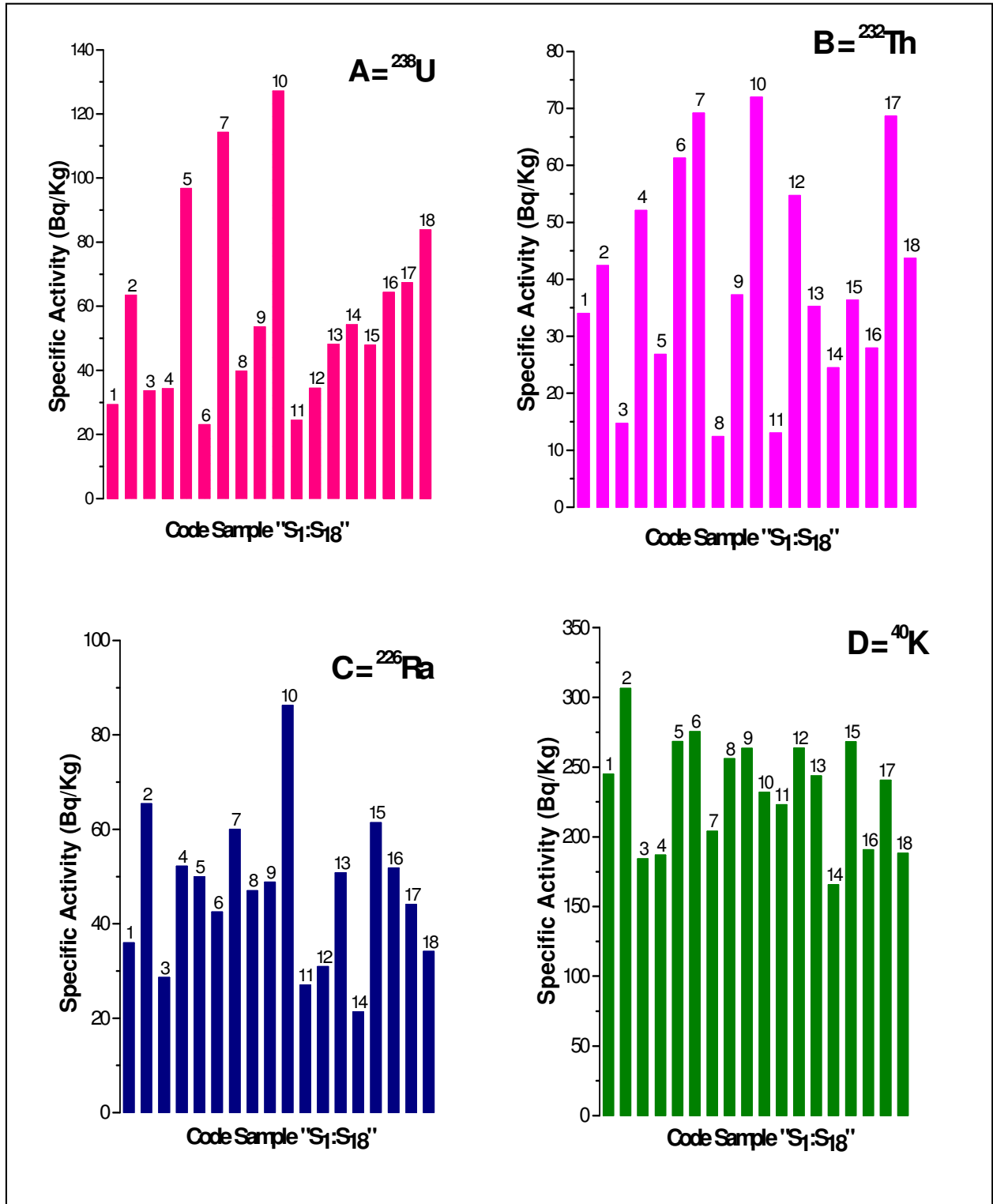

Fig. 4 : Show the values of potency concentrations for uranium, thorium, radium and potassium, respectively.(A= ^{238}U, B= ^{232}Th, C= ^{226}Ra and D= ^{40}K)

The measurements of Hazard Indices were Identified depending on the specific efficacy of radium, thorium and potassium, several risk factors and Shown in Table 5:

Table 5: Measurements of Hazard Indices in our current work

(ELCR) tot	(ELCR) m out	(ELCR) m in	AEDE (msv/y) total	AEDE (msv/y) outdoor	AEDE (msv/y) indoor	Iγ	H$_{ex}$	H$_{in}$	D(nGy/h)	^{226}Ra$_{(eq)}$	Code sample
0.838	0.168	0.671	0.279	0.056	0.224	0.699	0.262	0.341	45.576	96.840	S1
1.257	0.251	1.006	0.419	0.084	0.335	1.051	0.399	0.571	68.348	147.701	S2
0.589	0.118	0.471	0.196	0.039	0.157	0.494	0.186	0.277	32.029	68.874	S3
1.051	0.21	0.841	0.35	0.07	0.28	0.874	0.333	0.425	57.151	123.153	S4
1.299	0.26	1.039	0.433	0.087	0.346	1.092	0.421	0.683	70.617	155.794	S5
1.145	0.229	0.916	0.382	0.076	0.305	0.950	0.356	0.419	62.246	131.879	S6
1.902	0.38	1.521	0.634	0.127	0.507	1.590	0.618	0.927	103.367	228.917	S7
0.666	0.133	0.533	0.222	0.044	0.178	0.560	0.209	0.316	36.210	77.246	S8
1.083	0.217	0.866	0.361	0.072	0.289	0.905	0.343	0.488	58.847	127.092	S9
2.058	0.412	1.647	0.686	0.137	0.549	1.722	0.670	1.013	111.897	247.903	S10
0.527	0.105	0.422	0.176	0.035	0.141	0.442	0.163	0.229	28.656	60.262	S11
1.146	0.229	0.917	0.382	0.076	0.306	0.953	0.359	0.453	62.276	133.019	S12
1.001	0.200	0.800	0.334	0.067	0.267	0.836	0.317	0.447	54.392	117.366	S13
0.856	0.171	0.685	0.285	0.057	0.228	0.717	0.276	0.423	46.514	102.062	S14
1.031	0.206	0.825	0.344	0.069	0.275	0.861	0.325	0.455	56.035	120.504	S15
0.996	0.199	0.797	0.332	0.066	0.266	0.835	0.321	0.495	54.165	118.970	S16
1.555	0.311	1.244	0.518	0.104	0.415	1.296	0.497	0.679	84.526	183.999	S17
1.339	0.268	1.071	0.446	0.089	0.357	1.121	0.434	0.661	72.781	160.737	S18
1.130	0.226	0.904	0.377	0.075	0.301	0.944	0.361	0.517	61.424	133.462	Average
2.058	0.412	1.647	0.686	0.137	0.549	1.722	0.670	1.013	72.781	247.903	Max.
0.527	0.105	0.422	0.176	0.035	0.141	0.442	0.163	0.229	28.656	60.262	Min.

Generally, it was found that the highest value of radium equivalent 226Ra(eq) is (247.903) Bq/Kg in sample No. (10) and the lowest value was (60.262) Bq/Kg in sample No. (11), either the average of these values was within (133.4621) Bq/Kg. while the highest value of the dose absorbed in air Dr(nGy/h) is (72.781) nGy.h-1 in sample No. (18) and the lowest value was (28.656) nGy.h-1 in sample (11), the average values was within 61.424 (nGy.h^{-1}). As for the internal hazard index (Hin), it was found that its highest value was (1.013) in sample No. (10) and the lowest value was (0.229) in sample No. (11) and the average value was (0.517). Also the external hazard index (Hex) it was found that, its highest value was (0.670) in sample No. (10) and the lowest value was 0.163) in sample No. (11), and the average value was (0.361). After measuring the activity concentration index (Iγ), it was found that its highest value was (1.722) in Sample No. (10) and the lowest value was (0.442) in Sample No. (11) and the average measured values were (0.944). After measuring the annual external effective dose AEDE$_{(outdoor)}$, it was found that its highest value was (0.137)

mSv.y^{-1} in sample No. (10) and the lowest value is (0.035) mSv.y-1 in sample number (11). These doses were (0.075) mSv.y^{-1}. The internal annual effective dose AEDE$_{(indoor)}$ measurement found that its highest value was (0.549) mSv.y^{-1} in sample No. (10) and the lowest value was (0.141) mSv.y-1 in sample No. (11). Inner annual effective dose of (0.301)mSv.y^{-1}. Also, according to excess lifetime cancer risk factors in out((ELCR (out)), it was found that its highest value was (0.412) in sample No. (10) and the lowest value was (0.105) in sample No. (11) and the average measured values were (0.226). while the excess lifetime cancer risk factors in Inside (ELCR (in)), it was found that the highest value was (1.647) in sample No. (10) and the lowest value was (0.422) in sample No. (11) and the rate was Measured values (0.904). the total excess lifetime cancer risk factors ((ELCR (t)), it was found that its highest value was (2.058) in sample No. (10) and the lowest value was (0.527) in sample No. (11), and the rate was Measured values (1.130). The aforementioned can be illustrated in Figure 5:
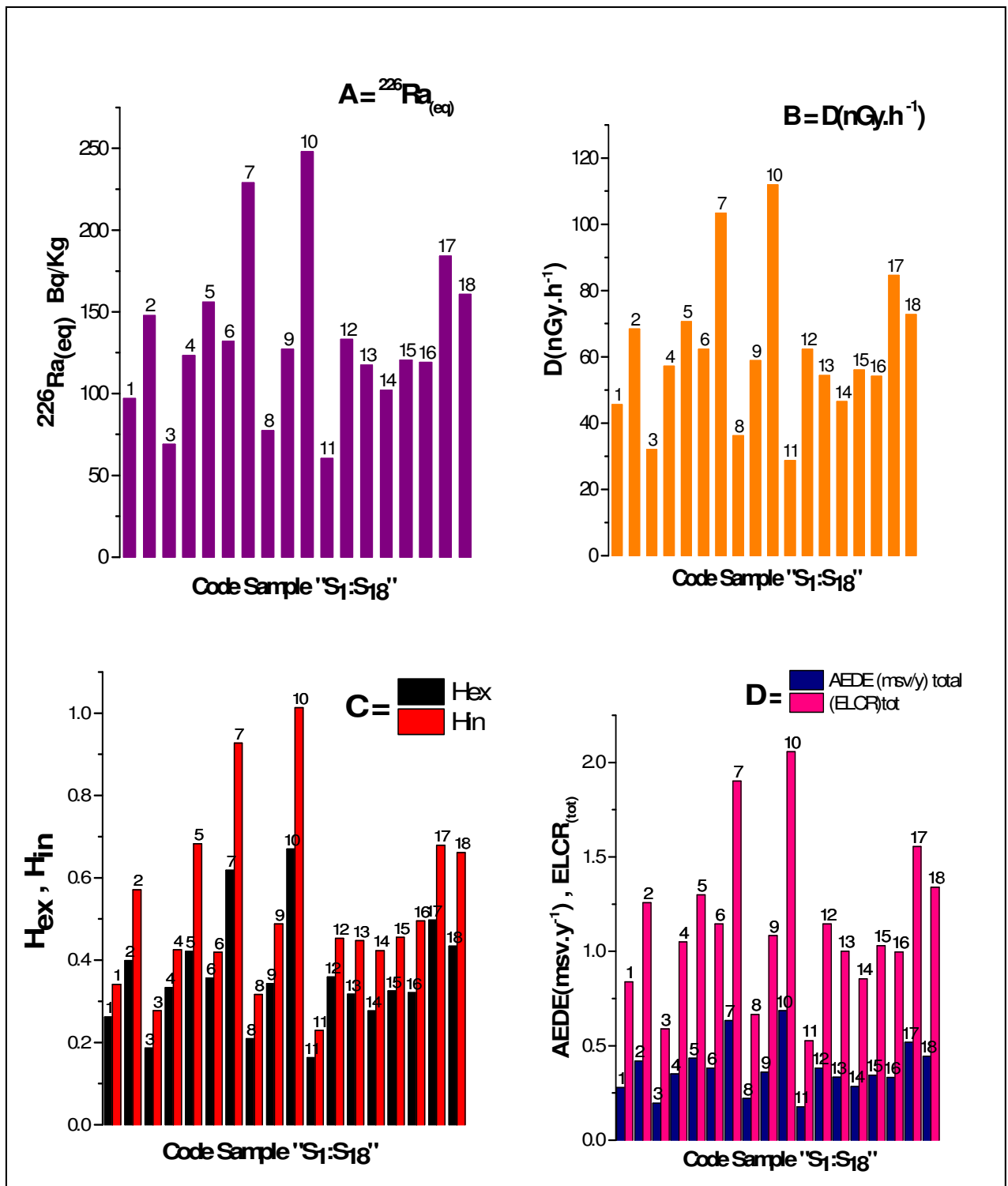
Fig. 5 : Measurements of Hazard Indices in our current work, (A= 226Ra(eq),
B= D(nGy/h), C= Hex, Hin, D= AEDE (msv/y) total, (ELCR)tot)

Conclusions

In the current work, spectral measurements were performed using the NaI (Tl) gamma spectroscopy system. The number of selected samples was eighteen samples, for different regions of Basra Governorate, after analyzing the results, it was found that the specific radioactivity of thorium, uranium and potassium nuclei takes variable values from one region to another. Firstly, for uranium 238U, the highest specific efficacy value was (86.237±0.910) Bq/Kg in Sample No. 10, and the lowest value was (21.345±0.469) Bq/Kg in Sample No.14, and the average of these values was (46.548±0.684) Bq/Kg, Note that the limits allowed globally are 25 Bq/Kg. secondly, the highest specific efficacy value

for thorium 232Th was (71.949 ± 1.544) Bq/Kg in Sample No. (10), while its lowest value was (12.386 ± 0.716) Bq/Kg in Sample No. (8), and the average of these values was (40.325 ± 1.151) Bq/Kg, also, the limits allowed globally are 25 Bq/Kg[16], thirdly, The highest specific activity value of 40K potassium was (306.390±2.312) Bq/Kg in sample No. 2, which is due to the presence of phosphate fertilizers in this region, while the lowest value for it was (165.599 ± 1.860) Bq/Kg in sample No. 14. It was found that the average of these values is (233.514 ± 2.106) Bq/Kg, Which falls within the allowed limits of 370 Bq/Kg[16], finally, the radium equivalent 226Ra, the highest specific activity value was (247.903) Bq/Kg in sample No. 10, and the lowest value was (60.262) in Bq/Kg in sample No. 11, and the average of these

values was (133.462) Bq/Kg, all of them are within the allowed limits of 370 Bq/Kg[16]. All results of the dose absorbed in the air and the annual effective internal and external dose of the studied models were within the internationally permissible limit. The values of the internal and external risk coefficient of the models were all within the permissible limits internationally, with the exception of sample 10, the value of the Internal Hazard Index (Hin) it was equal to (1.013), which is outside the permissible limits which must be less or equal to one. The temporal lifetime of the increased risk of cancer in internal and external with average value equals (0.904, 0.226) respectively which is within the globally permitted global rate, with the exception of samples 5,7,10,17 and 18 internally (ELCRin), greater than one, which is outside the permissible limits which must be less or equal to one.

Acknowledgments

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