

## Radioactive Hazard Indicators of Some Radioactive Nuclei in Al-Kifl Bricks Factories, Babil Governorate, Iraq

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### ABSTRACT

The study included an assessment of the level of natural and industrial specific radioactivity of soil samples using the spectral analysis technique of a high-purity germanium detector, where 8 samples of soil were collected at depth 20 cm in the city of Al-Kifl - Babil Governorate. Where it was found that the rate of specific effectiveness for each of  $^{226}\text{Ra}$ ,  $^{214}\text{Pb}$ ,  $^{214}\text{Bi}$ ,  $^{232}\text{Th}$ ,  $^{212}\text{Pb}$ ,  $^{228}\text{Ac}$ ,  $^{40}\text{K}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$  in the studied soil samples ( $26.3\pm 3.38$ ), ( $31.2\pm 3.15$ ), ( $14.2\pm 2.43$ ), ( $11.5\pm 2.36$ ), ( $57.5\pm 5.45$ ), ( $56.8\pm 4.86$ ), ( $131.6\pm 10.3$ ), ( $0.802\pm 0.07$ ), ( $0.53\pm 0.05$ ) respectively.

The radioactive hazard indicators were also calculated, and the results of the calculation were different between the calculated indicators, as the majority of the calculated indicators were universally accepted. Some indicators have exceeded the permissible limits globally.

### Introduction

Calculating radioactive risk indicators is very important for many reasons, including choosing sites for facilities that are direct emitters of these radioactive pollutants, developing contingency plans to track and identify any cases of increased radioactivity, and preserving public health from the danger of these pollutants. Many countries around the world measure natural radiation exposure. This helps protect the security of the homeland and its people [1].

As a part of the environmental monitoring program on radioactivity in nations, measurements of the exposure rate started almost 20 years ago. The radiation doses resulting from the various population exposure methods can be calculated, and approved risk functions can be used to determine the health effects as a result of this environmental radioactivity pollution [2]. nuclides radioactive natural existing in air and soil and water and materials Building she Source the main to nature background radiation .three isotopes a task she uranium and thorium and potassium and uranium heavy .There is uranium in quantities different in nature in rocks and soil and water and air and plants and animals and body Human and places other [3].

from the important measurement content radiation the soil in appreciation Risks resulting about her , like poverty the blood .Leukemia and cancer And the skin hepatic; and backwardness mental infect children Whose exposed their mothers For this radiation during pregnancy[4].Approximately 4.7doses effective annually receive it Persons on syntax confessor with it UNSCEAR 2016 Damages other on health Human resulting on exposure for uranium she Archaeology genetic to damage cells reproductive, Than Lead to happening leap genetic[5].

## Materials and methods

Eight samples were collected at a depth of 20 cm for each site selected in the current study, as shown in table 1: The samples were dried, grinded and sieved to obtain a homogeneous and fine powder, after which the samples were stored for thirty days to obtain a radioactive balance before conducting the radiological examination. 1 kg of dry soil was taken and placed in a container after washing it thoroughly with dilute hydrochloric acid and then with distilled water to conduct quantitative and qualitative assessment of radioactive nuclei using a high-purity germanium detector system.

**Table 1: The Sample code, Coordinates, Sampling Regions**

Sample code	Sampling Regions	Latitude (N)	Longitude (E)
<b>S1</b>	Gar Al-Imam	32.220679	44.492033
<b>S2</b>	Shibh Al-Gazira	32.220411	44.492111
<b>S3</b>	Al-Suwr Al-Ameen	32.218268	44.495215
<b>S4</b>	Al-Kawthar	32.216806	44,496,358
<b>S5</b>	Al-Nnaba	32.215287	44,498,413
<b>S6</b>	Asad Babil	32.214686	44,500,515
<b>S7</b>	Al-Murshidi	32.228892	44.481171
<b>S8</b>	Al-Umran	32,226,194	44.487442

## Energy calibration

The high-purity Ge (Hp) germanium detector was calibrated using standard radioactive sources such as the barium-133 isotope with energy (59.5) KeV and the cobalt-60 isotope with two energies (1332-1173), as well as the cesium-137 isotope with energy (662)KeV.

In the second step, the system's efficiency is calibrated by using various standard energy sources to cover a broad range of isotope energies to be obtained in the studied samples.

## Theoretical concept

The background radiation (BG) was calculated using the following equation [6].

$$A_{BG} = \frac{Net_{BG}}{I(E_{\gamma}) \times \varepsilon(E_{\gamma}) \times T} \dots \dots (1)$$

The specific activity is defined as its activity per unit mass (Bq/Kg), The specific activity of sample is calculated by the following formula [7] :

$$A(BqKg^{-1}) = \frac{N - B}{t \times \varepsilon \times I_{\gamma} \times m} \dots \dots (2)$$

where B is the background counts, N is the gross counts (sample + background), t is the counting time (s),  $I_{\gamma}$  is the gamma emission probability,  $\varepsilon$  is the absolute efficiency of the detector at particular gamma energy, m is the sample weight (kg).

hazard indicators are used to obtain the sum of those activities ( $^{232}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{40}\text{K}$ ) in Bq/kg, and assess hazards associated with materials that contain ( $^{232}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{40}\text{K}$ ) in Bq/kg by using to radium equivalent activity and is mathematically defined as.

$$Raeq (Bq/kg) = ARa + 1.43A_{Th} + 0.077AK \dots \dots (3)$$

The total dose of the dose absorbed in air can be calculated in terms of the concentrations of terrestrial cores by the following equation [8]:

$$Dr (nGy/h) = 0.462AU + 0.604A_{Th} + 0.0417AK \dots \dots (4)$$

The external risk index is an evaluation of the natural gamma radiation risk, calculated from the following equation[9]:

$$Hex = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \dots \dots (5)$$

The internal exposure is due to radon gas inhalation and its offspring, which can be expressed in terms of the intern risk factor, and is calculated by the following equation[10]:

$$Hin = \frac{ARa}{185} + \frac{A_{Th}}{259} + \frac{AK}{4810} \dots \dots (6)$$

The total electric charge produced in a given mass of air when radiation passes through it is called radiation exposure. The radiation exposure dose ratio can be calculated using the relation[11]

$$I = 1.90 AU + 2.82A_{Th} + 0.179AK \dots \dots (7)$$

To know the annual effective dose That is a radioactive coefficient used to judge the extent The health effects of the absorbed dose are measured in unit (mSv.y-1). The annual effective dose is estimated by using the conversion factor (0.7 Sv.Gy-1), which converts the absorbed dose in air into the effective dose as well as using the internal occupancy factor (0.8) and the indoor occupancy factor (0.2) As in the two equations [12].

$$AEDE_{outdoor} = [D_r \times 8766 \times 0.2 \times 0.7] \times 10^{-6} \dots \dots (8)$$

$$AEDE_{indoor} = [D_r \times 8766 \times 0.8 \times 0.7] \times 10^{-6} \dots \dots (9)$$

The calculated value of the risk of increasing life time for cancer risk (ELCR) was calculated by the following equation Accord calculated [7,9]:

$$ELCR = AEDE_{outdoor} \times DL \times RF \dots \dots (10)$$

$$ELCR = AEDE_{indoor} \times DL \times RF \dots \dots (11)$$

where, ELCR is Excess Lifetime Cancer Risk, DL is the average life of human and RF is the risk factor (sv-1). The range of 0.569139 to 0.74732 with an average of 0.639954 . According to these results, the risk of cancer is negligible

The equivalent dose to gonads resulting from the concentration of radioactivity (<sup>232</sup>Th, <sup>226</sup>Ra, <sup>40</sup>K) is given by the following relationship [13].

$$AGDE(mSv/y) = (3.09A_{Ra} + 4.19A_{Th} + 0.314AK) / 1000 \dots \dots (12)$$

**Results and discussion.**

**Specific effectiveness of radioactive elements.**

Six radioactive isotopes belonging to the two series of uranium-238 and thorium-232 were diagnosed, in addition to the radioactive isotope potassium-40, and some industrial elements of cesium-137 and cobalt-60 were found in low concentrations in some samples. Table 2: shows the specific activity of the soil samples selected in the current study.

**Table 2: Specific radioactivity of all selected Samples**

Sample code	Ra-226	Pb-214	Bi-214	Th-232	Pb-212
1S	24±2.66	12±2.24	15.4±2.28	10.7±2.34	60±5.98
2S	28±2.89	16±2.63	13.8±2.55	9.5±2.35	10±2.13
3S	11.5±1.31	33±2.75	13±2.29	12.2±2.64	70±6.14
4S	35±4.31	47±4.15	15.8±2.57	13.4±2.17	70±5.43
5S	38±4.55	56±4.70	14.4±2.44	13.9±3.70	50±3.20
S6	28±3.87	14±2.04	14.1±2.53	11.1±1.87	90±8.30



<b>7S</b>	33±3.20	47±3.27	16.3±2.78	14±2.69	70±7.49
<b>8S</b>	13±4.30	25±3.48	11.4±2.01	7.5±1.16	40±4.96
<b>Average ±SD</b>	26.3±3.38	31.2±3.15	14.2±2.43	11.5±2.36	57.5±5.45
<b>Max. ±SD</b>	38±4.55	56±4.70	16.3±2.78	14±2.69	90±8.30
<b>Min. ±SD</b>	11.5±1.31	12±2.24	11.4±2.01	7.5±1.16	10±2.13
<b>Sample code</b>					
<b>1S</b>	<b>Ac-228</b>	<b>K-40</b>	<b>Co-60</b>	<b>Cs-137</b>	
<b>2S</b>	60±4.36	143±11.23	1.6±0.13	Nil	
<b>3S</b>	66±5.12	146±11.76	0.4±0.02	Nil	
<b>4S</b>	37±3.96	122±9.69	Nil	Nil	
<b>5S</b>	71±6.11	140±10.54	0.4±0.06	Nil	
<b>6S</b>	33±3.94	140±9.76	0.9±0.11	Nil	
<b>7S</b>	74±6.69	101±8.47	0.71±0.03	Nil	
<b>8S</b>	58±4.45	124±9.65	Nil	0.53±0.05	
<b>Average ±SD</b>	56.8±4.86	131.6±10.3	0.802±0.07	0.53±0.05	
<b>Max. ±SD</b>	74±6.69	146±11.76	1.6±0.13	/	
<b>Min. ±SD</b>	33±3.94	101±8.47	0.4±0.06	/	

Through the results shown in the table above, we find that, the highest value for radium<sup>226</sup>Ra (38 ± 4.55) Bq/kg for the sample (5S) and the lowest value (11.5 ± 1.31) Bq/kg for the sample (S3) at the rate of (26.3±3.38)Bq/Kg, As for lead <sup>214</sup>Pb, the highest value was found (56 ± 4.70) Bq/kg for the sample (S5), while the lowest value was (12 ± 2.24) Bq/kg for the sample (S1), at an average(31.2±3.15) Bq/kg, the highest value for bismuth <sup>214</sup>Bi was found (16.3 ± 2.78) Bq/kg for the sample (S7) and the lowest value (11.4 ± 2.01) Bq/kg for the sample (S8) at a rate (14.2±2.43) Bq/kg, We note that the measured natural radioactive element concentrations of the uranium U-238 decay series are within the internationally permissible limits, which is equal to 35 Bq/kg [13]. and thus they do not constitute a radioactive hazard. As for the concentration of thorium<sup>232</sup>Th had the highest value (14 ± 2.69) Bq/kg for the sample (S7) and the lowest value (7.5 ± 1.16) Bq/kg for the sample (S8), with an average(11.5±2.36)Bq/kg It is less than the permissible rate of 30 Bq/kg[13]. While the highest value of <sup>212</sup>Pb lead was (90 ± 8.30) Bq / kg for the sample (S6) and the lowest value was (10 ± 2.13) Bq/kg (S2), at a rate(57.5±5.45)Bq/kg, and reached the highest value for actinium<sup>228</sup>Ac (74 ± 6.69) Bq / kg for the sample (S6) and the lowest value was (33 ± 3.94) Bq / kg for the sample (S5) at the rate of (56.8±4.86)Bq/Kg we note that the average values measured for these two isotopes exceeded the permissible global average, which is equal to 30 Bq / kg[13], and this is due to the fact that the sampling areas are agricultural areas that may have been fertilized with phosphate salts, which led to an increase in the concentration of lead <sup>212</sup>Pb and actinium <sup>228</sup>Ac.

The single potassium nucleus concentration<sup>40</sup>K in soil samples found the highest value (146 ± 11.76) Bq / kg for the sample (S2) and the lowest value (101± 8.47) Bq / kg for the sample (S6) at a rate of (131.6±10.3) Bq/kg which corresponds to the permissible limits 420Bq/kg [13]. It was the highest value for industrial cobalt <sup>60</sup>Co Bq/kg (1.6±0.13) for the sample (S1) and the lowest value (0.4±0.06) Bq/kg for the two samples (S2, S4) at a rate of (0.802±0.07) Bq/kg, It is within the international limits of 0.8Bq/kg [13]. while not all samples were within the detection limit for cesium<sup>137</sup>Cs excluding sample (S7) with Bq/kg activity (0.53±0.05) Bq/kg And within the permissible limits that are equal to 14.8 Bq/kg [13]. Figures (1- 4) It shows the discrepancy in the specific activity values of the measured radioactive elements.

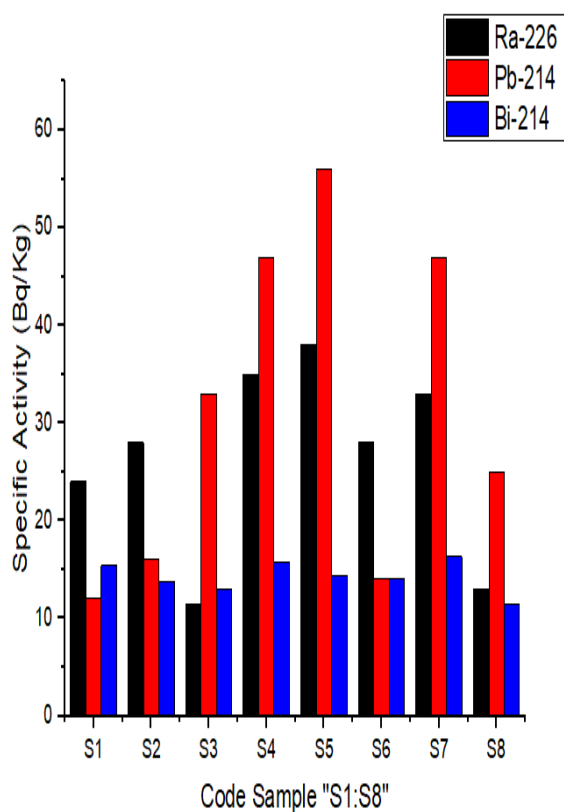


Fig.1. S.A to (<sup>226</sup>Ra, <sup>214</sup>Pb, <sup>214</sup>Bi) in Bq/Kg

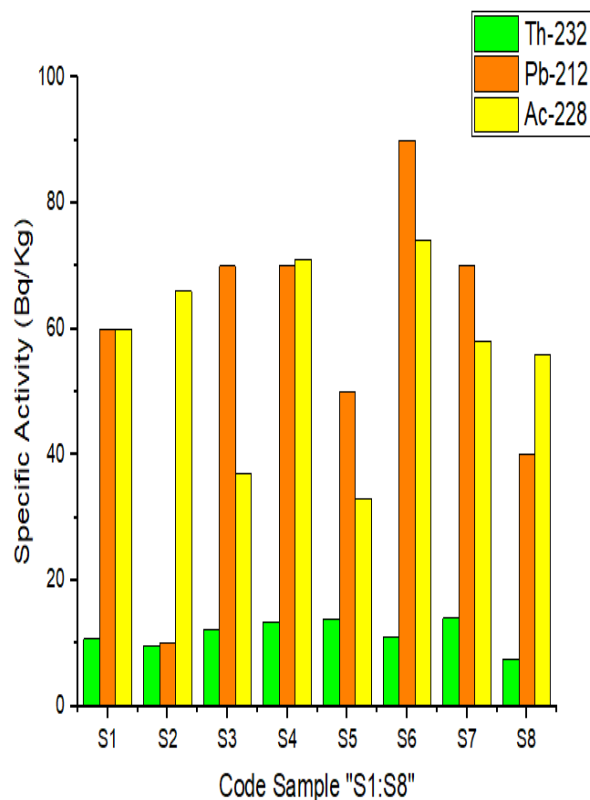


Fig.2. S.A to (<sup>232</sup>Th, <sup>212</sup>Pb, <sup>228</sup>Ac) in Bq/Kg

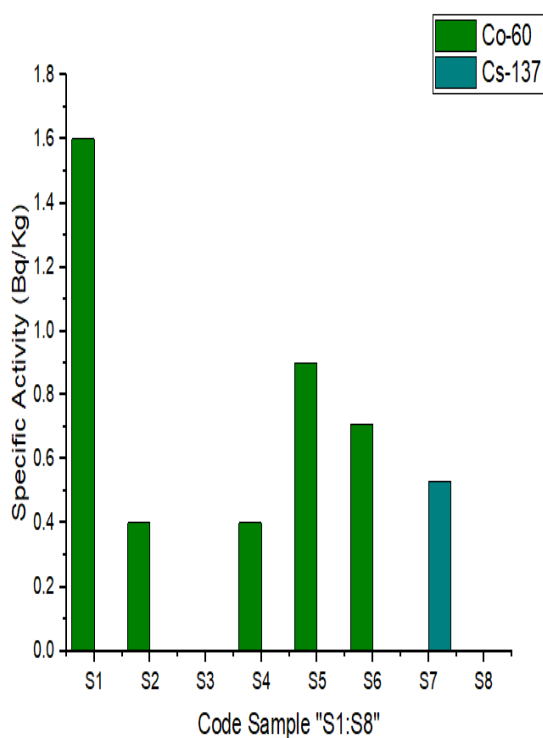


Fig.3. S. A to (<sup>60</sup>Co, <sup>137</sup>Cs) in Bq/Kg

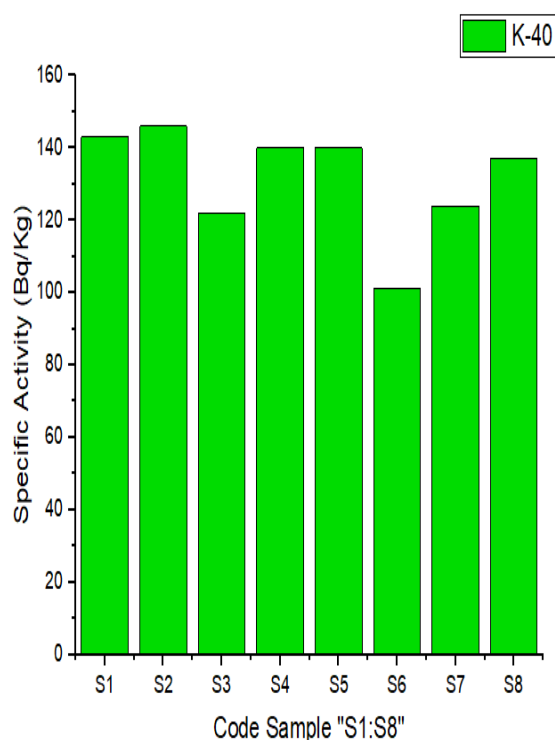


Fig.4. S. A to (<sup>40</sup>k) in Bq/Kg

### Radiation hazard indicators.

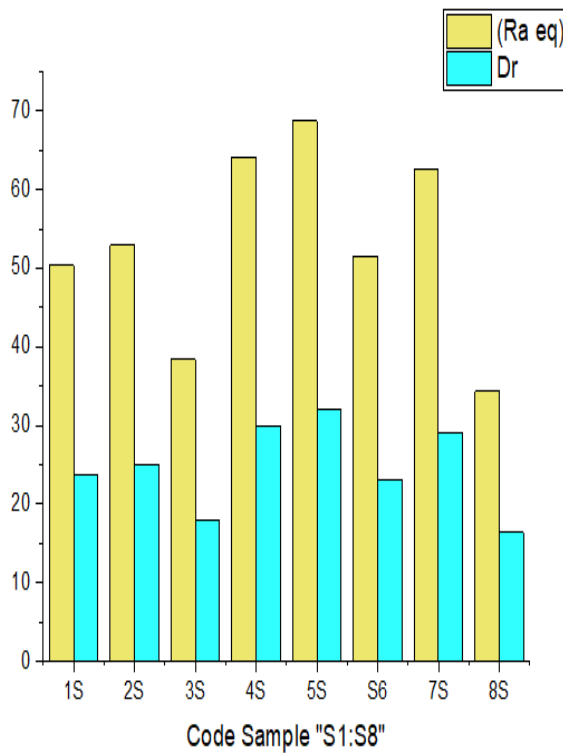
determined united nations atomic energy commission fixed indicators of radioactive contamination and that to estimate radiological risks the environment to humans As well as to

determine the level of radiation doses that are safe for human health and the environmental system[13]. These determinants were adopted in the current study of the selected soil samples, table 3: it shows these radioactive indicators that have been calculated.

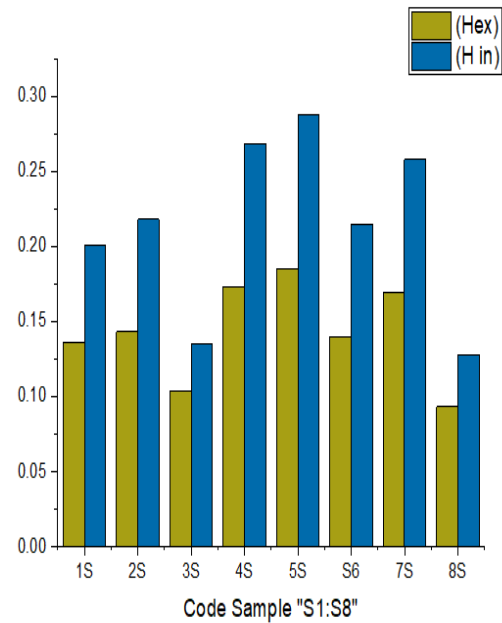
**Table 3: Measurements of hazard indices in present study**

Code sample	Ra (eq) (Bq/kg)	D (nGy/h)	(Hex)	(H in)	(I)	AEDE (msv/y) outdoor	AEDE (msv/y) indoor	(ELCR) (out)	ELCR (in)	AGDE mSv/y
1S	50.312	23.696	0.136	0.201	0.362	1.42559	0.0116	4.98958	4.06847	0.119
2S	52.872	24.924	0.143	0.218	0.379	1.49947	0.0122	5.24813	4.2793	0.126
3S	38.34	17.977	0.104	0.135	0.280	1.08151	0.0088	3.7853	3.0865	0.087
4S	64.172	29.912	0.173	0.268	0.454	1.7996	0.0147	6.29859	5.13584	0.164
5S	68.657	32.026	0.185	0.288	0.486	1.92675	0.0157	6.74363	5.49872	0.176
S6	51.56	23.041	0.140	0.215	0.365	1.44635	0.0118	5.06222	4.12771	0.133
7S	62.568	29.111	0.169	0.258	0.443	1.17513	0.0143	6.1298	4.99821	0.161
8S	34.274	16.376	0.093	0.128	0.253	9.85242	0.0088	3.44835	2.81176	0.072
Average	52.844	24.632	0.142	0.213	0.377	2.52585	0.0122	5.2132	4.25081	0.129
Max.	68.657	32.026	0.185	0.288	0.486	9.85242	0.0157	6.74363	5.49872	0.176
Min.	34.274	16.376	0.093	0.128	0.253	1.08151	0.0088	3.44835	2.81176	0.072

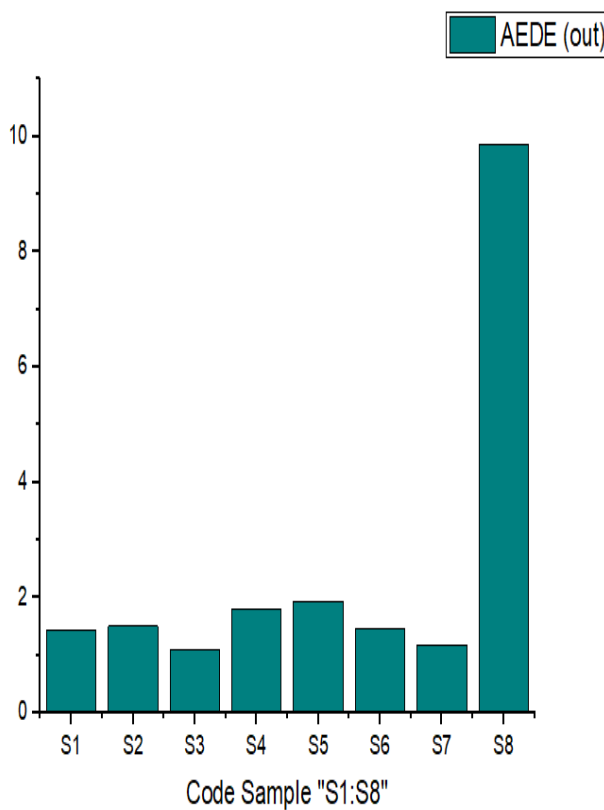
After calculating the radioactive hazard indicators for soil samples and obtaining the results as shown in Table 3: It was found that the highest value toradium equivalent ( $Ra_{eq}$ ) (68.657) Bq/Kg to sample (5S) and was less valuable (34.274) Bq/Kg to sample (S8) was the average values(52.393) Bq/kg These values are below the permissible limit of 370 Bq/kg. It was the highest value to absorbed dose in the air (Dr) (32.026) nGy/h to sample (S5) and less value (16.376) nGy/h for sample (S5)The rate was (24.632) nGy/h Which corresponds to the global limit of 84 nGy/h.while the highest value to external risk level ( $H_{ex}$ ) (0.185) for the sample (S5) and the lowest value (0.093) for the sample (S 8) at a rate of (0.142) These values did not exceed the global allowable limit which is equal to 1, While the highest value for the internal risk level( $H_{in}$ ) was (0.288 ) for the (S5)And the lowest value (0.128)for sample (S8) and the rate values were (0.213) Also within the global allowable limit which is equal to 1. and the highest value for radiation exposure(I) was (0.486) for the sample (S5) and the lowest value (0.253) for the sample (S8) with an average of (0.377) It also does not constitute a danger because it is within the permissible rate which is equal to 1 .It was the highest value to annual effective dose equivalent external ( $AEDE_{out}$ ) ( $9.85242 \times 10^{-6}$ ) mSv/y for sample (S8) and less value ( $1.08151 \times 10^{-6}$ ) mSv/y for the sample (S3) and the average ( $2.52585 \times 10^{-6}$ ) mSv/y,while the highest value toannual effective dose equivalent internal( $AEDE_{in}$ ) (0.0157) mSv/y,and less value (0.0088) mSv/y with an average (0.0122) mSv/y These rates are within the global average of 0.884 mSv/y. and reached the highest value to the severity of the cancer external with average age ( $ELCR_{out}$ ) ( $6.74363 \times 10^{-12}$ ) for the sample (S5) and the lowest value ( $3.44835 \times 10^{-12}$ ) for the sample (S8) at a rate of ( $5.2132 \times 10^{-12}$ ),The highest value for the risk of endogenous cancer was with the average age(  $ELCR_{in}$ ) ( $5.49872 \times 10^{-8}$ ) to sample (S5)and the lowest value ( $2.81176 \times 10^{-8}$ ) to sample (S8) at a rate reach ( $4.25081 \times 10^{-8}$ ) These values exceeded the permissible limit which is equal to 0.3and 1.2 respectively, The reason is that the selection areas for the samples are agricultural and it is possible that they are fertilized or bombed by war. while reaching the highest value to an equivalent dose of gonads (AGDE) (0.176) mSv/y for sample (S9) and less value (0.072) mSv/y to sample (S5) at a rate of (0.129) mSv/y It is lower than the global allowed rate of 0.3mSv/y. Figures (5-10) Changes are shown in the values of the severity indicators discussed above.



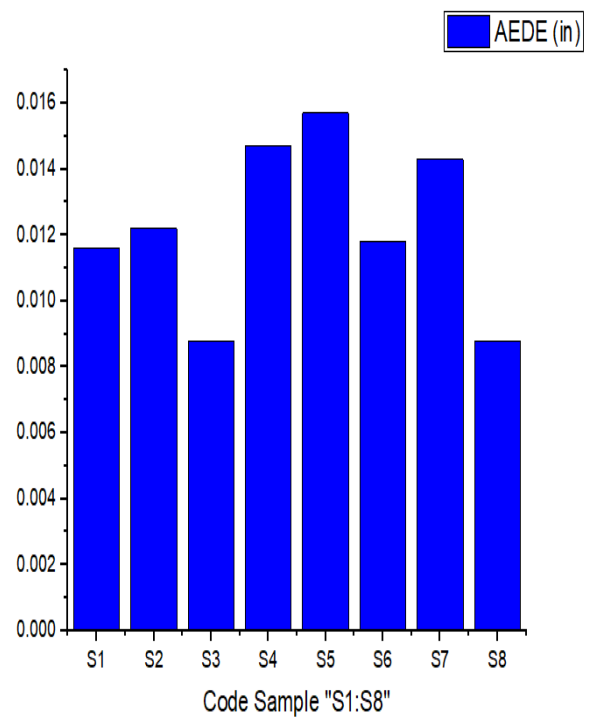
**Fig.5.** Radium equivalent (Bq/Kg), Absorbed



**Fig.6.** External hazard index and internal hazard dose in nGy-1 hazard index

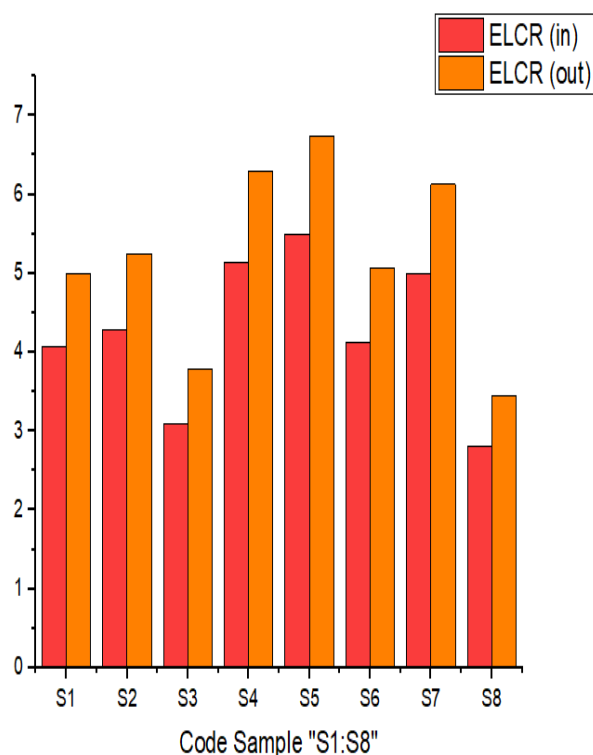


**Fig.7.** Annual external effective dose (msv/y)

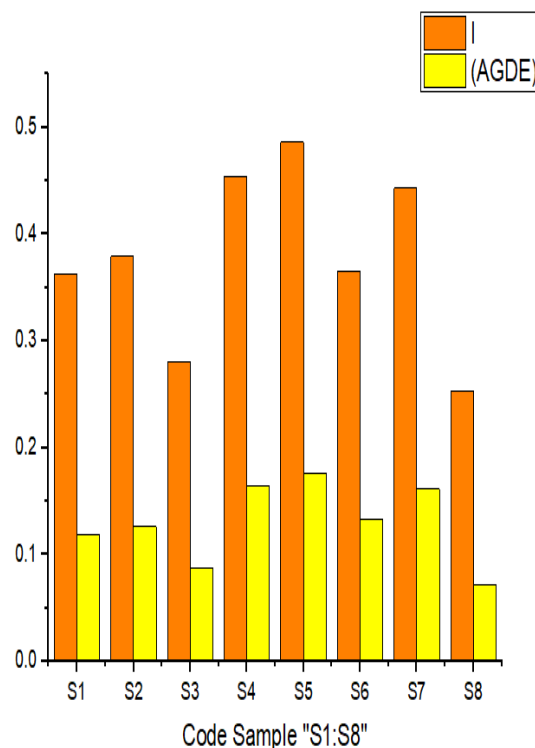


**Fig.8.** Annual internal external effective dose (msv/y)





**Fig.9.**Lifetime cancer risk factors in ELCR in and andequivalent dose excecc lifetime cancer risk factors in ELCR m out



**Fig.10.**radiation exposure of gonads (msv/y)

## Conclusions

The results of the current study showed that ( $^{226}\text{Ra}$ ,  $^{214}\text{Pb}$ ,  $^{214}\text{Bi}$ ,  $^{232}\text{Th}$ ,  $^{212}\text{Pb}$ ,  $^{228}\text{Ac}$ ,  $^{40}\text{K}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ ) were within the internationally permissible limits, which while concentrations of ( $^{228}\text{Ac}$ ,  $^{212}\text{Pb}$ ) were found higher than the international permissible limits. These values indicate that the soil is radioactively contaminated, which is attributed to military operations and agricultural activities. It was found that the radioactive risks of each of ( $R_{\text{aeq}}$ ,  $D_r$ ,  $H_{\text{ex}}$ ,  $H_{\text{in}}$ ,  $I$ ,  $\text{AEDE}_{\text{indoor}}$ ,  $\text{AGDE}$ ) within the global determinants, and it was found that the concentrations of ( $\text{ELCR}_{\text{out}}$ ,  $\text{ELCR}_{\text{in}}$ ,  $\text{AEDE}_{\text{outdoor}}$ ) that these high indicators are considered dangerous to human health and living organisms.

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