Determination of the Natural Radioactivity and Heavy Elements from Some Soil Samples

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Soil samples were collected from various regions of Baghdad, Iraq's capital, and the activity concentration was determined using a high-purity germanium (HPGe) detector. The average activity concentrations of 226Ra, 232Th, and 40K are (16.60–22.94) Bq/Kg, (11.13–12.00) Bq/Kg, and (108.12- 213.45) Bq/Kg, respectively. Radium equivalent activity, internal and external hazard indices, air absorbed dose rate, and annual effective doses have been calculated to find the radiological effects. The parameters were found to be less than the reported values. As a result, the radioactivity in the study area presents no radiological risk to the public. Finally, X-ray fluorescence spectrometry (XRF) was used to determine the concentration elements of uranium and thorium in soil samples; the average concentration elements are (11.13-12.00) with uranium and (11.13-12.00) with thorium.

Keywords: high-purity germanium (HPGe), X-ray fluorescence spectrometry (XRF), Radioactive.

1. Introduction

Humans are exposed to two types of radiation: natural sources such as cosmic rays and radionuclides found in soil, water, air, and plants, as well as artificial radioactivity from nuclear tests and medical applications [1]. Natural radioactive isotope values are determined by the physical, chemical, and biological properties of the soil. Natural radioactive isotopes are increased by rainfall, different types of cultivated plants, soil management techniques, and the use of fertilizers [2]. The most important terrestrial radionuclides to consider are ^{238}U, ^{232}Th, and ^{40}K because they are abundant in the Earth's crust and have a long half-life [3]. Uranium has both chemical and radiological toxic effects; in general, its chemical toxicity far outweighs its radiological toxicity [4]. Although the levels of natural radioactive materials are very low and have no noticeable effect, they have an important impact on human life and the environment, so attention must be paid to monitoring radionuclides and their levels and studying the natural radioactivity of the soil. International organizations have recommended monitoring the radioactive environment through continuous surveying, documentation, and reporting of soil to ensure control over potential changes [5]. As a result, researchers from all over the world are very interested in measuring natural radioactivity and assessing the health impact of radionuclides on humans [6-10].

The purpose of this study is to determine the level of radioactivity, measure the concentration of ^{238}U, ^{232}Th, and ^{40}K activity in the soil, and assess radiological risks. These studies play an important role in radiation protection and human health, and the data will help determine whether the studied region is in an area with normal or high background radiation. Gamma spectrometry is an indirect method for determining uranium and thorium through their decay products; however, this method takes a long time to establish equilibrium radiation with decay products [11], so other techniques such as energy dispersive X-ray fluorescence (EDXRF) were used to determine the concentration elements of thorium and uranium. This method is very important because it is used to determine trace elements, direct measurement, easy, sensitive, precision, accuracy, hazardous waste is very low, quick, and nondestructive analysis. It applies to a wide range of elements, including sodium (11) and uranium (92), and has detection limits of sub-ppm [12].

2. Materials and Method

2.1 Sample Collection and Preparation

Study areas: Baghdad is Iraq's capital and most densely populated city, located in the center of the country. This study was carried out in six areas, and four samples for each area were selected. These areas are Al-Sader, Dora, Al-Baldeyat, Abu Ghraib, Al-Jamaa district, and Al-Adel, as shown in Fig. 1.

To ensure accurate results, samples were crushed into a fine powder with a particle size of around 200 µm using an electric agate grinder. The samples were then dried in an oven at a constant temperature of 200 degrees Celsius for 2 hours. The samples were stamped, stored in an impervious container to prevent the escape of radiogenic gases such as radon, and kept for at least one month to allow the radioactive equilibrium between the daughter products of ^{222}Ra and ^{220}Rn to decay their short-lived isotopes [13]. 500 g were taken and placed in a Marinelli beaker Model 533 N to determine the activity concentration using HpGe detector. Then it was weighed at 4-5 g for each sample and pressed using a hydraulic press to determine concentration elements using XRF.

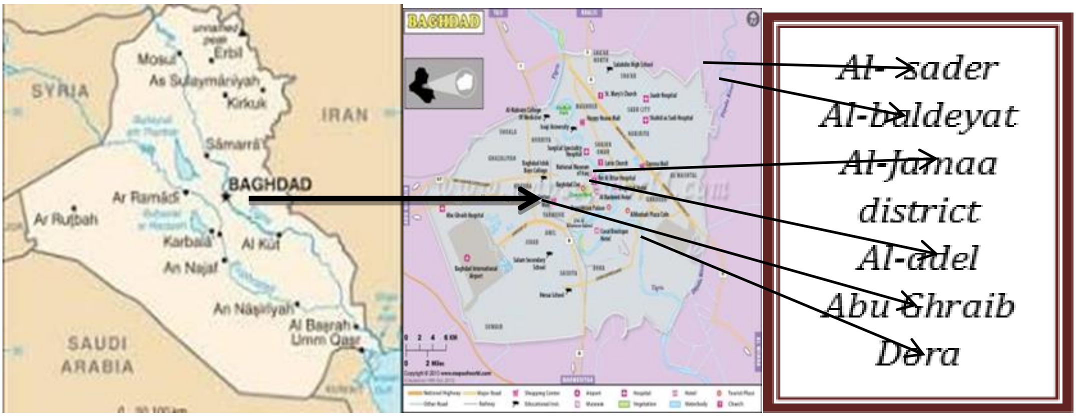

Fig.1: Selected areas from Baghdad

2.2 The Instrumentations

2.2.1 High-purity germanium: The measurement system employs gamma-ray spectrometry analysis with an HPGe detector attached to a digital spectrum analyzer model (DSA-2000) (Canberra Industries, USA). The system was controlled from a personal computer via Ethernet. Data were collected, saved, and analyzed using the Genie-2000 software (Canberra Industries, USA). The detector's energy resolution is 2.0 keV at the 1332 keV gamma emission of ^{60}Co, with a relative efficiency of 50%. Shielding the detector with lead bricks reduced the radiation background levels. The weight of each sample was determined.

2.2.2 X-Ray Florescence (XRF): Energy dispersive XRF (EDXRF) with Silicon Drift Detectors (SDD) was used to determine the concentration of uranium and thorium elements. The detector tube manufactured by Rigaku-Company, NEX CG II, was connected to the computer via. Quantez software is powerful and easy to use for controlling spectrometer functions and analyzing data. Five targets were used to generate various X-ray energies.

Calculated the detection limit (DL) and quantification limit (QL) of the XRF system by the equations (1,2) [11]:

$$\text{The limit of detection (LD)} = \mathrm{bo} + \frac{3 * \mathrm{S(bo)}}{\mathrm{b1}} \qquad (1)$$

$$\text{The limit of quantification} = \mathrm{bo} + \frac{10 * \mathrm{S(bo)}}{\mathrm{b1}} \qquad (2)$$

where, b_o, is the blank value, $S(b_0)$: standard deviation of blank values , slope of the calibration curve.

2.3 Calculation of radiological effects :

1. Radium equivalent activity (Ra_{eq}): calculated this factor using equation [15]:

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \quad (3)$$

Where A_U ,A_{Th} and U_K are the specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K in (Bq/ kg) respectively.

2. Radiation Hazard Indices (H_{ex}) : We calculated The internal hazard (H_{in}) and external hazard (H_{out}) indices due to exposure to gamma ray by Equation [16]

   a. The external hazard index (H_{out})

$$H_{out} = A_U/370 + A_{Th}/259 + A_K/4810 \leq 1 \quad (4)$$

   b. The internal hazard index (H_{in})

$$H_{in} = A_U/185 + A_{Th}/259 + A_K/4810 \leq 1 \quad (5)$$

3. The Absorbed Dose Rate in Air (D): calculate the absorbing dose radiation for the uniform distribution of the naturally occurring radionuclides at 1m above the ground surface due gamma radiations by eqs. :

   a. $$D\gamma_{out}\,(nGy/h) = 0.462A_U + 0.604A_{Th} + 0.041A_K \quad (6)$$

   b. $$D\gamma_{in}\,(nGy/h) = 0.92A_U + 1.1A_{Th} + 0.081A_K \quad (7)$$

4. Activity Utilization Index (AUI): calculated this parameter using eq [17]

$$AUI = (A_U/50)\, f_U + (A_{Th}/50)\, f_{Th} + (A_K/500) f_K \quad (8)$$

Where f_u, f_{Th} and f_k are the fractional contributions for ^{238}U , ^{232}Th and ^{40}K that equal (0.462) , (0.604) and(0.041) respectively

5. Representative level index (I) : The gamma index $I\gamma$ calculated using equation:

$$I_\gamma = A_U /300 + A_{Th}/200 + A_K/3000 \quad (9)$$

6. The Annual Effective Doses Equivalent (AEDE)

a. The annual effective doses equivalent outdoor $(AEDE)_{Outdoor}$

$$AEDE_{out}\,(\mu Sv/y) = D\gamma_{out}(nGy/h) \times 8760(h/y) \times 0.20 \times 0.7(Sv/Gy) \times 10^{-3} \quad (10)$$

b. The annual effective doses equivalent indoor $(AEDE)_{indoor}$

$$AEDE_{in}\,(\mu Sv/y) = D_{\gamma in}(nGy/h) \times 8760(h/y) \times 0.80 \times 0.7(Sv/Gy) \times 10^{-3} \quad (11)$$

7. Excess lifetime cancer risk (ELCR): The equation (17 and 18) can be used to evaluate the outdoor and indoor cancer risk if we assumed the average human life seventy and the risk factor (RF) equal $0.05\times10^{-3}\ Sv^{-1}$ [17]

a. $ELCR_{in} = AEDE_{in} \times DU \times RF$ (12)

b. $ELCR_{out} = AEDE_{out} \times DU \times RF$ (13)

8. Annual gonadal dose equivalent (AGDE)

$$AGDE(\mu Sv/y) = 2.09\ A_{Ra} + 4.18 A_{Th} + 0.314 A_{K} \quad (14)$$

9. Representative level index(RLI) [18]:

$$RLI = (1/150)A_{U} + (1/100)A_{Th} + (1/1500)A_{K} \leq 1 \quad (15)$$

3. Results and Discussion

3.1 Radioactivity Levels

3.1.1 Activity concentration: The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in some regions of Baghdad governorate were (15.21-24.13)Bq/kg, (9.93-14.76)Bq/kg, and (101.53-253.96) Bq/kg, respectively, with an average of (18.96, 11.78, and 136.40) Bq/kg, as shown in table (1). The average specific activity in this study is compared to the international values, which are 35 Bq/kg, 30 Bq/kg, and 400 Bq/kg for ^{226}Ra, ^{232}Th, and ^{40}K, respectively [18]. As shown in Fiq. 2, the results show that the average specific activity of ^{238}U, ^{232}Th, and ^{40}K is lower than the international value. Table 2 shows a comparison of the activity concentrations in soil samples from this study to those from surrounding countries.

3.1.2 Radiation hazards: The calculated assessment of radiation hazards is shown in Tables 1 and 2. Owing to activity concentrations of ^{232}Th, ^{226}Ra and ^{40}K, Ra_{eq} natural radionuclides from all sites vary in the range of (38.40-64.79) Bq/kg with average 46.31 Bq/kg, which is much less than the threshold value of 370 Bq/kg. External and internal radiation hazard indices (H_{ex}, H_{in}) as shown in Table 1 are (0.10 - 0.18) with average 0.13 and (0.14 - 0.24) with an average of 0.18, respectively, this index value must be less than unity to keep the radiation hazard trivial. The minimum values for D_{out} , D_{in} , AUI and I ɣ are (17.75 nGy/h , 34.21 nGy/h, 0.27 , 0.14) respectively, and the maximum value are (30.48 nGy/h , 59.01 nGy/h , 0.42, 0.24) and the average are (21.47 nGy/h, 41.45 nGy/h, 0.33 , 0.17). The present results showed that the values of D_{out} , D_{in} , AUI and $I_{ɣ}$ were lower than the recommended value. Calculating the AEDEout, AEDEin, ELCRout, ELCRin, AGDE, and RLI, the result shows the minimum values are (21.77 μSv/y, 167.82 μSv/y , 0.08 $\times10^{-3}$, 0.59 $\times10^{-3}$, 109.29 μSv/y , 0.28) respectively ,and the higher value are (37.38 μSv/y, 289.46 μSv/y, 0.13 $\times10^{-3}$, 1.01 $\times10^{-3}$, 191.87 μSv/y, 0.48) respectively, and the average are (26.33 μSv/y, 203.35 μSv/y, 0.09 $\times10^{-3}$, 0.71 $\times10^{-3}$, 131.70 μSv/y, 0.34) respectively. This result camper with the international values, which are (80, 420, 0.29, 1.16, <300,1) respectively [18,19]. Fig. (3-5) shows that the average value of radiation hazards is less than the recommended value.

Table 1: The activity concentration of, ^{226}Ra ^{232}Th and ^{40}K in Bq/kg in soil sample at

Baghdad and the radium equivalent activity (Ra_{eq}), external and Internal hazard index

sample	Location	Code no.	^{226}Ra	^{232}Th	^{40}K	Ra_{eq} Bq/kg	H_{out}	H_{in}
Al sader	33° 23′ 20″ N, 44° 27′ 30″ E	S1	23.81	12.74	234.67	60.1	0.16	0.23
		S2	22.12	13.65	175.22	55.13	0.15	0.21
		S3	21.66	11.96	201.87	54.31	0.15	0.21
		S4	24.13	14.76	253.96	64.79	0.18	0.24
		S5	23.11	13.42	221.52	59.36	0.16	0.22
		Ave.	22.966	13.306	217.448	58.738	0.16	0.222
Dora	33°15′5″N 44°23′31″E	S1	17.85	10.57	122.69	42.41	0.11	0.16
		S2	20.56	13.44	121.87	49.16	0.13	0.19
		S3	19.32	12.38	125.43	46.68	0.13	0.18
		S4	17.14	11.79	131.43	44.12	0.12	0.17
		Ave.	18.72	12.04	125.35	45.59	0.12	0.17
albaldeyat	33°34′6″N, 44°49′05″E	S1	18.55	10.36	121.97	42.76	0.12	0.17
		S2	20.22	9.93	121.73	43.79	0.12	0.17
		S3	18.93	12.71	126.12	46.82	0.13	0.18
		S4	20.11	11.51	123.36	46.07	0.12	0.18
		S5	19.69	13.82	129.73	49.44	0.13	0.19
		Ave.	19.5	11.67	124.58	45.78	0.12	0.18
Abu Ghraib	33°29′82″N, 44°08′05″E	S1	20.01	10.81	124.98	45.09	0.12	0.18
		S2	19.41	11.31	119.32	44.77	0.12	0.17
		S3	18.83	10.37	114.93	42.51	0.11	0.17
		S4	19.37	10.98	120.61	44.36	0.12	0.17
		S5	20.03	12.16	176.98	51.05	0.14	0.19
		Ave.	19.53	11.126	131.364	45.556	0.122	0.176
Al-Jamaa district	33°31′90″N, 44°31′88″E	S1	15.84	10.84	118.37	40.46	0.11	0.15
		S2	17.33	11.53	104.45	41.86	0.11	0.16
		S3	16.29	12.21	109.23	42.16	0.11	0.16
		S4	18.11	10.83	113.18	42.31	0.11	0.16
		S5	15.42	11.22	101.53	39.28	0.11	0.15
		Ave.	16.6	11.33	109.35	41.21	0.11	0.16
Aladel	33°33′33″N, 44°32′38″E	S1	15.21	10.32	109.45	38.4	0.1	0.14
		S2	16.82	11.73	112.43	42.25	0.11	0.16
		S3	17.32	12.31	101.87	42.77	0.12	0.16
		S4	16.83	10.63	115.25	40.91	0.11	0.16
		S5	15.93	11.32	101.61	39.94	0.11	0.15
		Ave.	16.42	11.26	108.12	40.85	0.11	0.15
		World average	11 - 64	17 - 60	140 - 850			
		World's average	30	35	400[18]	370	<1	<1

Table 2 : Radiological effects parameters in Baghdad soil samples

sample	Code no.	D_{out} nGy/h	D_{in} nGy/h	AUI	I ɣ	$AEDE_{out}$ µSv/y	$AEDE_{in}$ µSv/y	$ELCR_{out}$ $x10^{-3}$	$ELCR_{in}$ $x10^{-3}$	AGDE µSv/y	RLI
Al sader	S1	22.28	43.93	0.27	0.171	27.32	215.49	0.1	0.75	134.9	0.34
	S2	25.65	49.56	0.38	0.2	31.455	243.11	0.11	0.85	158.31	0.4
	S3	25.51	49.43	0.36	0.199	31.282	242.51	0.11	0.85	158.65	0.4
	S4	30.48	59.01	0.42	0.239	37.375	289.46	0.13	1.01	191.87	0.48
	S5	27.86	53.97	0.39	0.218	34.173	264.74	0.12	0.93	173.95	0.44
	Ave.	26.36	51.2	0.36	0.205	32.321	251.062	0.114	0.878	163.54	0.41
Dora	S1	19.66	37.99	0.3	0.153	24.113	186.35	0.08	0.65	120.01	0.31
	S2	22.61	43.57	0.36	0.176	27.733	213.74	0.1	0.75	137.42	0.35

	S3	21.55	41.55	0.34	0.168	26.424	203.84	0.09	0.71	131.51	0.34
	S4	20.43	39.38	0.31	0.16	25.053	193.2	0.09	0.68	126.37	0.32
	Ave.	21.06	40.62	0.32	0.16	25.83	199.28	0.09	0.69	128.83	0.33
albaldeyat	S1	19.83	38.34	0.31	0.154	24.317	188.09	0.09	0.66	120.37	0.31
	S2	20.33	39.39	0.32	0.158	24.933	193.21	0.09	0.68	121.99	0.32
	S3	21.59	41.61	0.34	0.169	26.482	204.13	0.09	0.71	132.29	0.34
	S4	21.3	41.15	0.33	0.166	26.123	201.89	0.09	0.71	128.88	0.33
	S5	22.76	43.82	0.36	0.178	27.917	214.99	0.1	0.75	139.65	0.36
	Ave.	21.16	40.86	0.33	0.17	25.95	200.46	0.09	0.70	128.64	0.33
Abu Ghraib	S1	20.9	40.42	0.33	0.162	25.629	198.3	0.09	0.69	126.25	0.32
	S2	20.69	39.96	0.33	0.161	25.375	196.04	0.09	0.69	125.31	0.32
	S3	19.68	38.04	0.31	0.153	24.13	186.61	0.08	0.65	118.79	0.31
	S4	20.53	39.67	0.32	0.16	25.173	194.59	0.09	0.68	124.25	0.32
	S5	23.85	46.14	0.35	0.187	29.255	226.34	0.1	0.79	148.26	0.37
	Ave.	21.13	40.85	0.33	0.16	25.91	200.37	0.09	0.7	128.57	0.33
Al-Jamaa district	S1	18.72	36.08	0.29	0.146	22.957	177.02	0.08	0.62	115.58	0.29
	S2	19.25	37.09	0.31	0.15	23.612	181.93	0.08	0.64	117.21	0.3
	S3	19.38	37.27	0.31	0.152	23.767	182.81	0.08	0.64	119.38	0.3
	S4	19.55	37.74	0.31	0.152	23.974	185.15	0.08	0.65	118.66	0.3
	S5	18.06	34.75	0.29	0.141	22.153	170.48	0.08	0.6	111.01	0.28
	Ave.	18.99	36.59	0.30	0.15	23.29	179.48	0.08	0.63	116.37	0.29
Aladel	S1	17.75	34.21	0.27	0.139	21.766	167.82	0.08	0.59	109.29	0.28
	S2	19.47	37.48	0.31	0.152	23.872	183.88	0.08	0.64	119.49	0.3
	S3	19.61	37.73	0.32	0.153	24.054	185.07	0.08	0.65	119.64	0.31
	S4	18.92	36.51	0.29	0.148	23.205	179.11	0.08	0.63	115.8	0.3
	S5	18.36	35.34	0.29	0.144	22.52	173.35	0.08	0.61	112.52	0.29
	Ave.	18.82	36.25	0.3	0.15	23.08	177.85	0.08	0.62	115.35	0.3
World average		55[13]	84[14]	<2[19]	1	80[19]	420[19]	0.29[19]	1.16[19]	<300	1[19]

Table 3 : Natural radioactivity of some surrounding countries

Country	^{226}Ra(Bq /kg)	^{232}Th(Bq /kg)	^{40}K(Bq /kg)	Ref
Iran	8.69	3.30	75.78	[20]
Turkey	24.5	51.8	344.9	[21]
Saudi Arabia	38.7	23.5	217.9	[22]
Egypt	11.3	6.8	112	[23]
Jorden	57.7	18.1	138.1	[24]

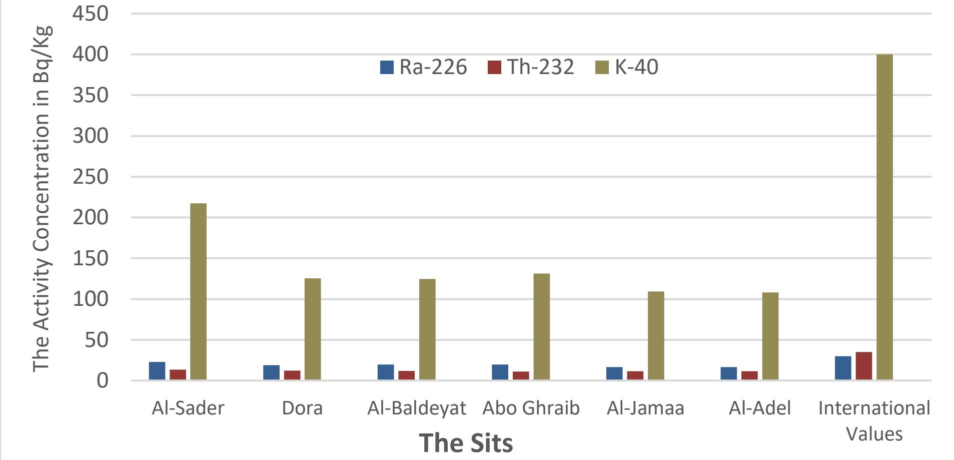

Fig 2: The Activity Concentration in Some Region of Baghdad

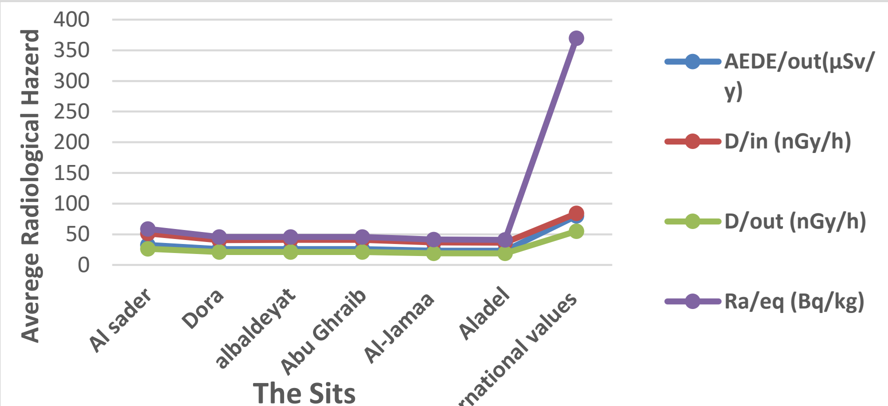

Fig 3: Radiological Effecte Parameter in Baghdad Soil

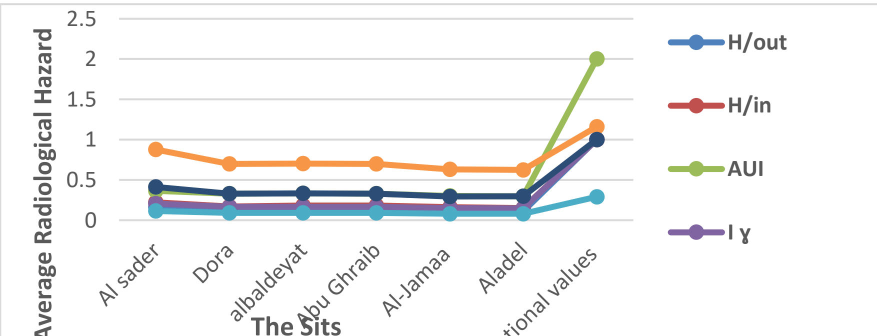

Fig 4 :Radiological Effects Parameters in Baghdad Soil Samples

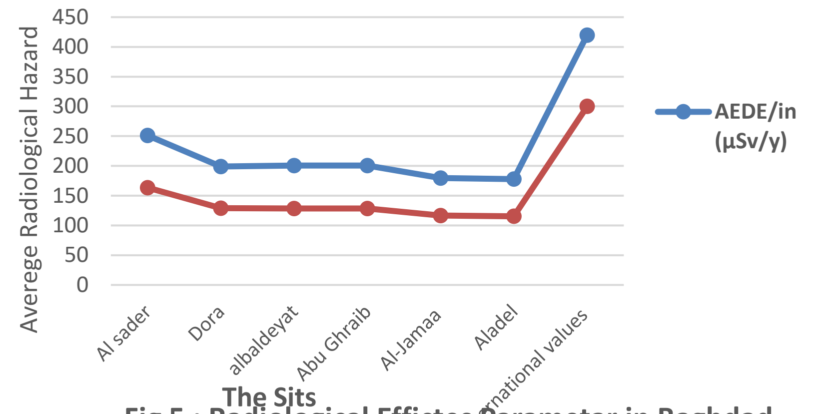

Fig 5 : Radiological Efficites Parametar in Baghdad Soil Samples

3.1.3 Basic statistical analysis: Basic statistical analysis, such as maximum, minimum, standard deviation, variance, and skewness, can be used to describe the statistical properties of radionuclide activities, as shown in Table 5. The standard deviation of ^{232}Th, ^{226}Ra, and ^{40}K from all measurements is less than the mean value, which indicates an irregular distribution. The skewness data revealed an asymmetric distribution of activity concentrations [25]. The skewness of ^{226}Ra, ^{232}Th, and ^{40}K is positive in all regions, indicating that their distributions are symmetric. In this study, the skewness value is low, indicating that the shape is normal [25].

Table 5: Basic statistical analysis

	^{232}Th	^{226}Ra	^{40}K
Maximum	14.76	24.13	253.96
Minimum	9.93	15.21	101.53
Average .	11.78	18.96	136.40
Standard deviation	1.22	2.43	41.65
Variance	1.48	5.93	1734.75
Skewness	0.66	0.46	1.76

3.2 Concentration elements using XRF.

To determine the concentration of uranium, thorium, and potassium, 4 grams were taken from each previously prepared sample. Each sample was pressed using a hydraulic piston with a pressure of 15 tons per square centimeter and a tablet diameter of 32 millimeters.

Table 6. Elemental concentrations of Uranium, Thorium, Potassium, and eU/eTh, eTh/eU, in soil samples

sample	Code no.	U ppm	LLD	LLQ	Th ppm	LLD	LLQ	K ppm	LLD	LLQ	eU/eTh	eTh/eU
Al sader	S1	2.81	1.26	3.71	9.43	0.92	3.25	9367	30.21	79.2	0.3	3.36
	S2	2.63	1.23	3.67	9.16	0.94	3.01	9183	29.95	77.2	0.29	3.48
	S3	2.28	1.12	2.91	8.90	0.85	2.95	8971	28.7	76.7	0.26	3.9
	S4	2.61	1.23	3.73	9.36	0.91	3.11	9214	28.9	77.4	0.28	3.59
	S5	2.84	1.26	3.52	9.25	0.89	3.24	9402	29.2	78.5	0.31	3.26
Dora	S1	1.86	0.90	2.71	10.7	0.68	2.04	9359	14.1	42.4	0.17	5.75
	S2	1.36	0.64	2.21	6.34	0.61	2.0	7739	25.85	68.76	0.21	4.66

	S3	1.19	0.42	2.38	5.76	0.59	2.03	7623	24.6	66.35	0.21	4.84
	S4	1.43	0.59	2.40	7.28	0.68	2.25	7976	26.23	70.46	0.2	5.09
albaldeyat	S1	1.68	0.89	2.51	7.79	0.77	2.31	8896	23.7	71.0	0.22	4.64
	S2	2.32	1.25	3.81	9.41	0.89	3.21	9421	29.7	79.3	0.25	4.06
	S3	1.96	0.91	2.71	8.14	0.81	2.71	8958	25.1	75.0	0.24	4.15
	S4	2.63	1.41	3.49	9.77	0.91	3.41	9632	30.1	81.6	0.27	3.71
	S5	2.08	1.12	2.91	8.69	0.85	2.95	9176	28.7	77.2	0.24	4.18
Abu Ghraib	S1	3.24	1.19	3.91	10.94	1.02	2.54	9365	30.45	78.46	0.3	3.38
	S2	2.83	1.26	3.71	9.45	0.93	3.25	9391	30.23	79.31	0.3	3.34
	S3	3.19	1.18	3.82	10.73	1.01	2.46	9165	29.45	77.44	0.3	3.36
	S4	3.31	1.18	3.86	11.54	1.12	2.74	9422	30.49	79.16	0.29	3.49
	S5	2.80	1.26	3.71	9.40	0.92	3.25	9357	30.20	79.19	0.3	3.36
Al-Jamaa district	S1	ND	------	-------	7.79	0.77	2.31	8844	22.1	66.4	------	-------
	S2	2.61	0.91	2.75	11.1	0.91	2.68	9404	16.0	48.1	0.24	4.25
	S3	2.69	1.01	3.03	11.2	0.92	2.68	9645	22.4	61.83	0.24	4.16
	S4	1.86	0.9	2.71	10.6	1.1	2.91	9712	22.6	62.21	0.18	5.7
	S5	2.31	0.92	2.81	10.89	0.83	2.55	9873	25.1	77.5	0.21	4.71
Aladel	S1	ND	------	------	ND	-----	-----	7581	21.7	65.1	-------	-------
	S2	2.64	0.92	2.75	11.1	1.01	2.68	9404	16.0	48.1	0.24	4.2
	S3	2.73	1.01	3.03	11.2	1.02	2.68	9645	22.4	61.83	0.24	4.1
	S4	2.51	0.92	2.74	11.01	1.01	2.61	9787	24.15	69.88	0.23	4.39
	S5	2.21	0.91	2.73	10.9	0.94	2.53	9944	25.9	77.8	0.2	4.93

The concentrations elements of U, Th and K for soil samples that were measured, and their range were (1.19 – 2.73) ppm, (5.76-11.2) ppm, (7581-9944) ppm respectively.

Conclusion

The natural radioactivity of ^{232}Th, ^{226}Ra, and ^{40}K in soil samples from the Baghdad region was determined, and the results showed that the average radioactivity is lower than the world average values as reported in UNSCEAR. The calculated radiation effect values indicate that the population living in the study areas is not at risk of radiation exposure. Repeating similar studies regularly is critical for monitoring human health and the environment.

Employing the XRF to determine the concentration of uranium and thorium, the samples can be analyzed directly without preparation, increasing the accuracy of the results. The results showed that the concentration of thorium is higher than that of uranium.

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