Natural Radionuclide (Gamma and Alpha Emitters) in Grain Samples Collected from Kerbala Governorate, Iraq

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Abstract

The aim of this research is to detect nature radioactivity for gamma emitters (specific activity ^{238}U , ^{232}Th , and ^{40}K) using NaI(Tl) detectors and alpha emitters (concentrations of ^{222}Rn , ^{226}Ra , and ^{238}U) using CR-39 detectors in selected samples of grain that are collected from Kerbala governorate. Also, annual effective dose and some radiological parameters due to gamma and alpha emitters to assess the health risk were calculated. Results have been shown that the average value of specific activities for ^{238}U , ^{232}Th and ^{40}K were 6.61 ± 0.91 Bq/kg, 3.07 ± 0.22 Bq/kg and 227.59 ± 32.34 Bq/kg respectively, while the average value of alpha emitters concentrations for ^{222}Rn , ^{226}Ra , and ^{238}U were 3.99 ± 1.13 Bq/m³, 4.69 ± 1.28 mBq/kg and 0.072 ± 0.019 Bq/kg respectively. The results of average total of annual effective dose associated with the exposure due to gamma and alpha emitted from ingestion grain samples in the present study were 0.139 ± 0.013 mSv/y and 0.172 ± 0.047 $\mu\text{Sv/y}$, respectively. The results of natural Radionuclide and radiological parameter hazard based on gamma and alpha emitters from grain samples were discovered to be within the world acceptable levels. Finally, natural radioactivity from the grain samples that collected from Kerbala governorate were safety for the human consumption.

Introduction

Gamma radiation is an electromagnetic radiation emitted from the nucleus of radioactive atom. It is consisting of photons that have been emitted from the nucleus. Photon radiation can also be hazardous if its emitting from nuclear materials is taken into the body [1]. While, alpha particles consist of two neutrons and two protons and it's emitted by a heavy radioactive element, such as Radium, Thorium, Uranium and Plutonium [2]. when alpha emitting nuclear material are taken into the body (for example, by breathing them in or by ingesting them), the energy of the alpha particles is completely absorbed into bodily tissues. For this reason, alpha radiation is only an internal hazard [3]. Gamma and alpha emitters are very important nature elements that contribute to a max part of radioactivity dose received by people, with a wide distribution have been discovered classification radiation are encountered in earth layers or bodies of water ocean, sea and lakes. It accumulated easily into the chain of food [4]. Natural radioactive decay series such as ^{238}U and ^{232}Th as well as singly occurring radionuclides such as ^{40}K exist in the earth and atmosphere in varied levels. The radioactivity present on air or in the agricultural land and in soil may transfer to the crops grown on it. It happens, however that an amount of some radioactive elements find their way into human bodies. Ingestion with food or drinks, or with other materials which come into contact with the mouth [5]. This is usually a result of poor housekeeping, a lack of personal hygiene or allowing consumption of food in radioisotope areas. Ingested materials pass through the gastrointestinal tract with absorption and excretion being determined by solubility. Water soluble material will gain entry to the blood stream and be readily passed to body organs. Insoluble material will pass through the gut and be excreted [5]. Roots get their nutrients primarily from the solution of soil. Natural, radionuclides is found everywhere in the soil. It is transfer to plants through the consumption of radioactivity either through system of root or by external surfaces of plant [2]. Root uptake consumes the solutes in the solution of soil on a continuous basis However, it is also regenerated from the solid state of

the soil. Because of the intricate, temporal, and geographical structure of the soil plant relationship, estimating radionuclide uptake from soil is difficult. People being are encouraged to consume very much grain in every day because this grain are rich in minerals, fibers and protein. They are containing essential and toxic metals and radionuclides proven benefits to the general health of People [6]. The grain contains protein, pectin, lipid, salt, and mineral in addition to being abundant in nutrient, fibers of dietary, and carbohydrates [6]. A number of studies have determined the radiation content in grain [7–10]. As a result, the goal of this study is to research and analyze the level of radioactivity (gamma and alpha emitters) in grains samples in Kerbala governorate, Iraq.

Methodological Of Research

3.1. Collections of Sample

Twenty of types of grains samples (wheat, barley, corn, millet, mungbean, and rice), these samples were collected from different sites of Kerbala Governorate. The grains samples were labeled with special codes. The information complete about samples was written, as shown in Table 1.

TABLE 1. Grains samples from deferent sites in kerbala

No.	Type of grain	Sample code	Original
1	Wheat	G1	Iraq (Eayn Al-Tamr)
2		G2	Iraq (Al-Jadwal Al-Gharbiu)
3	Barley	G3	Iraq (Eayn Al-Tamr)
4		G4	Iraq (Al-Jadwal Al-Gharbiu)
5	Corn	G5	Iraq (Eayn Al-Tamr)
6		G6	Iraq (Al-Jadwal Al-Gharbiu)
7	Millet	G7	Iraq (Eayn Al-Tamr)
8		G8	Iraq (Al-Jadwal Al-Gharbiu)
9	Mung bean	G9	Iraq (Eayn Al-Tamr)
10		G10	Iraq (Al-Jadwal Al-Gharbiu)
11		G11	Iraq (Aoun)
12	Rice	G12	India (Gold)
13		G13	USA (Camolino)
14		G14	Iraq (Eayn Al-Tamr)
15		G15	Iraq (Al-Jadwal Al-Gharbiu)
16		G16	Iraq (Al-Jadwal Al-Gharbiu)
17		G17	India (Abu Araba)
18		G18	India (Royal)
19		G19	Iraq (Aoun)
20		G20	USA (Jasmine)

3.2. Preparations of Sample

After collecting the grains samples were transferred in nuclear laboratory in Kerbala university for preparation to measure gamma and alpha emitters. The preparation method of samples was done by several processing such as cleaned the samples, dried in an oven at 100 °C for 4 hours, crushed the samples, sieved by sieve for 2 mm mesh, weighted by digital balance, and put samples in marinelli beakers (l L) and plastic container (radius 5 cm, higher 7 cm) for measuring gamma and alpha emitters, respectably. Next, all samples were stored at least for 1 month for getting secular equilibrium between radium-226 and radon-222 [11, 12].

3.3. Experimental Methods

In the present study, it was measured gamma emitters (Uranium-238, Thorium-232, and Potassium-40) using NaI(Tl) detection system and alpha emitters (Radon-222, Radium-226, and Uranium-238) using CR-39 detectors. The NaI(Tl) detector was a 3"×3" crystal dimension which it is calibrated using ^{137}Cs , ^{22}Na , ^{60}Co , and ^{152}Eu . There are three energies of spectrum used to find specific activity of gamma emitters according to secular equilibrium propriety which it is 1764.5 KeV for ^{214}Bi (^{238}U or ^{226}Ra), 2614 KeV for ^{208}Tl (^{232}Th), and 1460 KeV for ^{40}K (^{40}K) [13]. A CR-39 detector has density 1.32 gm/m³, thickness 1mm and dimension 2.5×2.5cm², which it is made by TASTRAK Analysis System, Ltd., UK. Also, it has special code that suited the TASL image system. The chemical etching procedure was carried out by NaOH with a 6.25 N at temperature 85°C [14]. CR-39 in the present study was calibrated factor using standard source ^{226}Ra for different time exposure such as 0.5, 1, 1.5, 2, 2.5, and 3 days which it is equal (0.28±0.043) Track.cm² /Bqm⁻³.day. The background radiation for two detection system (NaI(Tl) and CR-39) was measured at same container and time for sample measurements that used in the present study.

3.4. Theoretical Equations

3.4.1. Gamma emitters

The specific activity (A) for gamma emitters that depend on many parameters as shown in Equation (1) was found by following [15,16]:

$$A \left(\frac{\text{Bq}}{\text{kg}} \right) = \frac{(N - B)}{t \times \varepsilon \times I_\gamma \times m} \quad (1)$$

where, N is area of under photopeak, B is the areas under photopeak background. t is counting time which it is equal 18000 secs, ε is the efficiency of the detector, I_γ is the probability of gamma emission, and m is the mass of sample.

Radium Equivalent Activity (Ra_{eq}) and Internal hazard index (H_{in}) due to gamma emitters that calculated using equations (2) and (3), respectively [17, 18]:

$$Ra_{eq} \left(\frac{\text{Bq}}{\text{kg}} \right) = A_U + 1.43A_{Th} + 0.077A_K \quad (2)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (3)$$

While, the annual effective dose (AED) in grain samples of the present study was calculated using equation (4), as following [19]:

$$AED \left(\frac{mSv}{y} \right) = I \times \sum_i^3 A_i \times CF_i \quad (4)$$

where, I mean consumption rate of grains samples in unit (Kg/y) which taken from previous studies [20-26], A_i is the specific activity for gamma emitters, and CF_i is conversion factor in unit Sv/Bq that equal 2.80×10^{-7} for ^{238}U (^{226}Ra), 2.30×10^{-7} for ^{232}Th , and 6.20×10^{-9} for ^{40}K [27].

Also, it was calculated threshold consumption rate (DI_{thresh}) in grains samples using equation (5), as following [28]:

$$DI_{\text{thresh}} \left(\frac{Kg}{y} \right) = \frac{E_{ave}}{\sum_i^3 A_i \times CF_i} \quad (5)$$

where, E_{ave} is equal 0.320 that means an acceptable limit of annual effective dose [5].

Finally, for gamma emitters theoretical equations, can be calculated Excess lifetime cancer risk (ELCR) using equation (6) [15, 28]:

$$ELCR = AED \times DL \times RF \quad (6)$$

where, DL is life expectancy (70 y) while RF is fatal risk factor in (Sievert) and it is pegged at 0.05 per Sievert.

3.4.1. Alpha emitters

^{222}Rn Concentrations that measured in the airspace of container (C) and within samples (C_{Rn}), were determined by equations (7) and (8), respectively, as following [29, 12]:

$$C \left(\frac{Bq}{m^3} \right) = \frac{\rho}{K T} \quad (7)$$

$$C_{\text{Rn}} \left(\frac{Bq}{m^3} \right) = \frac{C \lambda_{\text{Rn}} h T}{l} \quad (8)$$

where ρ is the track density which determined by TASL device, T is time irradiation for sample with CR-39 detector in container which was equal 90 days, K is calibration factor, λ_{Rn} is radon-222 of the decay constant which equal 0.1814 1/day, h is distance of samples to CR-39 detector, and l is higher of samples in container.

While, equation (9) was used to find the effective radium content in sample (C_{Ra}) as following [5]:

$$C_{Ra} \left(\frac{Bq}{kg} \right) = \frac{C h A}{M} \quad (9)$$

The uranium concentration (C_U) in samples of the present study in unit (ppm) was calculated using equation (10), which depend on secular equilibrium propriety between uranium-238 and radon-222, as following [30]:

$$C_U (ppm) = \frac{M_U}{M} \dots \dots \dots (10)$$

The equation (11) was used to determine AED due to alpha emitters in food samples which depend on many parameters such as specific activity of radon-222, radium-226 and uranium-238 in sample (C_{Alpha}) in unit (Bq/kg), consumption rate of samples (I) in unit (Kg/y), and conversion dose factor (CF) in unit (Sv/Bq), as following [30]

$$AED \left(\frac{nSv}{y} \right) = C_{Alpha} \times I \times CF \dots \dots \dots (11)$$

Where, the values of conversion dose factor are 3.5 nSv/Bq [27] for radon-222, 280 nSv/Bq [31] for radium-226 and 45 nSv/Bq for uranium-238 [31]. Finally, can be determined ELCR using equation (6).

Results And Discussion

4.1. Gamma emitters

The results of the specific activity as well as stander division (S.D) of gamma emitters (uranium-238, thorium-232 and potassium-40) in different grain samples at Kerbala governorate were presented in Table (2). From Table (2), the range value of the specific activity in unite Bq/kg for uranium-238, thourium-232 and potasium-40 were 88.67-586.61, 1.52–5.94, and 3.13–18.58, while the average value with stander error (S.E) were 227.59 ± 32.34 , 3.07 ± 0.22 , and 6.61 ± 0.91 , respectively. The maximum of the specific activity for or uranium-238, thourium-232 and potasium-40 were found in samples G14 (rice, Eayn Al-Tamr), G19 (rice, Aoun), and G10 (mung bean, Al-Jadwal Al-Gharbiu), while the minimum were in samples G2 (wheat, Al-Jadwal Al-Gharbiu), G13 (rice, USA), and G16 (rice, Al-Jadwal Al-Gharbiu), respectively. Also, from Table (2), the average value of specific activity of ^{238}U was higher than the average of ^{232}Th , while the average of ^{40}K is larger than the values of ^{238}U , and ^{232}Th . Figures (1), (2), and (3) were shown histograms for ^{238}U , ^{232}Th , and ^{40}K in grains samples in present study, respectively. When the comparison of the specific activity (in unit Bq/kg) for ^{238}U , ^{232}Th , and ^{40}K of grain samples in the present study with the specific activity of worldwide according to UNSCEAR 2008 [19] which equal 33 for ^{238}U , 45 for ^{232}Th , and 412 for ^{40}K , it is found that all values of ^{238}U , ^{232}Th , and ^{40}K lower than these

values, except samples G9, G10, and G11 have the specific activity ^{40}K larger than worldwide, these because increasing used chemical fertilizers by peasants.

Table 2
Results of ^{238}U , ^{232}Th , and ^{40}K in grains samples in present study

No.	Sample code	Specific activity Bq/kg					
		^{238}U		^{232}Th		^{40}K	
		Average	S.E.	Average	S.E.	Average	S.E.
1	G1	4.12	0.54	2.61	0.26	222.62	4.12
2	G2	3.13	0.48	1.74	0.22	181.06	3.79
3	G3	5.43	0.63	4.12	0.33	269.63	4.64
4	G4	3.18	0.50	3.11	0.30	228.31	4.40
5	G5	4.04	0.53	2.99	0.28	185.72	3.75
6	G6	3.45	0.51	2.97	0.29	139.90	3.38
7	G7	11.18	0.93	2.17	0.25	217.65	4.26
8	G8	4.11	0.55	3.73	0.32	215.83	4.19
9	G9	6.21	0.66	2.38	0.25	539.13	6.40
10	G10	4.64	0.58	2.37	0.25	586.61	6.81
11	G11	4.25	0.54	2.35	0.25	523.47	6.30
12	G12	6.51	0.66	4.59	0.33	112.53	2.86
13	G13	4.78	0.58	1.52	0.20	104.93	2.84
14	G14	18.58	1.09	3.84	0.30	136.24	3.10
15	G15	11.64	0.90	3.68	0.31	125.39	3.10
16	G16	3.43	0.47	2.33	0.23	88.67	2.48
17	G17	5.47	0.61	3.00	0.27	136.49	3.17
18	G18	7.67	0.72	2.89	0.27	132.41	3.10
19	G19	14.61	0.94	5.94	0.36	259.32	4.14
20	G20	5.72	0.65	3.04	0.29	145.97	3.42
Range		3.13–18.58		1.52–5.94		88.67-586.61	
Average $\pm$ S.E		6.61 $\pm$ 0.91		3.07 $\pm$ 0.22		227.59 $\pm$ 32.34	

Table (3) is shown the values of radium equivalent activity (Ra_{eq}) and internal hazard index (H_{in}) based on the specific activity of ^{238}U , ^{232}Th , and ^{40}K in grain samples in the present study that calculates using equations (2) and (3), respectively. The range values of Ra_{eq} were 13.6–53.2 Bq/kg with an average value 28.52 ± 2.56 Bq/kg, while H_{in} were 0.046–0.156 with an average value 0.095 ± 0.007 . From these results the values of Ra_{eq} and H_{in} were less than 370 Bq/kg [32] and 1 [27], respectively that is safety stage.

Table 3
Results of Ra_{eq} and H_{in} in grains samples in present study

No.	Sample code	Ra_{eq} (Bq/kg)	H_{in}
1	G1	25.0	0.079
2	G2	19.6	0.061
3	G3	32.1	0.101
4	G4	25.2	0.077
5	G5	22.6	0.072
6	G6	18.5	0.059
7	G7	31.0	0.114
8	G8	26.1	0.081
9	G9	51.1	0.155
10	G10	53.2	0.156
11	G11	47.9	0.141
12	G12	21.7	0.076
13	G13	15.0	0.054
14	G14	34.6	0.144
15	G15	26.6	0.103
16	G16	13.6	0.046
17	G17	20.3	0.070
18	G18	22.0	0.080
19	G19	43.1	0.155
20	G20	21.3	0.073
Range		13.6–53.2	0.046–0.156
Average $\pm$ S.E.		28.52 $\pm$ 2.56	0.095 $\pm$ 0.007

The results of AED, DI_{thresh} and ELCR in grains samples in present study were shown in Table 4. Based on the results (Table 4), the range value of AED in unit mSv/y due to ^{238}U , ^{232}Th and ^{40}K were 0.007–0.120, 0.005–0.049, and 0.008–0.187 with an average value 0.049 ± 0.007 , 0.024 ± 0.002 , and 0.065 ± 0.009 , respectively. While, the range of total AED were 0.020–0.254 mSv/y, with an average 0.139 ± 0.013 mSv/y which it is lower than the acceptable limit 0.32 mSv/y that recommended by UNSCEAR 2008 [27]. The

range value of Dl_{thres} and average values (Table 4) in unit (kg/y) were 45.3–157 and 91.22 ± 6.90 . Also, from Table (4) the results of ELCR were ranged between 0.049×10^{-3} to 0.716×10^{-3} , with an average value of $(0.365 \pm 0.03) \times 10^{-3}$. From these results found ELCR from all grain samples in the present study due to gamma emitters were within world limit that equal 2.5×10^{-3} [4, 33]. From the results of natural radioactivity for gamma emitters were found that all grain samples in the present study were safety for human consumption.

Table 4
Results of AED, DI_{thresh} and ELCR in grains samples in present study

No.	Sample Code	AED mSv/y			AED _{total} mSv/y	DI _{thresh} (kg/y)	ELCR $\times 10^{-3}$
		²³⁸ U	²³² Th	⁴⁰ K			
1	G1	0.046	0.024	0.055	0.125	102	0.360
2	G2	0.035	0.016	0.045	0.096	133	0.275
3	G3	0.076	0.047	0.084	0.207	77	0.594
4	G4	0.045	0.036	0.071	0.151	106	0.434
5	G5	0.009	0.006	0.009	0.023	108	0.066
6	G6	0.008	0.005	0.007	0.020	127	0.056
7	G7	0.113	0.018	0.049	0.180	64	0.518
8	G8	0.042	0.031	0.048	0.121	96	0.348
9	G9	0.057	0.018	0.110	0.186	57	0.533
10	G10	0.043	0.018	0.120	0.181	58	0.519
11	G11	0.039	0.018	0.107	0.164	64	0.471
12	G12	0.066	0.038	0.025	0.129	89	0.370
13	G13	0.048	0.013	0.023	0.084	137	0.242
14	G14	0.187	0.032	0.030	0.249	46	0.716
15	G15	0.117	0.030	0.028	0.176	66	0.505
16	G16	0.035	0.019	0.020	0.074	157	0.211
17	G17	0.055	0.025	0.030	0.110	104	0.317
18	G18	0.077	0.024	0.030	0.131	88	0.375
19	G19	0.147	0.049	0.058	0.254	45.3	0.049
20	G20	0.058	0.025	0.033	0.115	100	0.331
Range		0.008–0.187	0.005–0.049	0.007–0.120	0.020–0.254	45.3–157	0.049–0.716
Average $\pm$ S.E.		0.065 $\pm$ 0.009	0.024 $\pm$ 0.002	0.049 $\pm$ 0.007	0.139 $\pm$ 0.013	91.22 $\pm$ 6.90	0.365 $\pm$ 0.03

4.2. Alpha emitters

²²²Rn concentration (C and C_{Rn}), effective radium content (C_{Ra}), and uranium concentrations (C_U) in grain samples of Kerbala governorate were determined using CR-39 detector that shown in Tables 5.

From results that shown in Table (5), the range of C were 0.34-19.80 Bq/m³, with an average value of 3.99±1.13 Bq/m³, while the range of C_{Rn} were 4.37-242.46 Bq/m³ with an average value 50.41±13.75 Bq/m³. For C_{Ra}, the specific activity in unit mBq/kg were ranged from 0.40 to 22.57, with an average value 4.69±1.28. Also from Table 5, the range of C_U in two unites ppm and Bq/kg were 0.0005-0.0279 and 0.006-0.345, with an average values 0.0058±0.0015 and 0.072±0.019, respectively. Results showed that the maximum values of alpha emitters (C, C_{Rn}, C_{Ra}, and C_U) was found in sample G19 (rice, Aoun) and the minimum was found in sample G6 (corn, Al-Jadwal Al-Gharbiu). Figure (4) shows histograms for ²²²Rn in grains samples in present study. There are several reported to demine recommended values of radon gas in air such as ICRP was 300 Bq/m³[34], U.S.EPA was divided in three value higher levels > 148 Bq/m³, low level 74 Bq/m³, and acceptable range level from 74 to148 Bq/m³ and low level 74 Bq/m³ [35], WHO was100 Bq/m³ [36], and CFR U. was 39 Bq/m³ [37]. Therefore, all values of radon gas concentration in grain samples of the present study were lower than the recommended values according to ICRP, U.S.EPA, WHO, and CFR U. Also, it is found that all values of C_{Ra} and C_U were lower than acceptable levels according to UNSCEAR [27] which equal 30 Bq/kg and 11.7 ppm, respectively.

TABLE 5: Results of alpha emitters (²²²Rn, ²²⁶Ra and ²³⁸U) in grains samples in present study

No.	Sample code	^{222}Rn		^{226}Ra	^{238}U	
		C (Bq/m ³)	C _{Rn} (Bq/m ³)	C _{Ra} (mBq/kg)	C _U (ppm)	C _U (Bq/kg)
1	G1	5.75	70.45	6.56	0.0083	0.100
2	G2	2.02	24.78	2.30	0.0029	0.035
3	G3	0.39	4.85	0.45	0.0006	0.007
4	G4	2.57	31.58	2.94	0.0036	0.045
5	G5	1.19	14.57	1.35	0.0017	0.021
6	G6	0.34	4.37	0.40	0.0005	0.006
7	G7	4.92	60.25	5.61	0.0069	0.086
8	G8	1.34	16.52	1.53	0.0019	0.024
9	G9	5.39	66.08	6.15	0.0076	0.094
10	G10	0.35	33.04	3.07	0.0038	0.047
11	G11	1.90	23.32	2.17	0.0027	0.033
12	G12	2.22	27.21	2.53	0.0031	0.039
13	G13	0.67	8.26	0.76	0.0010	0.012
14	G14	14.72	180.26	16.78	0.0208	0.256
15	G15	10.31	126.33	11.76	0.0145	0.180
16	G16	0.75	9.23	0.85	0.0011	0.013
17	G17	2.65	32.55	3.03	0.0037	0.046
18	G18	0.99	12.14	1.13	0.0014	0.017
19	G19	19.80	242.46	22.57	0.0279	0.345
20	G20	1.62	19.92	1.85	0.0023	0.028
Range		0.34-19.80	4.37-242.46	0.40-22.57	0.0005-0.0279	0.006-0.345
Average±S.E		3.99±1.13	50.41±13.75	4.69±1.28	0.0058±0.0015	0.072±0.019

The results of annual effective dose (AED) as well as excess life time cancer risk (ELCR) due to alpha emitters (^{222}Rn , ^{226}Ra and ^{238}U) in grains samples in present study were computed using equations (10), and (6) respectively and tabulated in Table (6). From Table (6), the range and average values of AED in unite (nSv/y) were for ^{222}Rn 0.17-43.61 and 9.06 ± 2.49 , for ^{226}Ra 0.89-227.60 and 47.33 ± 13.00 , and 2.18-558.62 with an average value 116.17 ± 31.91 for ^{238}U , respectively. Also from same Table (Table 6), it is

found that the values of total AED were ranged from 0.003 $\mu\text{Sv/y}$ to 0.830 $\mu\text{Sv/y}$, with an average value of 0.172 ± 0.047 $\mu\text{Sv/y}$ which were less than 1.2 mSv/y as acceptable levels according to UNSCEAR report [38]. The results of $\text{ELCR} \times 10^{-6}$ due to alpha emitters were varies from 0.012 to 3.196, with an average 0.664 ± 0.182 , which is very nominal.

TABLE 6: Results of AED and ELCR in grains samples in present study

No.	Sample code	AED (nSv/y)			Total AED ($\mu\text{Sv/y}$)	$\text{ELCR} \times 10^{-6}$
		^{222}Rn	^{226}Ra	^{238}U		
1	G1	14.08	73.49	180.36	0.268	1.032
2	G2	4.96	25.85	63.43	0.094	0.362
3	G3	1.21	6.34	15.55	0.023	0.089
4	G4	7.89	41.18	101.07	0.150	0.578
5	G5	0.57	2.96	7.28	0.011	0.042
6	G6	0.17	0.89	2.18	0.003	0.012
7	G7	10.91	56.94	139.74	0.208	0.801
8	G8	2.99	15.61	38.32	0.057	0.219
9	G9	10.89	56.86	139.56	0.207	0.797
10	G10	5.45	28.43	69.78	0.104	0.400
11	G11	3.85	20.07	49.26	0.073	0.281
12	G12	4.89	25.54	62.69	0.093	0.358
13	G13	1.49	7.75	19.04	0.028	0.108
14	G14	32.42	169.22	415.32	0.617	2.375
15	G15	22.72	118.59	291.07	0.432	1.663
16	G16	1.66	8.67	21.27	0.032	0.123
17	G17	5.86	30.56	75.01	0.111	0.427
18	G18	2.18	11.40	27.99	0.042	0.162
19	G19	43.61	227.60	558.62	0.830	3.196
20	G20	3.58	18.70	45.89	0.068	0.262
Range		0.17-43.61	0.89-227.60	2.18-558.62	0.003-0.830	0.012-3.196
Average $\pm$ S.E		9.06 $\pm$ 2.49	47.33 $\pm$ 13.00	116.17 $\pm$ 31.91	0.172 $\pm$ 0.047	0.664 $\pm$ 0.182

The quantities of natural radioactivity (gamma and alpha emitters) of the grain samples in the present study were varied, because to natural of soil that grow of these grains such as type of soil, geological natural of the soil, and quantity of chemical fertilizers used for plants. As well as, there are another cause according to plants is influenced by a variety of soil parameters such as clay concentration, texture, exchangeable caption, dominating clay minerals, organic matter concentration, environmental and pH factors. Table (5) shows comparing of the average value of quantities of Uranium-238, Thourium-232, Potsium-40, and Radon-222 in different types of grains in present samples such as wheat, barley corn, millet, mung bean, and rice. From Table (5), the results for uranium-238 were found to be in the following order: rice > millet > mung bean > barley > corn > wheat, for thourium-232 were barley > rice > corn > millet > mung bean > wheat, for potsium-40 were mung bean > barley > millet > wheat > corn > rice, and for radon-222 were rice > wheat > millet > mung bean > barley > corn. These due to change of radionuclides' chemical and physical properties, plant type, and growth stage. The findings, it may be say the results of natural radioactivity (gamma and alpha emitters) with radiological parameters were within acceptable levels of global world average.

TABLE 7: Results of average for gamma and alpha emitters in all types of grain samples in present study

Type of sample	Uranium-238 (Bq/kg)	Thourium-232 (Bq/kg)	Potsium-40 (Bq/kg)	Radon-222 (Bq/m ³)
Wheat	3.625	2.175	201.84	3.885
Barley	4.305	3.615	248.97	1.48
Corn	3.745	2.98	162.81	0.77
Millet	7.645	2.95	216.74	3.13
Mung bean	5.03	2.37	549.74	2.55
Rice	8.71	3.43	137.99	5.97

The correlation coefficients between gamma emitters (^{238}U , ^{232}Th , and ^{40}K) using NaI(Tl) detector and ^{222}Rn concentrations using CR-39 were calculated in all grain samples of the present study, as shown in Table (8). From Table (8), it is found high positive of correlation coefficients between ^{222}Rn and ^{238}U (086), this because radon-222 and uranium-238 put in same nuclear series as well as originality of soil that growth of grain samples in this study. While correlation coefficients between another radionuclide were noted that low and negative because located in different series.

TABLE 8: Results of correlation coefficient between radionuclides in all types of grain samples in present study

Radionuclides	Uranium-238	Thorium-232	Potassium-40
Radon-222	0.86	0.61	-0.04
Uranium-238	1	0.52	-0.14
Thorium-232	0.52	1	-0.16
Potassium-40	-0.14	-0.16	1

Conclusion

The data obtained in this study improve the suitability of the NaI(Tl) and CR-39 techniques for such complex samples. The results of radiological hazard due to natural radionuclides of gamma and alpha emitters in grain samples that collected from Kerbala governorate were less than acceptable levels that recommended by different world organization such as UNSCEAR, ICRP, OECD, WHO, and other. Also, the results of natural radioactivity in all types of grain samples were varied which depend on natural soil and natural of samples. It is found that, there is a high positive correlation coefficient ($R = 0.86$) in all samples between ^{222}Rn concentrations that measured using CR-39 detector and ^{238}U that measured using NaI(Tl) detector. While another radionuclide, the correction coefficient was low and negative quantity. Finally, it can be concluded that the grain samples in this work does not pose any severe health risks to human's consumption.

Declarations

- **Availability of data and materials** : The dataset supporting the conclusions of this article is available in the Zenodo repository via
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Figures

Uranium-238

Figure 1

Histogram of Uranium-238.

Thourium-232

Figure 2

Histogram of Thourium-232.

Potassium-40

Figure 3

Histogram of Potassium-40.

Radon-222

Figure 4

Histograms of Radon-222.