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

Zahraa Saad Hamzah  
Kerbala University: University of Kerbala

Abdalsattar Hashim  
Kerbala University: University of Kerbala

Ali Abojassim (ali.alhameedawi@uokufa.edu.iq)  
University of Kufa  https://orcid.org/0000-0001-5950-5220

Research Article

Keywords: natural radioactivity, gamma ray, radon gas, grain, and kerbala governorate

Posted Date: October 1st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-919273/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. 
Read Full License
Abstract

The aim of this research is to detect nature radioactivity for gamma emitters (specific activity $^{238}\text{U}$, $^{232}\text{Th}$, and $^{40}\text{K}$) using NaI(Tl) detectors and alpha emitters (concentrations of $^{222}\text{Rn}$, $^{226}\text{Ra}$, and $^{238}\text{U}$) 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 $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were $6.61\pm0.91$ Bq/kg, $3.07\pm0.22$ Bq/kg and $227.59\pm32.34$ Bq/kg respectively, while the average value of alpha emitters concentrations for $^{222}\text{Rn}$, $^{226}\text{Ra}$, and $^{238}\text{U}$ were $3.99\pm1.13$ Bq/m$^3$, $4.69\pm1.28$ mBq/kg and $0.072\pm0.019$ 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 $0.139\pm0.013$ mSv/y and $0.172\pm0.047$ µSv/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 $^{238}\text{U}$ and $^{232}\text{Th}$ as well as singly occurring radionuclides such as $^{40}\text{K}$ 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 (I 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 $^{137}\text{Cs}$, $^{22}\text{Na}$, $^{60}\text{Co}$, and $^{152}\text{Eu}$. 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 $^{214}\text{Bi}$ (238U or 226Ra), 2614 KeV for $^{208}\text{Tl}$ (232Th), and 1460 KeV for $^{40}\text{Ar}$ (40K) [13]. A CR-39 detector has density 1.32 gm/m$^3$, thickness 1mm and dimension 2.5×2.5cm$^2$, 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 $^{226}\text{Ra}$ 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.cm$^2$/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]:

$$A \left( \frac{Bq}{kg} \right) = \frac{(N - B)}{t \times \varepsilon \times I_{\gamma} \times m}$$  \hspace{1cm} (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, $\varepsilon$ is the efficiency of the detector, $I_{\gamma}$ is the probability of gamma emission, and $m$ is the mass of sample.

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

$$R_{a_{eq}} \left( \frac{Bq}{kg} \right) = A_U + 1.43A_{T_h} + 0.077A_K$$  \hspace{1cm} (2)

$$H_{in} = \frac{A_U}{185} + \frac{A_{T_h}}{259} + \frac{A_K}{4810}$$  \hspace{1cm} (3)

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

...
\[ AED \left( \frac{mSv}{y} \right) = I \times \sum_{i=1}^{3} A_i \times CF_i \]  \hspace{1cm} (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\times10^{-7} \text{ for } ^{238}\text{U (}^{226}\text{Ra)}, 2.30\times10^{-7} \text{ for } ^{232}\text{Th}, \text{ and } 6.20\times10^{-9} \text{ for } ^{40}\text{K} [27].

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

\[ DI_{\text{thresh}} \left( \frac{Kg}{y} \right) = \frac{E_{\text{ave}}}{\sum_{i}^{3} A_i \times CF_i} \]  \hspace{1cm} (5) 

where, \( E_{\text{ave}} \) 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]:

\[ ELCR = AED \times DL \times RF \]  \hspace{1cm} (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

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

\[ C \left( \frac{Bq}{m^3} \right) = \frac{\rho}{K \cdot T} \]  \hspace{1cm} (7) 

\[ C_{\text{Rn}} \left( \frac{Bq}{m^3} \right) = \frac{C \cdot \lambda_{\text{Rn}} \cdot h \cdot T}{l} \]  \hspace{1cm} (8) 

where \( \rho \) 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, \( \lambda_{\text{Rn}} \) is rador-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 (\( C_{\text{Ra}} \)) as following [5]:
The uranium concentration \( (C_U) \) in samples of the present study in unit (ppm) was calculated using equation (10), which depends on secular equilibrium properties between uranium-238 and radon-222, as follows [30]:

\[
C_U (\text{ppm}) = \frac{M_U}{M} \quad \ldots \ldots (10)
\]

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 \( (C_{\text{Alpha}}) \) in unit (Bq/kg), consumption rate of samples \( (I) \) in unit (Kg/y), and conversion dose factor \( (CF) \) in unit (Sv/Bq), as follows [30]

\[
AED \left( \frac{nSv}{y} \right) = C_{\text{Alpha}} \times I \times CF \quad \ldots \ldots (11)
\]

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 standard deviation (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 unit Bq/kg for uranium-238, thorium-232 and potassium-40 were 88.67-586.61, 1.52–5.94, and 3.13–18.58, while the average value with standard 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 uranium-238, thorium-232 and potassium-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 the 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 | Average | S.E. | $^{232}$Th | Average | S.E. | $^{40}$K | 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 ± S.E | 6.61 ± 0.91 | 3.07 ± 0.22 | 227.59 ± 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 $^{238}\text{U}$, $^{232}\text{Th}$, and $^{40}\text{K}$ 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<sub>eq</sub> and H<sub>in</sub> in grains samples in present study

| No. | Sample code | Ra<sub>eq</sub> (Bq/kg) | H<sub>in</sub> |
|-----|-------------|------------------------|-------------|
| 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 ± S.E. | 28.52 ± 2.56        | 0.095 ± 0.007 |

The results of AED, DI<sub>thresh</sub>, 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 Dlthresh 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 $0.049 \times 10^{-3}$ to $0.716 \times 10^{-3}$, 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 $2.5 \times 10^{-3}$ [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\(_{\text{thresh}}\) and ELCR in grains samples in present study

| No. | Sample Code | AED mSv/y \(^{238}\text{U}\) | AED mSv/y \(^{232}\text{Th}\) | AED mSv/y \(^{40}\text{K}\) | AED\(_{\text{total}}\) mSv/y | DI\(_{\text{thresh}}\) (kg/y) | ELCR \(\times 10^{-3}\) |
|-----|-------------|----------------------------|----------------------------|----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 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 | Average \(\pm\) S.E. | \(\text{AED}_{\text{total}}\) mSv/y | DI\(_{\text{thresh}}\) (kg/y) | ELCR \(\times 10^{-3}\) |
|-------|------------------------|----------------------------|-----------------------------|-----------------------------|
| 0.008–0.187 | 0.008–0.049 | 0.007–0.120 | 0.020–0.254 | 45.3–157 | 0.049–0.716 |
| 0.065±0.009 | 0.024±0.002 | 0.049±0.007 | 0.139±0.013 | 91.22±6.90 | 0.365±0.03 |

### 4.2. Alpha emitters

\(^{222}\text{Rn}\) concentration (C and C\(_{\text{Rn}}\)), effective radium content (C\(_{\text{Ra}}\)), and uranium concentrations (C\(_{\text{U}}\)) 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/m$^3$, with an average value of 3.99 ± 1.13 Bq/m$^3$, while the range of C$_{Rn}$ were 4.37 - 242.46 Bq/m$^3$ with an average value 50.41 ± 13.75 Bq/m$^3$. 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 $^{222}$Rn 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/m$^3$[34], U.S.EPA was divided in three value higher levels > 148 Bq/m$^3$, low level 74 Bq/m$^3$, and acceptable range level from 74 to 148 Bq/m$^3$ and low level 74 Bq/m$^3$ [35], WHO was 100 Bq/m$^3$ [36], and CFR U. was 39 Bq/m$^3$ [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 ($^{222}$Rn, $^{226}$Ra and $^{238}$U) 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   | 5.75        | 70.45       | 6.56        | 0.0083    | 0.100       |
| 2   | 2.02        | 24.78       | 2.30        | 0.0029    | 0.035       |
| 3   | 0.39        | 4.85        | 0.45        | 0.0006    | 0.007       |
| 4   | 2.57        | 31.58       | 2.94        | 0.0036    | 0.045       |
| 5   | 1.19        | 14.57       | 1.35        | 0.0017    | 0.021       |
| 6   | 0.34        | 4.37        | 0.40        | 0.0005    | 0.006       |
| 7   | 4.92        | 60.25       | 5.61        | 0.0069    | 0.086       |
| 8   | 1.34        | 16.52       | 1.53        | 0.0019    | 0.024       |
| 9   | 5.39        | 66.08       | 6.15        | 0.0076    | 0.094       |
| 10  | 0.35        | 33.04       | 3.07        | 0.0038    | 0.047       |
| 11  | 1.90        | 23.32       | 2.17        | 0.0027    | 0.033       |
| 12  | 2.22        | 27.21       | 2.53        | 0.0031    | 0.039       |
| 13  | 0.67        | 8.26        | 0.76        | 0.0010    | 0.012       |
| 14  | 14.72       | 180.26      | 16.78       | 0.0208    | 0.256       |
| 15  | 10.31       | 126.33      | 11.76       | 0.0145    | 0.180       |
| 16  | 0.75        | 9.23        | 0.85        | 0.0011    | 0.013       |
| 17  | 2.65        | 32.55       | 3.03        | 0.0037    | 0.046       |
| 18  | 0.99        | 12.14       | 1.13        | 0.0014    | 0.017       |
| 19  | 19.80       | 242.46      | 22.57       | 0.0279    | 0.345       |
| 20  | 1.62        | 19.92       | 1.85        | 0.0023    | 0.028       |
|     | 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 µSv/y to 0.830 µSv/y, with an average value of 0.172±0.047 µSv/y which were less than 1.2 mSv/y as acceptable levels according to UNSCEAR report [38]. The results of ELCR×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 (µSv/y) | ELCR×10^{-6} |
|-----|-------------|-------------|-------------------|--------------|
| 1   | G1          | 14.08       | 180.36            | 0.268        |
| 2   | G2          | 4.96        | 63.43             | 0.094        |
| 3   | G3          | 1.21        | 15.55             | 0.023        |
| 4   | G4          | 7.89        | 101.07            | 0.150        |
| 5   | G5          | 0.57        | 7.28              | 0.011        |
| 6   | G6          | 0.17        | 2.18              | 0.003        |
| 7   | G7          | 10.91       | 139.74            | 0.208        |
| 8   | G8          | 2.99        | 38.32             | 0.057        |
| 9   | G9          | 10.89       | 139.56            | 0.207        |
| 10  | G10         | 5.45        | 69.78             | 0.104        |
| 11  | G11         | 3.85        | 49.26             | 0.073        |
| 12  | G12         | 4.89        | 62.69             | 0.093        |
| 13  | G13         | 1.49        | 19.04             | 0.028        |
| 14  | G14         | 32.42       | 415.32            | 0.617        |
| 15  | G15         | 22.72       | 291.07            | 0.432        |
| 16  | G16         | 1.66        | 21.27             | 0.032        |
| 17  | G17         | 5.86        | 75.01             | 0.111        |
| 18  | G18         | 2.18        | 27.99             | 0.042        |
| 19  | G19         | 43.61       | 558.62            | 0.830        |
| 20  | G20         | 3.58        | 45.89             | 0.068        |
|     | Range       | 0.17-43.61  | 0.89-227.60        | 2.18-558.62  |
|     |             | 0.003-0.830 | 0.012-3.196        |
|     | Average±S.E | 9.06±2.49   | 47.33±13.00        | 0.172±0.047  |
|     |             | 116.17±31.91| 0.664±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/m³) |
|----------------|---------------------|----------------------|--------------------|-------------------|
| 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**
## 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 $^{222}\text{Rn}$ concentrations that measured using CR-39 detector and $^{238}\text{U}$ 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

- **Competing interests**: No competing interests.

- **Funding**: No funding.

- **Authors' contributions**: The author(s) read and approved the final manuscript.

- **Acknowledgements**: I would like to thank Prof. Dr. Hayder Hamza Hussain of the faculty of Science, University of Kufa and all staff members of the Department of Physics, college science, Kerbala university.

- **Authors' information**: 1) Zahraa Saad Hamzah, Department of Physics, College of Science, Kerbala University, Kerbala, Iraq, email: zahraa.saad@s.uokerbala.edu.iq. 2) Abdalsattar Kareem Hashim, Department of Physics, College of Science, Kerbala University, Kerbala, Iraq, email: abdalsattarkareem@gmail.com. 3) Ali Abid Abojassim, Department of Physics, Faculty of Science, University of Kufa, Al-Najf, Iraq, email: ali.alhameedawi@uokufa.edu.iq.
References

1. Almayahi, B. (Ed.). (2019). *Use of Gamma Radiation Techniques in Peaceful Applications*. BoD–Books on Demand.
2. Abojassim, A. A. (2019). Measurement of natural radioactivity in certain types of nut samples in Iraq. Iranian Journal of Medical Physics, 16(2), 120-125.
3. Hassan, A. B., Alweli, L. A., & Abojassim, A. A. (2020). The Impact of Alpha Particles on Physiology of Human Body. *Oncol Clin Res*, 2(1), 75-78.
4. Idriss, H., & Elhassan, H. M. (2020). Preliminary survey of $^{226}$Ra, $^{232}$Th and $^{40}$K activity level and their cancer risk in some foodstuff, Sudan. *British Food Journal*, 107, 2411-2502.
5. Abojassim, A. A., & Lawi, D. J. (2018). Alpha particles emissions in some samples of medical drugs (capsule) derived from medical plants in Iraq. *Plant arches*, 18(1), 1137-7.
6. Quinn, B., & Carlisle, L. (2019). *Grain by grain: a quest to revive ancient wheat, rural jobs, and healthy food*. Island Press.
7. Abojassim, A. A., Al-Gazaly, H. H., & Kadhim, S. H. (2014). Estimated the radiation hazard indices and ingestion effective dose in wheat flour samples of Iraq markets. *International Journal of Food Contamination*, 1(1), 1-5.
8. Salih, N. F., Hussein, Z. A., & Sedeeq, S. Z. (2019). Environmental radioactivity levels in agricultural soil and wheat grains collected from wheat-farming lands of Koya district, Kurdistan Region-Iraq. *Radiation Protection and Environment*, 42(4), 128.
9. Hussein, H. A., salah Naeem, H., & Algareb, R. S. (2020). The estimation of radon gas measurement in grains in Samawah city markets using CRM-1029. *Solid State Technology*, 63(6), 7164-7172.
10. Kadhim, A. Y., Al-Ataya, K. H., & Aswood, M. S. (2021, May). Distribution and uptake of uranium in rice and wheat from soil samples collected from Al-Diwaniyah, Iraq. In *Journal of Physics: Conference Series* (Vol. 1897, No. 1, p. 012065). IOP Publishing.
11. Abojassim, A. A., Al-Alasadi, L. A., Shitake, A. R., Al-Tememie, F. A., & Husain, A. A. (2015). Assessment of annual effective dose for natural radioactivity of gamma emitters in biscuit samples in Iraq. *Journal of food protection*, 78(9), 1766-1769.
12. Hashim, A. K., Mezher, H. A., Kadhim, S. H., & Abojamin, A. A. (2021, March). Annual Average Internal Dose Based on Alpha Emitters in Milk Sample. In *Journal of Physics: Conference Series* (Vol. 1829, No. 1, p. 012027). IOP Publishing.
13. Abojassim, A. A., & Rasheed, L. H. (2021). Natural radioactivity of soil in the Baghdad governorate. *Environmental Earth Sciences*, 80(1), 1-13.
14. Zhang, Y., Wang, H. W., Ma, Y. G., Liu, L. X., Cao, X. G., Fan, G. T., ... & Fang, D. Q. (2019). Energy calibration of a CR-39 nuclear-track detector irradiated by charged particles. *Nuclear Science and Techniques*, 30(6), 1-9.
15. Abojassim A. A., Hamad Al-Gazaly, H., Sabah Obide, E., & Madlool Al-Jawdah, A. (2020). Radioactivity in samples of cleaning materials. International Journal of Environmental Analytical Chemistry,
16. Abojassim, A. A. (2017). Annual effective dose of gamma emitters in infants, children and adults for frozen chicken samples consumed in Iraq. Curr. Pediatr Res, 21(3), 520-525.

17. Aswood, M. S., Abojassim, A. A., & Al Musawi, M. S. A. (2019). Natural radioactivity measurements of frozen red meat samples consumed in Iraq. Radiation Detection Technology and Methods, 3(4), 1-4.

18. Dhahir, D. M., Ali, A. S., & Abojassim, A. A. (2019). Natural Radioactivity in Custard Samples of Iraqi Market from Different International Sources. Annals of Agri-Bio Research, 24(2), 372-376.

19. United Nations Scientific Committee on the Effects of Atomic Radiation. (2008). Ionizing radiation: Sources effects and risks of ionizing radiation. Report to the General Assembly. New York: United Nations.

20. Jibiri, N. N., Farai, I. P., & Alausa, S. K. (2007). Estimation of annual effective dose due to natural radioactive elements in ingestion of foodstuffs in tin mining area of Jos-Plateau, Nigeria. Journal of environmental radioactivity, 94(1), 31-40.

21. Olatunji, M. A., Uwatse, O. B., Khandaker, M. U., Amin, Y. M., & Faruq, G. (2014). Radiological study on newly developed composite corn advance lines in Malaysia. Physica Scripta, 89(12), 125002.

22. Abojassim, A. A., Dahir, D. M., Alaboodi, A. S., & Abonasria, A. H. (2016). Annual effective dose of gamma emitters in adults and children for some types of rice consumed in Iraq. Journal of food protection, 79(12), 2174-2178.

23. Alattabi, H. D., Shaﬁk, S. S., & Jabbar, F. T. A. (2019, July). Radioactivity Content of Wheat Fields in Wasit Governorate-Iraq. In Journal of Physics: Conference Series (Vol. 1279, No. 1, p. 012041). IOP Publishing.

24. Salman, A. Y., AHMED, A. Q., KADHIM, S. A., & Abojassim, A. A. (2019). Measurement of Radiation Contamination by 226Ra, 232Th and 40K in Different Types of Rice Implanted in Iraq. Annals of Agri-Bio Research, 24(2), 289-293.

25. Pourimani, R., & Mortazavi Shahroudi, S. M. (2018). Radiological assessment of the artificial and natural radionuclide concentrations of wheat and barley samples in Kerbala, Iraq. Iranian Journal of Medical Physics, 15(2), 126-131.

26. Pataczek, L., Zahir, Z. A., Ahmad, M., Rani, S., Nair, R., Schafleitner, R., ... & Hilger, T. (2018). Beans with Beneﬁts—The Role of Mungbean (Vigna radiate) in a Changing Environment. American Journal of Plant Sciences, 9(07), 1577.

27. UNSCEAR. "UNSCEAR 2000 Report to the general assembly, with scientiﬁc annexes. Volume I: Sources." (2000): 4-8.

28. Khandaker, M. U., Zainuddin, N. K., Bradley, D. A., Faruque, M. R. I., Almasoud, F. I., Sayyed, M. I., ... & Jojo, P. J. (2020). Radiation dose to Malaysian populace via the consumption of roasted ground and instant coffee. Radiation Physics and Chemistry, 173, 108886.

29. Abojassim, A. A. (2021). Radiological Risk Assessment of Radon Gas in Bricks Samples in Iraq. Journal of Nuclear Engineering and Radiation Science, 7(3), 032001.
30. Ibrahim, A. A., HASHIM, A. K., & Abojassim A. A. (2021). Determination of alpha activity in soil samples of agricultural college of kerbala university, Iraq. Annals of Agri Bio Research, 26(1), 125-131.

31. National Research Council. (1999). Risk assessment of radon in drinking water. National Academies Press.

32. Nuclear Energy Agency. (1979). Exposure to radiation from the natural radioactivity in building materials: report. OECD.

33. International Commission on Radiological Protection (ICRP), 1991.1990 Recommendation of International Commission of Radiological protection. Pergamon Press, Oxford, UK, ICRP Publication 60.

34. Tirmarche, M., Harrison, J. D., Laurier, D., Paquet, F., Blanchardon, E., & Marsh, J. W. (2010). ICRP Publication 115. Lung cancer risk from radon and progeny and statement on radon. Annals of the ICRP, 40(1), 1-64.

35. Zdrojewicz, Z., & Strzelczyk, J. (2006). Radon treatment controversy. Dose-Response, 4(2), dose-response.

36. World Health Organization. (2009). WHO handbook on indoor radon: a public health perspective. World Health Organization.

37. CFR, U. (2009). Code of Federal Regulations Title 40: Protection of Environment, Part 136–Guidelines establishing test procedures for the analyses of pollutants, Appendix B to Part 136–definition and procedure for the determination of Method Detection Limit rev. 1.11.

38. United Nations Scientific Committee on the Effects of Atomic Radiation. (1988). Sources, effects and risks of ionizing radiation.

**Figures**
Figure 1

Histogram of Uranium-238.
Figure 2

Histogram of Thourium-232.
Potassium-40

Figure 3

Histogram of Potassium-40.
Figure 4

Histograms of Radon-222.