Evaluation of the natural radioactivity of samples of some types of field crops in different areas of Tikrit, Iraq.

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Abstract

This study aims to assess the concentrations of natural radionuclides activity ($^{226}$Ra, $^{232}$Th and $^{40}$K) and calculate a number of radiation risk indicators in some types of field crops in different areas of Tikrit City - Salah Al-Din Governorate - Iraq. The measurement was carried out using a gamma ray spectroscopy connected with a scintillation detector crystallized with thallium-activated sodium iodide NaI(Tl). The results were that the mean concentrations of elements ($^{226}$Ra, $^{232}$Th and $^{40}$K) were (6.79, 0.84, 0.49) Bq/kg, respectively. And the radiation risk indicators were less than the international permissible and the recommended average, so that the samples under study are safe and suitable for human and animal consumption.

Key Words: Field crops, specific activity, radiation risk.

Introduction

The process of automatic transformation of the radioactive nuclei of an element into the nuclei of atoms of other elements is more stable by emitting a certain type of radiation. This is known as radioactivity[1]. Among those emitted radiation are an alpha particle, a beta particle, and a gamma ray[2]. Ground gamma rays are considered to the human body as one of the most prominent external sources of radiation, whose source is natural isotopes. Among the most important of these sources are the uranium ($^{238}$U) series, the actinium ($^{235}$U) series, the thorium ($^{232}$Th) series, in addition to potassium ($^{40}$K)[3]. In the Earth's crust, an average amount of ($^{238}$U) is estimated at (2.7 g/kg)[4]. For ($^{232}$Th) the average quantity is (9.6 g/kg)[5]. Moreover, the abundance ratio is ($^{40}$K) to the eighth component of the Earth's crust, at (2.8%)[6]. Radioactive cores in soil and plants depend in their focus on soil contents and external environmental pollution[7,8]. Natural radiation may occur not only to unstable radionuclides in the Earth's crust, but radiation to the atmosphere from outer space[9]. Moreover, radioactive elements such as $^{137}$Cs and $^{90}$Sr that occur artificially in nature. Which comes from nuclear weapons tests and nuclear energy accidents and in the field of energy production increases radioactivity. Consequently, there is an increase in the overall probability of exposure to radiation. This is attributed to the fact that 81% is natural radiation and 19%...
is industrial[10,11]. As cereal crops are used by humans as food and fodder for animals. The average consumption of grains in the world is( 170 Kg/year) and in West Asia it is about( 210 Kg/year)[12]. Wheat contributes 19% of energy and 20.8% of protein worldwide, and thus it is considered one of the main food ingredients in the world according to the reports of the Food and Agriculture Organization. The average annual per capita consumption around the world is 67 Kg, and it constitutes half of the global diet[13]. Water, air and soil are the sources of radioactive elements in plants. Where these elements move through the roots or by direct absorption through the aerial parts (stems - leaves - fruits)[14]. And after contamination of plants with radioactive elements, it can cause harm to animals or to humans when they eat meat and dairy products. Food is considered a major source of many elements and radionuclides for humans, so measuring radioactivity in the environment and food is of prime importance to assess the direct and indirect exposure of humans to different radioactive levels[15]. The natural sources of ionizing radiation that people absorb are estimated at an average annual effective dose of( 2.4 mSv/y), of which( 0.32 mSv/y) comes from ingestion of radionuclides[16]. Natural radioactive elements reside as 40K, 232 Th and 238U in certain organs of the body, depending on the biological effect. The organs targeted for storing these elements are the lungs, the kidneys, the liver, the Bones the muscles. These nuclides can cause biochemical changes, such as genetic mutations or cancer when deposited on these organs[17]. With this background in mind, herein lies the importance of our study.

Materials and Methods

Geographical Location

The city of Tikrit is the study area, the administrative center of Salah al-Din Governorate, north of Iraq, away from the capital Baghdad (180 Km) northwest. The astronomical position is at 34 latitude north and 43 east longitude. Figure (1) shows the study area.

Sample Collection and Preparation

Thirteen samples of field crops were collected from different areas of Tikrit city by random integration method. Experimental sampling was a common process. To this end, the study area was divided into several squares. After that, some of the boxes were randomly selected and three samples were taken from each square that was selected, then mixed. And put in polyethylene bags, and on which the name of the region and the variety of the crop were recorded, its location was determined by the (G.P.S.) system, and he gave it a specific code, then transferred it to the laboratory. As shown in Table (1), where the mass of one sample was (1 kg). The samples were dried at (100°C) for two hours using an electric oven to remove moisture, after which the samples were ground into a fine powder with an electric mill and then sifted with a diameter sieve that opened it (300 nm) to obtain a homogeneous sample sample, after that we used a digital scale to weigh Samples (300 gm) are then packed in a homemade Marnelli bowl container prepared for this purpose with a tight lid and left for a period of no less than a month to reach a state of radial balance.
Table 1: varieties, symbols, coordinates of sites and place name for samples of field crops.

| Sample ID | Classify the sample | Sample Location | Location coordinates from (GPS) |
|-----------|---------------------|-----------------|---------------------------------|
| P1        | Cihan wheat         | Medial tibia    | W: 34.5502989 L: 43.6311284    |
| P2        | Wheat wheat 6       | Western tibia   | W: 34.5558675 L: 43.6392798    |
| P3        | White barley        | Underside tibia | W: 34.5814924 L: 43.6342581    |
| P4        | Baraka wheat        | Serpentine      | W: 34.6539356 L: 43.5819731    |
| P5        | Tigris wheat goodness | Southern tibia | W: 34.5152332 L: 43.6738906    |
| P6        | Wheat Mustard       | High Flag Island| W: 34.7250873 L: 43.7406348   |
| P7        | Hybrid yellow corn  | High Flag Island| W: 34.7232685 L: 43.7422974   |
| P8        | Barley parchment    | High Flag Island| W: 34.7243181 L: 43.7529805   |
| P9        | Iraqi yellow corn   | Flag Taoist     | W: 34.7087684 L: 43.6740564    |
| P10       | Wheat Adna          | Flag Taoist     | W: 34.7097701 L: 43.6965748    |
| P11       | Bora wheat          | Alba Ajil       | W: 34.5603277 L: 43.7312753    |
| P12       | Sham wheat 6, not coated | Soft    | W: 34.6401084 L: 43.9052792    |
| P13       | Mixed Wheat (Sham 6 + Adna) | Khank       | W: 34.6841248 L: 0.62778557    |

Calculation of Activity Concentration

After the system was calibrated for energy using standard radioactive sources $^{60}$Co at energies (1332.5 keV, 1173.2 keV) and $^{137}$Cs at energy (661.6 keV) in order to convert the system reading from the channel number to a unit of energy (keV), the specific activity was calculated after placing the flash detector crystal inside the Marnelli in which the sample entered the sample with surrounding the...
Marnelle and crystal the detector by means of a plate of lead with a thickness of (5 cm) and collecting the spectrum for a period of (18000 seconds), which is the time used to measure the assembly of the spectrum of samples, and then calculate the area under the curve for the specified energies and after that We use it in calculating the concentrations of radioactive elements (\(^{226}\text{Ra}, ^{232}\text{Th}, ^{40}\text{K}\)) using the following relationship\(^{[18]}\):

\[
A = \frac{N - B}{\epsilon \times I_p \times t \times m} \pm \frac{S \cdot D}{\epsilon \times I_p \times t \times m} \quad \ldots \quad \ldots \quad \ldots \quad (1)
\]

Where, \(A\): The specific activity of radionuclides per unit \(\text{Bq/Kg}\) \(N\): The total area under the optical peak of the energy of the radiating element, \(B\): The total area under the light peak of the laboratory radiative background, \(\epsilon\): is the absolute gamma peak efficiency for the detector at particular gamma-ray energy, \(I_p\): is the decay intensity of the specific energy peak, \(t\): is the counting time for the measurement in seconds, \(m\): is the mass of the sample in Kg, \(S\), \(D\): is the standard deviation of the net count rate per second.

Evaluation of Radiological Hazard Effects

In order to know the amount of radioactive risk for field crops, a number of risk indicators have been calculated based on the values of the concentrations of the specific radioactivity of the samples under study, measured in units \(\text{Bq/Kg}\).

**Radium Equivalent Activity (Ra\(_{eq}\))**

It is defined as the sum of the ratios of the concentrations of the three radioactive elements (\(^{226}\text{Ra}, ^{232}\text{Th}, ^{40}\text{K}\)), which is calculated according to the following relationship\(^{[19,20]}\):

\[
Ra_{eq}(\text{Bq/Kg}) = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \quad \ldots \quad \ldots \quad \ldots \quad (2)
\]

Where, \(Ra_{eq}\): Radium Equivalent, \(A_{Ra}, A_{Th}, A_{K}\): It is the radioactivity specificity of each of \((^{226}\text{Ra}, ^{232}\text{Th}, ^{40}\text{K}\)\)), respectively, per unit \(\text{Bq/Kg}\). The maximum value of the radio equivalent is \((370 \text{ Bq/Kg})\)\(^{[10]}\).

**Absorbed Gamma Dose (D\(_\gamma\))**

The amount of energy absorbed in joules per unit mass of the irradiated material, in kilograms, is measured in units \(\text{Gray}\). It was calculated from the following relationship\(^{[19,20]}\):

\[
D_{\gamma}(\text{nGy/h}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{K} \quad \ldots \quad \ldots \quad \ldots \quad (3)
\]

Where, \(D_{\gamma}\): Absorbed Gamma Dose per unit \(\text{nGy/h}\) \(A_{Ra}, A_{Th}, A_{K}\): It is the radioactivity specificity of each of \((^{226}\text{Ra}, ^{232}\text{Th}, ^{40}\text{K}\)\)), respectively, per unit \(\text{Bq/Kg}\). \((0.462, 0.604, 0.0417)\) Isotope conversion coefficients \((^{226}\text{Ra}, ^{232}\text{Th}, ^{40}\text{K}\)\) in a unit of \(\text{nGy/h}\).

**Equivalent Annual Effective Dose (AEDE)**

Here the dose absorbed in the air is converted to the equivalent dose for an adult person through a conversion factor of \((0.75\text{Sv.Gy}^{-1})\) and also multiplied by a factor of \((0.2)\), which represents the amount of how much a person spends outside the home, and here we get the equivalent of the annual effective dose outside the home \((AEDE_{outdoor})\) or a stroke \(B (0.8)\) Here we obtain the equivalent of the annual effective dose inside the home \((AEDE_{indoor})\) and calculated from the following two relationships\(^{[19,21]}\):

\[
AEDE_{outdoor} (\mu\text{Sv}/\text{y}) = D(\text{nGy}) \times 0.7 \times 0.2 \times 8760 \times 10^{-3} \quad \ldots \quad \ldots \quad \ldots \quad (4)
\]
\[ AEDE_{\text{indoor}} (\mu Sv/\text{y}) = D(nGy) \times 0.7 \times 0.8 \times 8760 \times 10^{-3} \]  
…… (5)

Where 8760 represents the number of hours in one year.

**External Hazard Index (H_{ex}) and Internal (H_{in}) and Ideal Level Index for gamma rays (I_{\gamma})**

These indicators are used to measure the external and internal exposure as well as the gamma index, which represents the sum of the ratio of the result of dividing the concentrations of the three radioactive elements \(^{226}\text{Ra}, ^{232}\text{Th}, ^{40}\text{K}\), by a specific value of that element to determine the extent of its risk and these values are related to the permissible risk level for each component or the amount of dose. The permissible exposure during a specified period may be external or internal. The external risk level \((H_{ex})\) can be calculated from the following relationship\(^{19,20}\):

\[ H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \leq 1 \]  
…… (6)

The internal severity level \((H_{in})\) of the relationship\(^{19,20}\)

\[ H_{in} = \frac{A_{Ra}}{105} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \]  
…… (7)

For the purpose of calculating the gamma index \((\text{Guide})(I_{\gamma})\), the following equation is used\(^{22}\):

\[ I_{\gamma} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_{K}}{1500} \leq 1 \]  
…… (8)

**Results and discussion**

Table (2) shows the results of the concentrations of natural radioactive elements in samples of field crops, and the concentrations of radium \(^{226}\text{Ra}\) ranged between \((2.09\pm0.179 \text{ Bq/Kg})\) in the sample P6 (pure wheat) and \((11.82\pm0.351 \text{ Bq/Kg})\) in the sample P5 (Tigris al-Khair wheat). For samples concentrations reached \((6.79\pm0.331 \text{ Bq/Kg})\) and all concentrations were less than the global average of \((35\text{Bq/Kg})\)\(^{12,23}\). Thorium concentrations \(^{232}\text{Th}\) ranged between \((2.66\pm0.361 \text{ Bq/Kg})\) in the sample P1 (Cihan wheat) and \((21.88\pm0.985 \text{ Bq/Kg})\) in the sample P13 (mixed wheat 6 + Adana) and the general average for the sample concentrations was \((10.79\pm0.640 \text{ Bq/Kg})\), and all results were less than the average. Global Allowed Adult \((30\text{Bq/Kg})\)\(^{12,23}\). Potassium concentrations \(^{40}\text{K}\) ranged between \((29.75\pm2.876 \text{ Bq/Kg})\) in the sampleP12 (6 uncoated sham wheat) and \((212.18\pm7.681 \text{ Bq/Kg})\) in the sample P8 (parchment barley), and the general average of sample concentrations was \((133.34\pm5.895 \text{ Bq/Kg})\), and all the results were less than the accepted international average of \((400 \text{ Bq/Kg})\)\(^{12,23}\). Figure (2) shows the change in the levels of natural radioactive elements concentrations and the global average with the varieties of samples of field crops.

Table (3) shows the results of calculating the radiation risk indicators, and the results showed that the efficacy of radium equivalent \((Ra_{eq})\) ranged between \((18.80\text{Bq/Kg})\) in the sample P1 (Cihan wheat) and \((49.20 \text{ Bq/Kg})\) in the sampleP8 (parley barley) and the general rate of samples reached \((33.27\text{Bq/Kg})\). All results were less than the permissible global average of \((370\text{Bq/Kg})\)\(^{12,23}\). And the percentage of absorbed dose of gamma rays \((D_{\gamma})\), the results ranged between \((9.15\text{nGy/yr})\) in the sampleP1 (Cihan wheat) and \((24.65\text{nGy/yr})\) in the sample P13 \((\text{mixed wheat Sham 6 + ADNA})\) and the general rate of samples was \((15.21\text{nGy/yr})\). All results are below the global average of \((55\text{nGy/yr})\)\(^{12,23}\). As for the results of the internal annual effective dose equivalent \((AEDE_{\text{indoor}})\), it ranges between \((44.89\mu Sv/\text{yr})\) in the sampleP1 and \((120.92\mu Sv/\text{yr})\) in the sample P13 and the general rate for samples was \((74.64 \mu Sv/\text{yr})\) and all the results were less than the permissible international
average of (1000 μSv/y)[12,23]. The external annual effective dose equivalent (AEDE_{outdoor}) ranges between (11.22 μSv/y) in the sample P1 and (30.23 μSv/y) in the sample P13 and the general rate for samples was (18.65 μSv/y) and all values were less than the recommended global average of (1000 μSv/y)[12,23]. The results of the internal severity index (H_{in}) ranged between (0.070) in the sample P1 and (0.160) in the sample P13 and the general rate of samples was (0.105) and all the results were less than the global average of (less or equal to one)[12,23]. As for the results of the external severity index (H_{ex}), the values ranged between (0.050) in the sample P1 and (0.143) in the sample P13 and the general average of the values reached (0.087) and all the values were less than the recommended global limit of (less or equal to one)[12,23].

As for the results of the ideal level of gamma rays index (I_{γ}), it ranges between (0.142) in the sample B1 and (0.397) in the sample B13 and the general average of the values was (0.241) and all the values were less than the global average of (less or equal to one)[12,23]. Figure (3) shows the change in levels of risk indicators with sample types.

Table (2) Concentrations of natural radioactive elements in field crop samples

| Sample ID | ^{226}Ra (Bq/Kg) | ^{228}Th (Bq/Kg) | ^{40}K (Bq/Kg) |
|-----------|-----------------|-----------------|----------------|
| P1        | 7.21±0.375      | 2.66±0.361      | 101.22±5.305   |
| P2        | 6.95±0.347      | 14.33±0.797     | 46.44±3.593    |
| P3        | 9.38±0.304      | 9.70±0.627      | 163.51±6.743   |
| P4        | 5.03±0.333      | 7.27±0.562      | 148.77±6.432   |
| P5        | 11.82±0.351     | 10.01±0.681     | 121.64±5.957   |
| P6        | 2.09±0.170      | 10.64±0.698     | 202.16±7.498   |
| P7        | 6.88±0.385      | 9.87±0.619      | 117.35±5.712   |
| P8        | 9.07±0.446      | 16.64±0.395     | 212.18±7.681   |
| P9        | 5.40±0.205      | 8.66±0.630      | 164.27±6.377   |
| P10       | 3.90±0.270      | 10.98±0.730     | 107.34±4.463   |
| P11       | 5.76±0.332      | 8.24±0.626      | 105.39±5.413   |
| P12       | 8.84±0.435      | 9.51±0.620      | 29.75±2.676    |
| P13       | 6.03±0.360      | 21.88±0.985     | 207.45±7.595   |
| Min.      | 2.09±0.170      | 2.66±0.361      | 29.75±2.876    |
| Max.      | 11.82±0.351     | 21.88±0.985     | 212.18±7.681   |
| Averag    | 6.79±0.331      | 10.79±0.640     | 131.34±5.895   |

Table (3) the values of risk indicators in field crop samples

| Sample ID | Ra_{eq} (Bq/Kg) | D_{γ} (nGy/h) | AEDE_{indoor} (μSv/y) | AEDE_{outdoor} (μSv/y) | H_{in} | H_{ex} | I_{γ} |
|-----------|-----------------|---------------|-----------------------|------------------------|--------|--------|-------|
| P1        | 18.80           | 9.15          | 44.88                 | 11.22                  | 0.070  | 0.050  | 0.142 |
| P2        | 31.01           | 13.80         | 67.69                 | 16.92                  | 0.102  | 0.083  | 0.220 |
| P3        | 35.84           | 17.01         | 83.44                 | 20.86                  | 0.122  | 0.096  | 0.208 |
| P4        | 26.88           | 12.91         | 63.33                 | 15.83                  | 0.086  | 0.072  | 0.205 |
| P5        | 35.96           | 16.82         | 82.51                 | 20.62                  | 0.129  | 0.097  | 0.263 |
| P6        | 32.87           | 15.82         | 77.60                 | 19.40                  | 0.094  | 0.088  | 0.255 |
| P7        | 30.03           | 14.03         | 68.82                 | 17.20                  | 0.099  | 0.081  | 0.222 |
| P8        | 49.20           | 23.08         | 113.22                | 28.30                  | 0.157  | 0.132  | 0.368 |
| P9        | 40.43           | 14.57         | 71.47                 | 17.86                  | 0.096  | 0.082  | 0.232 |
| P10       | 27.86           | 12.90         | 63.28                 | 15.82                  | 0.085  | 0.075  | 0.207 |
| P11       | 25.65           | 12.03         | 59.01                 | 14.75                  | 0.084  | 0.069  | 0.191 |
| P12       | 24.73           | 11.06         | 54.25                 | 13.56                  | 0.090  | 0.066  | 0.173 |
| P13       | 53.29           | 24.65         | 120.92                | 30.23                  | 0.160  | 0.143  | 0.397 |

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Table (4) shows a comparison of the results of our study with some local and international studies.
Figure (3) levels of radiation risk indicators with varieties of field crops samples

Conclusion

Through our study, in which the concentrations of natural radioactive elements represented by the elements were evaluated (226Ra, 232Th, 40K) and a number of radiation risk indicators were calculated, in Thirteen samples of field crops of different varieties using gamma ray spectroscopy connected with the scintillation detector, according to the results we obtained All the concentrations of natural radioactive elements and radiation risk indicators were lower than the recommended international average. It is recommended for future studies to evaluate the concentrations of natural radioactive elements in the groundwater in the areas under study to verify that it is not a source of radioactive contamination in plants.

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