Determination of radiological hazards resulting from natural radiological activity in soil samples in Al Azizia district in Wasit Governorate, Iraq

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Abstract This work aims to measure the concentrations of radionuclides of natural radioactivity of the three elements (40K, 238U, and 232Th), were determined in 24 soil samples, collected from Al- Azezia district of Wasit Governorate. They were studied and then evaluated. The standard sources are used for calibration of radiation activity by gamma spectrometer NaI (TI). The radioactivity of natural isotopes 40K, 238U and 232Th has been estimated. The results showed the radio activities of element in this study were within the acceptable standard levels. In addition, the radium equivalent activity, average air volume, annual effective dose rate and external risk index were assessed and found to be among the internationally tolerable values. The radioactivity of nuclides of 40K, 238U and 232Th in Al- Azezia district were calculated. The radioactivity of, 238U ranged from (0. 60±1. 71) to (17. 69 ±4. 70) Bq / kg with an average of (9. 145±3. 20) Bq / kg, while it was for 232Th ranged from (14. 55±1. 64) to (42. 386±1. 95) Bq / Kg / kg with an average of (30. 42±2. 31) Bq / Kg and 40K ranged from (119. 25±2. 06) to(170. 56±2. 74)Bq / kg with an average (146. 43±2. 40) Bq / Kg also, it is found that the average of radiological effects like the radium equivalent (Ra eq), the absorbed dose Rate (Dr), external hazard index (H ex), internal hazard index (H in), representative gamma hazard index (I γ), the effective dose equivalent (AEDE) lifetime the excess cancer risk (ELCR) due to natural radioactivity in soil samples for depth(0-15)cm were (66. 63±5. 37) Bq/Kg and (27. 18±1. 91) nGy/h, (0. 36±0. 01), (0. 69±0. 02), (0. 48±0. 02). (0. 48±0. 02) and (0. 30±0. 01) x10⁻³ respectively, there for no significant radiological hazard in Al- Azezia district.

Keywords. Natural radioactivity, absorbed dose rate, activity concentrations, external hazard index, Gamma spectroscopy.

1. Introduction
Radioactivity was first discovery by Henri Becquerel in 1896[1]. Radioactivity is a phenomenon that occurs naturally in a number of substances. Atoms of the substance spontaneously emit invisible but energetic radiations, which can penetrate materials, are opaque [2]. Natural radioactivity is energy generated by those of the radioactive elements that exist in the earth’s crust[3]. The background level of radiation in the natural environment surrounds us at all times. Since the Earth formed and life[4] developed, background radiation has been our constant companion. Some of these radiations are extraterrestrial, others are from the natural elements such as soil, air, and water. This natural radioactivity may include Uranium (238U), Thorium (232Th), as well as Potassium (40K) decomposition series that exerts Alpha, Beta, and Gamma radiations[5]. Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radio nuclides are carried to soil by rain and flows[6]. The aim of this the study is to investigate the natural radioactivity of 238U, 232Th and 40K in soil samples which was collected from different locations in the Al- Azezia city in Wasit province in Iraq as shown in Figure 1.
2. Study Locations
Al-Aziza province is one of the districts of Wasit province in Iraq and estimated the population of space and its subdivisions of more than 143 thousand people, according to the 2012 year, which is about 85 kilometers south of Baghdad and north of Kut by 90 and an area of about 2122 square meters. Results and discussion.

Figure 1. Geographical map of Al_Azizia district, Wasit Iraq

3. Experimental procedure
Twenty-four soil samples were collected at a depth of 15 cm from a soil in an elected area of 2122 Km2 from Al-Aziziah district of Wasit Governorate. This group has been guided by the standards recommended by the International Atomic Energy Agency (IAEA). First, the samples were cleaned to remove undesirable materials. Next, the samples were placed under the sun. After three days, the samples were analyzed for the selective homogeneous particle size by a sieve then300 μm producing net weights 0.75 kg. A sample was then filled in a single cubic in marinelli cup of fixed size to ensure the engineering homogeneity around the detector. The plastic cup was then sealed with tape and stored for a one month. The multivariate analyzer (1024) channel range combined with the analogue to digital unit through interface and desperation energy (FWHM) in the peak 1.33 keV for $^{60}$Co is 7.9 %a shield was set to prevent emitting a radiation. to the surrounding using ORTEC cylindrical chamber (diameter 22 cm) consists of two parts, one of the stainless steel of 20 cm and the second part of the lead with a width of 5 cm. The was calibrated for an energy acquisition by using a set of radioactive standard sources spectrometer of known energies and gamma-ray 1 μCi such as $^{137}$Cs, $^{60}$Co and $^{22}$Na. Energy efficiency was performed in a gamma spectrometer using the same calibration sources in a one cup of marinelli to cover power from 500 to 2500 keV. Then, a standard source was placed over the detector with an exact geometrical match between geometric sample and sample detector. A sample was placed in the middle of the chamber inside the shield with a period of about 5 hours according to its radioactivity. The energy with secular equilibrium was and determined at 1764.49 KeV from gamma power transition of $^{214}$Bi (probability of 15.96%) at 2614 KeV from gamma transfer energy of $^{208}$Tl, (probability 99%) respectively, while activity is 40K balance with them respectively, while activity is $^{40}$K. It is determined using a 1400 KeV a gamma ray Line (Probability of 10%).

4. Theoretical calculations

4.1. Specific Activity ($A$)
The qualitative efficacy ($A$) can be measured by the following equation [7]

$$A(Bq / Kg) = \frac{N}{\varepsilon \times I_\gamma \times M \times t} \quad (1)$$

Where ($N$) – net gamma counting rate (counts per second), ($\varepsilon$) efficiency of the detector ($I_\gamma$) intensity of the gamma-line in a radionuclide,($M$) mass of the sample, kg. ($t$) is the live time for collecting spectrum in the seconds[8].
4.2. External Hazard Index (Hex)
Measurement of Hazard Indices Depending on the specific efficacy of uranium, thorium and potassium, several risk factors were measured, including

4.2.1. Radium Equivalent: The radium equivalent (Ra eq)
This index is used to obtain the sum of those activities \( ^{232}\text{Th}, ^{238}\text{U} \) and \(^{40}\text{K}\) in (Bq/kg) and assess hazards associated with materials that contain \(^{232}\text{Th}, ^{238}\text{U} \) and \(^{40}\text{K}\) in (Bq/kg) by using radium equivalent activity and is mathematically defined as [8].

\[
\text{Ra eq} (\text{Bq/kg}) = A_U + 1.43A_{\text{Th}} + 0.077A_K
\]

Where \( A_U, \ A_{\text{Th}} \) and \( A_K \) are the specific activity in Bq/Kg of \(^{238}\text{U}, ^{232}\text{Th} \) and \(^{40}\text{K}\), respectively.

4.2.2. Absorbed Dose Rates (Dn)
These factors were used to calculate the total absorbed gamma dose rate in air at 1 m above the ground level using the following equation [9]:

\[
A_D (\text{nGy} / \text{h}) = 0.462A_U + 0.621A_{\text{Th}} + 0.0417A_K
\]

4.2.3. External Hazard Index (Hex)
Many of the radioactive materials decay naturally and when these materials decay produces external radiation field which exposed humans. In terms of dose, the principal primordial radionuclides are \(^{232}\text{Th}, ^{226}\text{Ra} \) and \(^{40}\text{K}\). Thorium and uranium head series of radionuclides which produce significant human exposure. The external hazard index (Hex) is calculated by equation [10].

\[
\text{Hex} = \frac{A_U}{370} + \frac{A_{\text{Th}}}{259} + \frac{A_K}{4810} \leq 1
\]

Where \( A_U, \ A_{\text{Th}} \) and \( A_K \) are the radioactivity concentrations in Bq/kg of \(^{238}\text{U}, ^{232}\text{Th} \) and \(^{40}\text{K}\), respectively. The value of this index must be less than unity for the radiation hazard to be negligible; Hex equal to unity corresponds to the upper limit of Ra eq (370Bq/kg) [10].

4.2.4. Internal Hazard Index (Hin)
Internal exposure to \(^{222}\text{Rn} \) and its radioactive particles is controlled by the internal hazard index (Hin), as in the following Equation [11]:

\[
\text{Hin} = \frac{A_U}{185} + \frac{A_{\text{Th}}}{259} + \frac{A_K}{1500} \leq 1
\]

This index value must be less than unity in order to keep the radiation hazard insignificant.

4.2.5. The Representative Level Index (Iγ)
In order to examine whether the samples meets these limits of dose criteria, Another radiation hazard index, the representative level index, \( I_\gamma \) is used to estimate the level of gamma radiation hazard associated with the natural radionuclides in specific investigated samples, it is defined as from the following Equation [12]:

\[
I_\gamma = \frac{A_U}{150} + \frac{A_{\text{Th}}}{100} + \frac{A_K}{1500}
\]

where \( A_U, A_{\text{Th}} \) and \( A_K \) are the concentrations of \(^{238}\text{U}, ^{232}\text{Th} \) and \(^{40}\text{K}\), respectively, in Bq/kg.

4.2.6. Effective Annual Dose
The annual effective dose was measured using the following equations [12]:

\[
AEDE \text{ Indoor(mSv \ y)} = A_D (\text{nGy/h}) \times 8760 \times 0.8 \times 0.7 \text{ Sv/Gy} \times 10^{-6}(7)
\]

\[
AEDE \text{ Outdoor(mSv \ y)} = A_D (\text{nGy/h}) \times 8760\times 0.2 \times 0.7 \text{ Sv/Gy} \times 10^{-6}(8)
\]

The coefficient (0.7 Sv / Gy) was used as a factor of conversion from the air-absorbed dose to the effective annual dose received by adults and (0.8) the time spent inside and 0.2 was the proportion of time spent abroad, (8760) refers to the number of hours of the year, and the global average effective annual dose is 0.48 (mSv) [13].
4.2.7. **Excess lifetime cancer risk**
The value of excess lifetime cancer risk can be calculated \[12\]

\[
\text{ELCR} = AEDE, DL, RF(9)
\]

Where ELCR – excess lifetime cancer risk; DL – average duration of human life; RF – risk factor, Sv-1). DL – average duration of life (estimated to be 70 years); RF – risk factor; Sv i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

5. Results and discussion

5.1. **Activity specified**
The results of specific activity for \(^{238}\text{U}\), \(^{232}\text{Th}\) and \(^{40}\text{K}\) radionuclide in a samples from the center of the Al-Azeizia district of Wasit Governorate is displayed in the Table 1, a set of activity defined for \(^{238}\text{U}\) it ranged from (0.60±1.71) Bq / kg in S7 as a minimum value to (17.69±4.70) Bq / kg in S22 as a maximum. For \(^{232}\text{Th}\) certain activity ranged from (14.55±1.64) Bq / kg in S16 to (42.38±1.95) Bq / kg in S18. While the activity was specified at \(^{40}\text{K}\) Ranged from (119.25±2.06) in S16 to (170.56±2.74) Bq / kg in S8. Geochemical composition of the soil was sandy clay. It seems the thorium Activity Higher than uranium activity in some samples. It is obviously seen that the radioactivity of thorium is several times higher than that of uranium in the same sites. Also, it is noted that radioactivity of \(^{40}\text{K}\) exceeds significantly much higher than both of \(^{238}\text{U}\) and \(^{232}\text{Th}\). Moreover, this can be due to the abundance of \(^{40}\text{K}\) in the soil because a lot of Potassium containing fertilizers was used in the vicinity of sampling locations. The results of an average particular radioactivity of collected soil samples in this study were below the global average levels according to UNSCEAR 2000 [14] which is 35, 30 and 400 Bq / kg for \(^{232}\text{Th}\), \(^{238}\text{U}\) and \(^{40}\text{K}\) respectively.

| No. | Sample Code | Specific Activity (Bq/Kg) | \(^{238}\text{U}\) | \(^{232}\text{Th}\) | \(^{40}\text{K}\) |
|-----|-------------|---------------------------|-----------------|-----------------|-----------------|
| 1   | S1          |                           | 8.23±1.19       | 20.67±1.95      | 139.29±3.02     |
| 2   | S2          |                           | 10.06±1.19      | 37.65±1.69      | 147.83±2.37     |
| 3   | S3          |                           | 7.58±1.33       | 36.31±2.00      | 146.89±2.93     |
| 4   | S4          |                           | 3.97±0.70       | 34.87±2.05      | 131.65±2.53     |
| 5   | S5          |                           | 6.67±1.21       | 40.22±2.41      | 127.63±2.32     |
| 6   | S6          |                           | 9.66±1.33       | 31.94±2.41      | 144.23±2.37     |
| 7   | S7          |                           | 0.60±1.71       | 35.03±2.67      | 154.92±2.83     |
| 8   | S8          |                           | 9.96±1.96       | 40.38±3.08      | 170.56±2.74     |
| 9   | S9          |                           | 6.25±1.14       | 30.19±3.08      | 156.90±2.49     |
| 10  | S10         |                           | 4.37±1.21       | 28.39±2.26      | 149.52±2.49     |
| 11  | S11         |                           | 5.32±1.71       | 31.01±4.21      | 170.35±2.55     |
| 12  | S12         |                           | 8.73±1.41       | 22.58±2.26      | 160.83±2.49     |
| 13  | S13         |                           | 5.93±1.51       | 36.21±2.31      | 155.22±2.72     |
| 14  | S14         |                           | 4.90±0.92       | 42.38±1.95      | 131.11±2.28     |
| 15  | S15         |                           | 4.17±1.00       | 30.09±2.67      | 150.47±2.77     |
| 16  | S16         |                           | 3.65±1.29       | 14.55±1.64      | 119.25±2.06     |
| 17  | S17         |                           | 2.09±0.84       | 19.59±1.95      | 122.85±3.12     |
| 18  | S18         |                           | 6.13±1.25       | 28.34±2.77      | 140.72±2.51     |
| 19  | S19         |                           | 5.14±1.19       | 28.29±2.88      | 170.52±3.12     |
| 20  | S20         |                           | 9.09±1.33       | 20.26±2.46      | 143.60±3.05     |
| 21  | S21         |                           | 6.07±1.51       | 15.74±1.64      | 132.00±2.27     |
| 22  | S22         |                           | 17.69±4.70      | 31.22±2.21      | 149.44±2.90     |
| 23  | S23         |                           | 12.32±1.37      | 34.56±2.05      | 148.46±2.62     |
### 5.2. Radiation effect

Table 2 Results $R_{eq}, D_r, H_{ex}, H_{in}$ and $I_γ$ from the soil samples collected from Al-Azizia district of Wasit Governorate

The equivalent radium activity calculated for the same soil sample ranges from (194.85 ± 8.08) to (33.65 ± 8.08) Bq/kg, an average (66.63 ± 5.37) Bq/kg. The absorbed dose rate ranges from (36.79 ± 2.81) to (10.16 ± 1.95) nGy/h, and the world’s outdoor exposure due to gamma rays (nG/h), based on UNSCEAR 2000 [14].

The recorded value in the study area for most samples is important for health and does not show any serious effects on people living there. In the end, the use of a specific activity measured in the soil is the detection of radioactive dose, which is delivered externally in the form of gamma dose. Externally the risk index was calculated from (0.63 ± 0.02) to (0.09 ± 0.01) at an average of (0.36 ± 0.01) and the mean values were lower than the unit according to the Radiation Protection Report [15].

### 5.2.1. Radiation effects

Table 2 Results $R_{eq}, D_r, H_{ex}, H_{in}$ and $I_γ$ from the soil samples collected from Al-Azizia district of Wasit Governorate.

| No. | Sample Code | $R_{eq}$ (Bq/kg) | $D_r$ (nGy/h) | $H_{ex}$ | $H_{in}$ | Representative Level Index $I_γ$ |
|-----|-------------|-----------------|--------------|---------|---------|-----------------------------|
| S1  | 1           | 48.52 ± 4.21    | 22.45 ± 1.88 | 0.13 ± 0.01 | 0.16 ± 0.01 | 0.35 ± 0.02 |
| S2  | 2           | 75.29 ± 3.80    | 34.19 ± 1.70 | 0.20 ± 0.01 | 0.23 ± 0.01 | 0.54 ± 0.02 |
| S3  | 3           | 70.82 ± 4.42    | 32.18 ± 1.98 | 0.19 ± 0.01 | 0.21 ± 0.01 | 0.51 ± 0.03 |
| S4  | 4           | 63.98 ± 3.84    | 28.98 ± 1.70 | 0.17 ± 0.01 | 0.18 ± 0.01 | 0.46 ± 0.02 |
| S5  | 5           | 74.02 ± 4.84    | 33.38 ± 2.15 | 0.19 ± 0.01 | 0.22 ± 0.01 | 0.53 ± 0.03 |
| S6  | 6           | 66.44 ± 4.97    | 30.31 ± 2.21 | 0.17 ± 0.01 | 0.21 ± 0.01 | 0.48 ± 0.03 |
| S7  | 7           | 62.62 ± 5.75    | 28.49 ± 2.57 | 0.16 ± 0.01 | 0.17 ± 0.01 | 0.45 ± 0.04 |
| S8  | 8           | 80.84 ± 6.31    | 36.79 ± 2.81 | 0.21 ± 0.01 | 0.25 ± 0.01 | 0.58 ± 0.04 |
| S9  | 9           | 61.51 ± 7.75    | 28.18 ± 2.55 | 0.16 ± 0.01 | 0.18 ± 0.01 | 0.44 ± 0.04 |
| S10 | 10          | 56.49 ± 4.63    | 25.89 ± 3.06 | 0.15 ± 0.01 | 0.16 ± 0.01 | 0.41 ± 0.03 |
| S11 | 11          | 62.79 ± 7.39    | 28.82 ± 3.26 | 0.16 ± 0.01 | 0.18 ± 0.01 | 0.45 ± 0.05 |
| S12 | 12          | 53.41 ± 4.84    | 24.76 ± 2.16 | 0.14 ± 0.01 | 0.17 ± 0.01 | 0.39 ± 0.03 |
| No. | Sample Code | AEDE\textsubscript{indoor} (mSv/y) | AEDE\textsubscript{outdoor} (mSv/y) | AEDE\textsubscript{total} (mSv/y) | ELCR \times 10^3 |
|-----|-------------|------------------|------------------|------------------|------------------|
| 1   | S1          | $0.11 \pm 0.00$  | $0.02 \pm 0.00$  | $0.13 \pm 0.01$  | $0.22 \pm 0.01$  |
| 2   | S2          | $0.16 \pm 0.00$  | $0.04 \pm 0.00$  | $0.20 \pm 0.01$  | $0.33 \pm 0.01$  |
| 3   | S3          | $0.15 \pm 0.00$  | $0.03 \pm 0.00$  | $0.19 \pm 0.01$  | $0.31 \pm 0.01$  |
| 4   | S4          | $0.14 \pm 0.00$  | $0.03 \pm 0.00$  | $0.17 \pm 0.01$  | $0.28 \pm 0.01$  |
| 5   | S5          | $0.16 \pm 0.01$  | $0.04 \pm 0.00$  | $0.20 \pm 0.01$  | $0.32 \pm 0.02$  |
| 6   | S6          | $0.14 \pm 0.01$  | $0.03 \pm 0.00$  | $0.18 \pm 0.01$  | $0.29 \pm 0.02$  |
| 7   | S7          | $0.13 \pm 0.01$  | $0.03 \pm 0.00$  | $0.17 \pm 0.01$  | $0.27 \pm 0.02$  |
| 8   | S8          | $0.18 \pm 0.01$  | $0.04 \pm 0.00$  | $0.22 \pm 0.01$  | $0.36 \pm 0.02$  |
| 9   | S9          | $0.13 \pm 0.01$  | $0.03 \pm 0.00$  | $0.17 \pm 0.01$  | $0.27 \pm 0.02$  |
| 10  | S10         | $0.12 \pm 0.01$  | $0.03 \pm 0.00$  | $0.15 \pm 0.01$  | $0.25 \pm 0.02$  |
| 11  | S11         | $0.14 \pm 0.01$  | $0.03 \pm 0.00$  | $0.17 \pm 0.02$  | $0.28 \pm 0.03$  |
| 12  | S12         | $0.12 \pm 0.01$  | $0.03 \pm 0.00$  | $0.15 \pm 0.01$  | $0.24 \pm 0.02$  |
| 13  | S13         | $0.15 \pm 0.01$  | $0.03 \pm 0.00$  | $0.19 \pm 0.01$  | $0.31 \pm 0.02$  |
| 14  | S14         | $0.16 \pm 0.01$  | $0.04 \pm 0.00$  | $0.20 \pm 0.01$  | $0.33 \pm 0.01$  |
| 15  | S15         | $0.13 \pm 0.01$  | $0.03 \pm 0.00$  | $0.16 \pm 0.01$  | $0.26 \pm 0.02$  |
| 16  | S16         | $0.07 \pm 0.00$  | $0.01 \pm 0.00$  | $0.09 \pm 0.01$  | $0.15 \pm 0.01$  |

Table 3. Results of AEDE\textsubscript{indoor}, AEDE\textsubscript{outdoor}, AEDE\textsubscript{total} and ELCR of the Al-Azizah district of Wasit Governorate
Figure 2. The specific activity $^{238}$U.

Figure 3. The specific activity $^{232}$Th.
6. Conclusions
The measurement level of natural radioactivity of the studied soil sample in the present study shows, normal levels of radioactivity concentration and all the obtained $^{40}$K values show levels within the natural permissible values. Preliminary, values for Radium equivalent, (Ra eq), Radiation hazard index ($H_e$) and Annual Effective dose equivalent indicate that the areas monitored can be regarded as having normal levels of natural radioactivity.

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