eISSN: 2789-858X

SCIENTIFIC JOURNAL FOR THE FACULTY OF SCIENCE - SIRTE UNIVERSITY

DOI: 10.37375/issn.2789-858X - Indexed by Crossref, USA

VOLUME 3 ISSUE 1 APRIL 2023

Bi-Annual, Peer- Reviewed, Indexed, and Open Accessed e-Journal

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DOI: 10.37375/issn.2789-858X

Assessment of Radioactivity in the Soil Samples from Al Bayda city, Libya, and its Radiological Implications

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DOI: https://doi.org/10.37375/sjfssu.v3i1.1058

ARTICLE INFO:

Received: 25 February 2023

Accepted: 28 March 2023

Published: 17 April 2023

Keywords:

(NaI(Tl) detector, Radioactivity, radiological hazards, soil).

A B S T R A C T

The radioactivity concentration of the terrestrial radionuclides (^{238}U, ^{232}Th, and ^{40}K) have been determined in soil samples collected from eight different locations around of Al Bayda city, Libya, using the sodium iodide (NaI) detector. Radioactivity concentrations for these elements were estimated and calculated at 0-10 cm depth, we found that an average values of 64.27 Bq/kg, 65.38 Bq/kg and 157.01 Bq/kg, respectively. As well as the radiological hazards were investigated at the same depth, it was found that the radium equivalent (Ra_{eq}) with an average value of 169.85 Bq/kg and the average values for external and internal hazard indices were 0.46 and 0.63, respectively. While, the average values for Gamma and Alpha indices were 0.32 and 0.60, respectively.
In addition, this study was conducted at a depth of 10-20 cm, and the average value of uranium was for ^{238}U, ^{232}Th and ^{40}K, were an average values of 63.76 Bq/kg, 57.89 Bq/kg, and 253.524 Bq/kg, respectively, and the radium equivalent (Ra_{eq}) with an average value of 166.06 Bq/kg, and the average values for external and internal hazard indices were 0.45 and 0.62, respectively.The values of Alpha and Gamma indices with average values of 0.32 and 0.59, respectively.
The average activity concentrations of the radionuclides were compared with Global average value where some values were higher than them. The radiological hazard indices of primitive radionuclides were also calculated and it was within the internationally permitted limits.

1 Introduction

Natural radioactivity in soil comes from the ^{238}U, ^{232}Th and natural ^{40}K series. The presence of this natural radioactivity in soil and building materials causes Internal and external exposure to the population. The accumulation of these natural radionuclides in the soil can lead to potential health risks[Agar *et al*., 2014], [Amanjeet *et al*., 2017], [Faheem *et al*., 2008], [Rafique *et al*., 2011].
Therefore, evaluation of the dose of gamma radiation from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world's population. [Selçuk, 2019], [Ademola and Obed, 2010],[Tufail *et al*., 2013]
Natural gamma dose rates vary depending on the concentration of the natural radionuclides, ^{238}U, ^{232}Th, their nascent products, and ^{40} K present in soil, sand, and rock, which, In turn, it depends on local geological and geographical conditions. Several investigations of the natural radioactivity and the level of natural gamma radiation have been reported by in situ measurement or by analysis of the radionuclide concentration in soil samples [Elmzainy *et al*., 2022], [Rangaswamy *et a*l., 2016], [Gamal *et al*., 2013], [Jabbar *et al*., 2010]
Thus, the evaluation of the natural dose rate behavior in this area is important to understand doses from natural radiation as well as establishing a baseline reference Assessment of normal radioactivity concentration In a group of sites across Al Bayda Measurements were made using a gamma ray spectrometer containing Sodium iodide reagent. Radium Equivalent and Exogenous Activities The radiation hazard index was evaluated and compared with National reports and guidelines proposed by United Nations Scientific

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Committee on Antiquities Atomic radiation (UNSCEAR 2008).

2 Materials and Methods

2.1. Study area:

The city of Al Bayda is located in the north-east of Libya at the top of the JabalAkhdar at the confluence of latitude 21º44'north with longitude 32º76' east and an area of 11429 km^2.It is bordered to the east by the city of Cyrene, to the west by the village of Massa, to the south by the village of Aslanta, and to the north by the Al-Wasita forests, which makes it in the middle of the JabalAkhdar. The main rocky features of the area It consists of limestone and clay layer located in the study area.

2.2. Sample collection and sample preparation

Sixteen samples of eight sites were taken from a site around the city of Al Bayda, Libya. Coordinates of the collected samples are shown the figure 1. Each sample was collected by selecting a square area of 3 m^2 per site, and the top surface of any organic material or debris was cleaned. Three samples were taken from each square at a depth of 0-10 cm and 10-20 cm. Each of the three samples of the same site were well mixed together, We now have eight samples at a depth of 0-10 cm and eight other samples at a depth of 10-20 cm, then all the mixed samples were kept in plastic bags and sent to the laboratory for further treatment to proceed with the analysis. Directions and locations of samples as given in Table1.

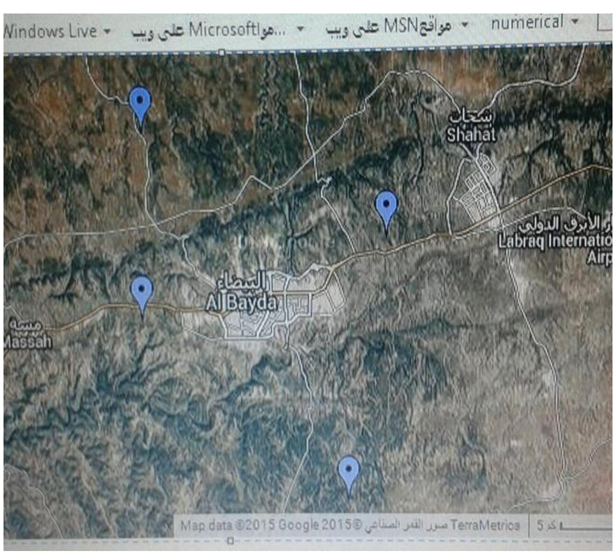

Figure 1. Map of the study area with sample collection points.

Table (1): Directions and locations of used samples**:**

Sample	Depth 0-10 cm and Depth 10-20 cm		
	Direction	Location((Latitude (N°))	Location ((Longitude (E°))
S1	South	32°49´31.2888	21°41´30.1272
S2	South	32°45´58.9213	21°43´28.2846
S3	North	32°49´15.7044	21°41´37.8276
S4	North	32°43´21.3132	21°48´11.1168
S5	West	32°45´35.9568	21°40´14.6496
S6	West	32°45´36.4320	21°40´14.9844
S7	East	32°48´21.9600	21°48´13.5072
S8	East	32°47´18.1824	21°49´3.6912

All soil samples were cleaned of stones and organic matter, then dried in an oven at a temperature 105 ^{0}Cand after drying they were crushed and passed through a 2 mm sieve. Their weights were measured and then kept in plastic bags and carefully sealed to prevent Radon gas leakage from the sample. Then Stored for at least 4 weeks to allow time for ^{238}U and ^{232}Th to reach balance with their daughter radionuclides and then measured using the sodium iodide NaI (Tl) detector.

2.3. Activity measurement

The activity concentrations of ^{40}K, ^{238}U, and ^{232}Th were measured in the prepared soil samples using gamma spectroscopy technology, which contains a sodium iodide NaI (Tl) detector for radiation detection. The system was calibrated using two radioactive sources, cobalt ^{60}Co with two energies (1173KeV), (1332KeV) and cesium^{137}C with energy (662KeV). Absolute efficiency was calculated. All measurements were carried out at the nuclear laboratory of Omar Al-Mukhtar University in Al-Bayda, Libya[13].The measurement time was chosen two hour for all samples, were the activity concentrations all samples (Bq/Kg) were calculated by using the following formula [Alsaadi et al., 2018]:

$$A = \frac{A_R}{\varepsilon(E)tPW} \quad (1)$$

Where A is the activity level of a certain radionuclide expressed in Bq/kg dry weight, A_R is the net counting rate of the sample after subtracting background (counts/s), ε(E) is the counting efficiency of the detector at energy (E), t is the time for the measurement of the samples, P is the absolute transition probability of γ–

decay (Abundance (%)), and W is the dried sample weight expressed in kg.

2.4. Determination of radiation hazards

2.4.1 Radium equivalent dose (Ra_{eq}):

This is the common factor used to compare the radionuclides present in any material and this has been adopted in this present study for the purpose of comparing the measured radioactive concentration in the soil samples used. Radium equivalent activities were determined based on the estimation of 370 Bq/kg ofUranium-238, 259 Bq/kg of Thorium-232, and 4810 Bq/kg 1 of potassium-40, respectively. Each of these radionuclides produces a gamma dose rate of Eq. (2)
was used to estimate the radium equivalent activity of the samples[UNSCEAR, 2008], [Ali et al., 2021],[Antoaneta et al., 2010].

$$R_{a_{eq}} = A_U + 1.43A_{Th} + 0.077A_K \qquad (2)$$

2.4.2. External hazard index (Hex).

The estimation of the external hazard assessment (Hex) associated with the gamma rays emitted from the soil sample was determined using equation (3) [Ali et al., 2021], [Beretka and Matthew, 1985].

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (3)$$

A_U, A_{Th} and A_K are the concentrations of activities in B/kg.

2.4.3. Internal hazard index (Hin):

Radon and its short-lived products are also dangerous for the respiratory organs. So the internal exposure to radon and its short-lived products is measured by the internal hazard index and expressed mathematically by equation (4). [Ali et al., 2021], [Beretka and Matthew, 1985]

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} (4)$$

Where Hin is the internal hazard index and A_U, A_{Th} and A_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K, respectively.

2.4.4. Gamma representative index (Iγ).

A representative gamma index is usually used to estimate the first risk associated with the occurrence of natural radionuclides in any particular material under study. The representation of the gamma index (Iγ) [Alsaadi et al., 2018],[Gbenuet al., 2016] is estimated using Eq.(5).

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} (5)$$

2.4.5. Alpha index representative (Iα).

The representative of the alpha index (Iα) is an important radiological hazard that has been developed in order to ensure the safety of the environment as a result of excessive exposure to radiation emitted from the ground that uses soil as a means of movement. Equation No. (6) was used to estimate.[Alsaadi et al., 2018],[Kriege, 1981]

$$I_\alpha = \frac{A_U}{200} \leq 1 \qquad (6)$$

3 Results

The measured values of the activity concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclides which obtained from soil samples at depths of 0-10 cm and 10-20 cm for eight different locations are presented in Table 2 and also in the Figure 2 and Figure 3.

Table (2): Activity concentration (Bq.kg^{-1}) for ^{238}U, ^{232}Th and ^{40}K at depth 0-10 cm and 10-20cm.

S.NO	Depth 0-10 cm			Depth 10-20 cm		
	^{238}U	^{232}Th	^{40}K	^{238}U	^{232}Th	^{40}K
S1	58.76	61.69	77.36	72.59	63.64	81.17
S2	52.76	82.69	263.82	39.36	97.37	78.46
S3	48.15	41.77	338.73	50.6	67.44	218.12
S4	53.07	64.00	55.73	68.67	31.39	553.01
S5	65.81	76.36	174.16	56.5	38.77	636.33
S6	64.57	77.34	93.57	73.28	37.36	130.78
S7	92.87	56.22	146.83	72.4	64.82	151.76
S8	78.14	62.96	105.85	76.65	62.30	178.56
Average	64.27	65.38	157.01	63.76	57.89	253.52

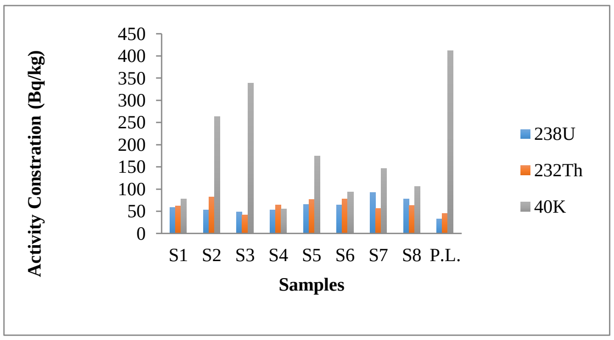

Figure 2: The activity of ^{238}U, ^{232}Th, ^{40}K, concentration for soil samples at Depth 0-10 cm.

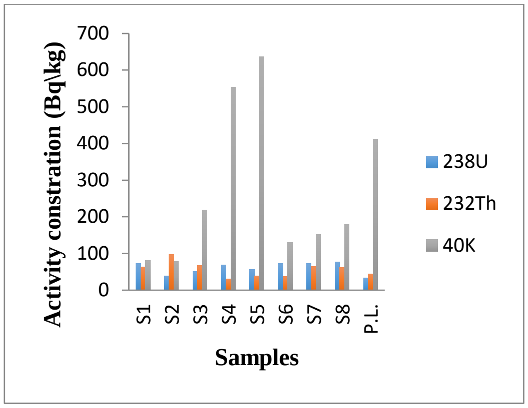

Figure 3: The activity of ^{238}U, ^{232}Th, ^{40}K, concentration for soil samples at Depth 10-20cm.

Radium Equivalent Activity (Ra_{eq}) Due to Activity the concentration of the three natural radionuclides they are ^{238}U, ^{232}Th and ^{40}K from all eight locations difference shown in Table 3and Figure 4.

Table (3): Radium equivalent dose (Ra_{eq}) at depth 0-10 cm and 10-20cm.

S.NO	Depth 0-10 cm	Depth 10-20 cm
	Ra_{eq}	Ra_{eq}
S1	152.93	169.85
S2	191.32	184.64
S3	133.96	163.83
S4	148.88	156.14
S5	188.42	160.94
S6	182.37	136.77
S7	184.57	176.78
S8	176.32	179.49
Average	169.85	166.06

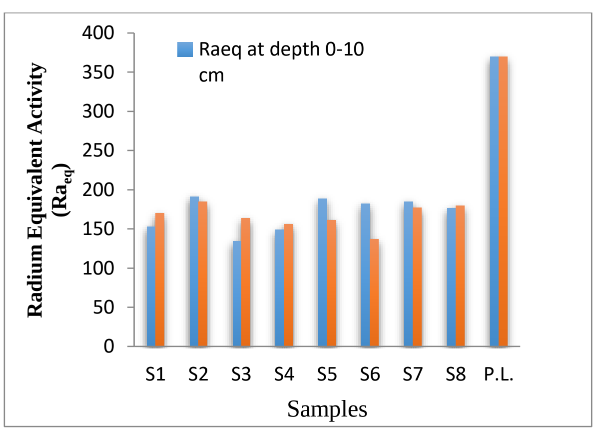

Figure. 4: The Radium Equivalent Activity (Ra_{eq}) for all samples.

The mean value of radiological hazard (Hex, Hin, Iα and Iγ). It is given in the following Table 4 and Figures 5 and 6 show the discrepancy in the values at the two depths from 0-10 cm and from 10-20 cm.

Table (4): The values of radiological hazard (Hex, Hin, Iα and Iγ) in the soil samples

Samples	Depth 0-10 cm				Depth 10-20 cm			
	Hex	Hin	Iα	Iγ	Hex	Hin	Iα	Iγ
S1	0.41	0.57	0.29	0.53	0.46	0.66	0.36	0.59
S2	0.52	0.66	0.26	0.68	0.5	0.61	0.2	0.64
S3	0.36	0.49	0.24	0.48	0.44	0.58	0.25	0.58
S4	0.4	0.55	0.27	0.52	0.42	0.61	0.34	0.57
S5	0.51	0.69	0.33	0.66	0.44	0.59	0.28	0.59
S6	0.49	0.67	0.32	0.63	0.37	0.57	0.37	0.48
S7	0.5	0.75	0.46	0.64	0.48	0.67	0.36	0.62
S8	0.48	0.69	0.39	0.61	0.49	0.69	0.38	0.63
Average	0.46	0.63	0.32	0.6	0.45	0.62	0.32	0.59

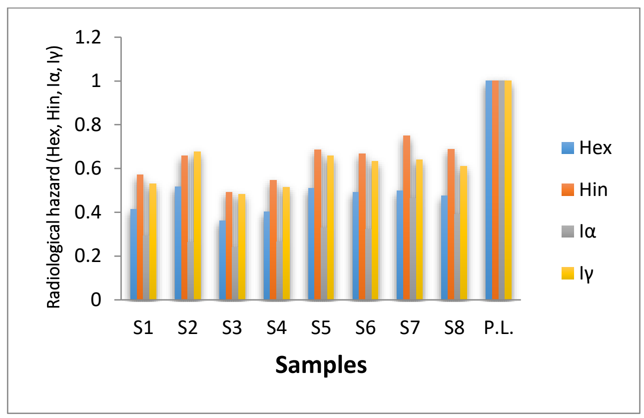

Figure 5: The Radiological Hazard at Depth 0-10 cm.

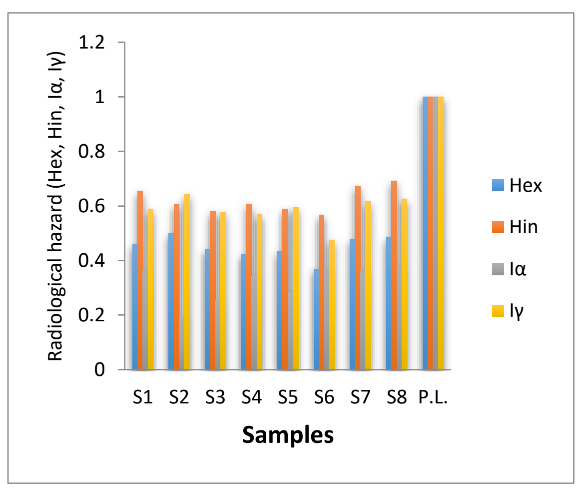

Figure 6: The Radiological Hazard at Depth10-20 cm.

4 Discussion

Activity concentration ^{238}U, ^{232}Th and ^{40}K at depth 0-10 cm range from 48.15 to 92.87 Bq/kg, 41.77 to 82.69 Bq/kg, and 55.73 to 383.73 Bq/kg with an average value of 64.27, 65.38, and 157.01 Bq/kg, respectively. While the concentrations are at a depth of 10-20 cm range from 39.36 to 76.65 Bq/kg 31.39 to 97.37 Bq/kg, and 78.46 to 636.33 Bq/kg with an average value of 60.76, 57.89, and 253.52 Bq/kg, respectively.

Figure 2 illustrates the activity of uranium, thorium and potassium concentrations for soil samples that were studied at a depth of 0-10 cm. Where it was found that the highest value of uranium at sample No. 7 and the highest value of thorium at sample No. 2, while the highest value of potassium was at sample No. 3. While the lowest value for them was in samples No. 3, 3, and 4, respectively.

As for the depth of 10-20 cm, as shown in Figure 3, the highest value of uranium at sample No. 8 and the highest value of thorium at sample No. 2, while the highest value of potassium was at sample No. 5. While the lowest value for them was in samples No. 2, 4, and 2, respectively.

The Radium Equivalent Activity (Ra_{eq}) ranged from 133.96 to 191.32 Bq/kg at depth 0-10cm with average value 169.85 Bq/kg. While it is at a depth of 10-20 cm, a range from 136.77 to 184.64 Bq/kg at depth 10-20cm with average value 166.06 Bq/kg. As shown in Table 3.

Figure 4 shows the radium equivalent, which was calculated from the concentrations of uranium, thorium and potassium obtained through equation No. 1, where it was found that its greatest value was at sample No. 2, while the lowest values were at sample No. 3 at a depth of 0-10 cm. As for the depth of 10-20 cm, the highest value was found in sample No. 2, while the lowest value was in sample No. 6.

From Table 4 it was found the external and internal hazard indices ranged from 0.36 - 0.52 and 0.49 - 0.75 respectively, and the average values for external and internal hazard indices were 0.46 and 0.63, respectively.While, the values of Alpha and Gamma indices ranged between 0.24 - 0.46 and 0.48 - 0.68, respectively, and the average values for Gamma and Alpha indices were 0.32 and 0.60, respectively.

As for 10-20 cm depth, the external and internal hazard indices ranged from 0.37 - 0.50 and 0.0.57 - 0.69, respectively, and the average values for external and internal hazard indices were 0.45 and 0.62, respectively. The values of Alpha and Gamma indices ranged between 0.20 - 0.38 and 0.48 - 0.64, respectively, with average values of 0.32 and 0.59, respectively.

Figure 5 shows the radiological hazard (Hex, Hin, Iγ and Iα). We note from the figure that the highest values were in sample No. 2 for (Hex and Iγ), and sample No. 7 for (Hin and Iα). while the lowest value for them appears at sample No. 3, at a depth of 0-10 cm.

Figure 6 shows the radiological hazard (Hex, Hin, Iγ and Iα). We note from the figure that the highest values were in sample No. 2 for (Hex and Iγ), and sample No. 8 for (Hin and Iα). While the lowest value for them appears at sample No. 6 for (Hex, Hin and Iγ) and sample No. 2 for Iα, at a depth of 10-20 cm.

5 Conclusions

The results showed that some values of the radioactivity levels of uranium, thorium and potassium in this study are relatively high compared to the internationally permitted limit. Due to the fact that the locations of the collected samples were not far from agricultural areas where chemical fertilizers are frequently used, this rise could be caused by fertilizers in the soil as well as transport factors such as wind and rain.

As for the radium equivalent (Ra_{eq}), and radiological hazard (H_{ex}, H_{in}, I_{α} and I_{γ}) at the sites studied in this study were within the internationally permissible limit.

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