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Determination of Radionuclide's Concentrations in Soil Around of Al-Tuwaitha Nuclear Research Center in Iraq by Using Gamma Spectroscopy Analysis System

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Abstract: The measurement of the radionuclide's namely ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in soil samples collected from 17 surrounding regions of Al- Tuwaitha nuclear research center in Iraq, were carried out by Gamma- Spectroscopy analysis system. The range of concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in the samples varies from (12.01 ± 3.47-37.19 ± 6.10) $Bq.kg^{-1}$, (14.05 ± 3.75-34.80 ± 5.90) $Bq.kg^{-1}$, (285.30 ± 16.89- 490.95 ± 22.16) $Bq.kg^{-1}$ and (2.92 ± 1.71-15.20 ± 3.90) $Bq.kg^{-1}$ with overall mean values of 21.83 ± 4.64 $Bq.kg^{-1}$, 25.29 ± 5.01 $Bq.kg^{-1}$, 363.47 ± 19.02 $Bq.kg^{-1}$ and 8.72 ± 2.92 $Bq.kg^{-1}$, respectively.

The radium equivalent rate (Ra_{eq}) calculated with concentrations between (57.60 ± 7.59 - 109.09 ± 10.44) Bq. kg^{-1} with a mean value (85.97 ± 9.24) Bq. kg^{-1}. The absorbed dose Rate (Dγ) of the ^{238}U, ^{232}Th and ^{40}K radionuclide's for the soil samples in the study area were from (27.70 - 51.67) nGy. h^{-1} with an average value of (40.51) $nGy.h^{-1}$ and ^{137}Cs from (0.5 - 2.58) $nGy.h^{-1}$ with an average value of (1.48) $nGy.h^{-1}$. The indoor annual effective dose rate $(AEDE)_{in}$ range (0.14 - 0.25) mSv. y^{-1} with an average value of (0.20) mSv. y^{-1}. The outdoor annual effective dose rate $(AEDE)_{out}$ range (0.03 - 0.06) mSv. y^{-1} with an average value of 0.05 $ms.y^{-1}$. The internal hazard index (H_{in}) range (0.19 - 0.4) with an average value of (0.29). The external hazard index (H_{ex}) range (0.16 - 0.29) with

an average value of (0.23). The gamma Index (Iγ) range (0.44 - 0.81) with an average value of (0.64). The average values of the specific activity of (^{238}U, ^{232}Th, ^{40}K and^{137}Cs), radium equivalent activity, indoor and outdoor annual effective dose rates, internal and external hazard index, and gamma index, all were found to be lower than their corresponding allowed limits.

Keywords: Radionuclide's concentrations, soil, Gamma- Spectroscopy, absorbed dose, Iraq.

INTRODUCTION

Nuclear radiation and sources of radioactivity, that is, radionuclides, have become a necessary part of our daily life. The quantity and quality of our food, our health, general well-being, and consequently our extended life span are due in large part to radioactive sources and their numerous applications in medicine, biology, agriculture, industry, and electric power generation [1] It is presently known that uranium naturally consists approximately of a mixture of ^{238}U (99.27%), ^{235}U (0.72%), and ^{234}U (0.006%). Thorium and potassium were also identified as the radioactive parents with some decay products [2].

The earth's crust contains long-lived radionuclide's such as ^{40}K and members of ^{238}U , ^{235}U and ^{232}Th decay chains, and these known as primordial radionuclide's [3]. Primordial radionuclides are widely distributed through the crust of the earth. Most materials contain trace amounts of ^{238}U, ^{235}U and ^{232}Th, which constitute the major source of naturally occurring radioactive material (NORM) in the environment [3]. Natural radioactivity is widespread in the earth environment and it exists in various geological formations such as earth crust, rocks, soils, plants, water and air. Natural radioactive concentration mainly depends on geological and geographical condition and appears at different level in soils of each different geological region [4].

Soil is the upper part of the earth's crust and is formed as a result of rock deformation by complex physicochemical processes, which include weathering, decomposition and water movement, so the soil is the result of the action of weather and human activities on the crust rocks of the earth [5]. The soil is naturally radioactive, because of the mineral content. The natural radioactivity may vary considerably from one type of soil to another [5].

Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. Volcanic geographic structures as well as rocks that are rich in phosphate, granite and salt contain natural radionuclides like uranium-238, thorium-232 and potassium-40. When rocks are disintegrated through natural processes, radionuclides are carried in soil by rain and flows. In addition to the natural sources, soil radioactivity is also affected from man-made activities [6].

MATERIALS AND METHODS

Collecting of samples: The natural radionuclides are measured in 37 samples of soil. All samples were collected from different locations of the 17 surrounding regions of Al- Tuwaitha nuclear research center of Iraq. The depth at which the soil samples were collected was (0-5 cm) for each location. All samples were collected in (February – May) 2015.

Table 1: shows the location and the coordinates (GPS) of the study samples

No.	Locations	Coordinates (GPS)
1	Taha mosque near square Salman	33°12'59.0"N 44°32'59.3"E
2	Stores of the Center for Research AL-Tuwaitha	33°13'15.9"N 44°32'22.7"E
3	Municipal Council from front of AL-Tuwaitha N.R.C.	33°13'12.3"N 44°31'31.3"E
4	Ibn Zahr hospital near AL-Tuwaitha Research Center	33°13'25.4"N 44°30'39.4"E
5	Beginning AL-Tuwaitha N.R.C.	33°13'19.6"N 44°30'40.7"E
6	End AL-Tuwaitha N.R.C.	33°12'14.3"N 44°29'42.3"E
7	Towers high-pressure behind the AL-Tuwaitha N.R.C.	33°10'55.7"N 44°30'01.5"E
8	An agricultural area close to the high-pressure Towers	33°10'40.6"N 44°29'49.8"E
9	Al Bustan near the end of the AL-Tuwaitha N.R.C.	33°12'05.3"N 44°29'39.4"E
10	Department liquefaction water near AL-Tuwaitha N.R.C.	33°12'54.5"N 44°30'17.5"E
11	Near a large mound of dirt AL-Tuwaitha N.R.C.	33°12'37.0"N 44°30'36.2"E
12	Jabir Ibn Abdullah Ansari neighborhood (farm A)	33°11'46.8"N 44°32'45.5"E
13	Jabir Ibn Abdullah Ansari neighborhood (farm B)	33°11'50.5"N 44°32'39.0"E
14	Jabir Ibn Abdullah Ansari neighborhood (farm C)	33°11'43.8"N 44°32'41.7"E
15	Jabir Ibn Abdullah Ansari neighborhood (farm D)	33°11'39.9"N 44°32'34.1"E
16	Ishtar region near AL-Tuwaitha N.R.C.	33°11'32.9"N 44°31'49.3"E
17	Al -Waredya region near AL-Tuwaitha N.R.C.	33°11'16.3"N 44°32'22.5"E

* (N.R.C) = Nuclear Research Center

Table 2: The Number of location, samples code and weight of soil samples.

No. of Location	Sample code	Weight (g)		No. of Location	Sample code	Weight (g)
1	S1	1330		10	S21	1650
	S2	1450			S22	1420
2	S3	1490		11	S23	1450
	S4	1330			S24	1555
3	S5	1750			S25	1480
	S6	1710			S26	1500
4	S7	1580		12	S27	1365
	S8	1689			S28	1340
5	S9	1370		13	S29	1400
	S10	1485			S30	1390
6	S11	1570		14	S31	1500
	S12	1425			S32	1500
7	S13	1340		15	S33	1500
	S14	1330			S34	1500
	S15	1360		16	S35	1630
8	S16	1445			S36	1680
	S17	1330		17	S37	1680
9	S18	1290				
	S19	1340				
	S20	1500				

Soil Samples Preparation: After collecting the samples, the samples were cleaned, placing each soil sample in an oven for drying at a temperature of 80°C for 2h until a constant weight was reached, The dried samples were grinded into a fine powder and passed through a standard of 75 µm mesh size. The

The samples were packaged in a Marinelli beaker with the size 1000 ml. The sealed Marinelli beaker was kept for one month before measurements in order to achieve the secular equilibrium for radionuclides. The net weight of the samples has been measured as shown in the **Tables (2**) by using a sensitive balance.

Samples Measurement: The samples measurement was carried out by Gamma ray spectrometry analysis system with Multichannel Analyzer computer card from (CANBERA) with integrated computer spectrometer version-2 software (ICS-PCI 4K) Copyright 2003-2005 which analyses the spectrum in 4096 channels with a maximum count 16M. The (HPGe) detector (CANBERA-model 7229N, USA) with an efficiency of (≥ 40%) is a high purity N-type semiconductor detector with physical characteristics of (geometric closed-end coaxial, 3×3 inch and operation voltage is (-3500V)) were used.

The (HPGe) detector is kept cold by immersing it in a liquid-nitrogen vessel at (-196^{o}C) to reduce the leakage current to acceptable levels. The detector is surrounded by lead shield of about 10cm thickness to reduce the background radiation. The calibration of the energy was carried out by using the standard source of Europium (^{152}Eu) with energies (121.8, 244.7, 344.3, 411.1, 444.6, 778.9, 964.0, 1085.8, 1112.0 and 1408.0 keV). Three points for energy calibration have been chosen. They are 121.8, 778.9 and 1408.0 keV which are entered into the (ICS-PCI 4K) program to do the calibration automatically.

The efficiency calibration spectrum and curve for (HPGe) detector system has been made by measuring the soil standard source of Europium (^{152}Eu).

The specific activity concentration of radionuclides in soil samples was measured by the equation (1) [7]:

$$\mathbf{S.\ A.} = \frac{\mathbf{N}}{\boldsymbol{\varepsilon}(\mathbf{E\gamma})\ \mathbf{x}\ \mathbf{I\gamma}(\mathbf{E\gamma})\ \mathbf{x}\ \mathbf{t}\ \mathbf{x}\ \mathbf{m}} \quad \ldots(1)$$

Where:

S.A.: The specific activity concentration of radionuclide's measured in (Bq. kg^{-1}).

N: the net peak area under the specific peak corrected for the background at energy E_{γ}.

ε (E_{γ}): the detection efficiency at energy E_{γ} .

I_{γ} (E_{γ}): the abundance at energy E_{γ}.

t: the time of measurement (7200sec).

m: weight of the sample (kg) .

Determination of Some Gamma Radiation Parameters:

Radium Equivalent Activity (Ra_{eq}): Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq.kg^{-1} to compare the specific activity of materials containing different amounts of ^{226}Ra (^{238}U), ^{232}Th, and ^{40}K can be calculated through the relation (2) [8]:

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.07C_K \quad \ldots..(2)$$

Where C_U, C_{Th} and C_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bq.kg^{-1}, respectively. The maximum value of Ra_{eq} must be less than (370 Bq.kg^{-1}) for safe use. Which corresponds to an effective dose of 1 mSv for the general public [8].

Absorbed Dose Rate (D): The mean activity concentrations of ^{238}U, ^{232}Th, and ^{40}K (Bq.kg^{-1}) in soil samples are used to calculate the absorbed dose rate given by the following formula [9] :

$$D = 0.462\ A_U + 0.604\ A_{Th} + 0.0417\ A_K\ (nGy.h^{-1}) \quad \ldots. (3)$$

Where D is the absorbed dose rate in nGy. h^{-1}, A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively. The dose coefficients in units of $nGy.h^{-1}$ per $Bq.kg^{-1}$ were taken from the UNSCEAR (2000) report [10].

The absorbed dose rate due to cesium was:

$$D_{Cs}\ (nGy.h^{-1}) = 0.17\ A_{Cs}\ (Bq.kg^{-1}) \quad \ldots.(4)$$

Where A_{Cs} is the activity concentration of ^{137}Cs. The dose coefficients in units of $nGy.h^{-1}$ per $Bq.kg^{-1}$ were taken from IAEA (2003) report [11].

The Annual Effective Dose Equivalent (AEDE): To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose ($0.7\ Sv{\cdot}Gy^{-1}$) and outdoor occupancy factor 0.2, and for indoor is 0.8. The annual effective dose equivalent in the outdoor environment in units of $mSv.y^{-1}$ is given by the equation (5) [12]:

$$AEDE_{out}\ (mSv.y^{-1}) = D\ (nGy.h^{-1}) \times 10^{-6} \times 8760\ h.y^{-1} \times 0.2 \times 0.7\ (Sv{\cdot}Gy^{-1}) \quad \ldots.. (5)$$

And for indoor environment the above formula is seen as:

$$AEDE_{in}\ (mSv.y^{-1}) = D\ (nGy.h^{-1}) \times 10^{-6} \times 8760\ h.y^{-1} \times 0.8 \times 0.7\ (Sv{\cdot}Gy^{-1}) \quad \ldots.. (6)$$

Where D is the calculated dose rate in $(nGy.h^{-1})$.

External (H_{ex}) and Internal (H_{in}) Hazard Indices: Another criterion used to estimate the level of gamma ray radiation associated with natural radionuclide's in specific construction materials is defined by the terms External hazard index (H_{ex}) and Internal hazard index (H_{in}) as shown in Eqs. (7) and (8):

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots..(7)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots..(8)$$

Where A_U, A_{Th} and A_K represent the measured activity concentrations in $(Bq.kg^{-1})$ for ^{238}U, ^{232}Th and ^{40}K, respectively. The value of the external hazard index and internal hazard index (H_{in}) must be less than unity for the external gamma radiation hazard to be considered negligible [13].

Representative Level Index Values: Another radiation hazard index called the representative level index, used to estimate the level of gamma radiation associated with different concentrations of some specific radionuclide's, which can be defined as follows:

$$I\gamma = \frac{1}{150} C_{Ra} + \frac{1}{100} C_{Th} + \frac{1}{1500} C_K \quad \ldots..(9)$$

Where C_{Ra}, C_{Th} and C_K are the specific activities of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K in $Bq.kg^{-1}$ respectively [12].

RESULTS AND DISCUSSION

Table 3 shows that the highest value of specific activity of (^{238}U) was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to ($37.19 \pm 6.10\ Bq.kg^{-1}$), while the lowest value of specific activity of (^{238}U) was found in (S34) sample (Jabir Ibn Abdullah Ansari

neighborhood (farm D)) region, which is equal to (12.01 ± 3.47 Bq.kg^{-1}), with an average value of (21.83 ± 4.64 Bq.kg^{-1}).

Table 3: Specific activity concentrations for soil samples of the surrounding regions of Al- Tuwaitha nuclear research center in Iraq.

	Specific Activity (Bq. kg^{-1})			
Sample Code	U-238	Th-232	K-40	Cs-137
S1	27.01 ± 5.20	22.93 ± 4.79	332.80 ± 18.24	11.07 ± 3.33
S2	13.78 ± 3.71	14.05 ± 3.75	308.20 ± 17.56	5.27 ± 2.30
S3	29.09 ± 5.39	21.85 ± 4.67	490.95 ± 22.16	5.47 ± 2.34
S4	20.52 ± 4.53	32.49 ± 5.70	339.63 ± 18.43	15.20 ± 3.90
S5	13.56 ± 3.68	22.40 ± 4.73	305.70 ± 17.48	7.25 ± 2.69
S6	19.44 ± 4.41	22.13 ± 4.70	286.50 ± 16.93	9.95 ± 3.15
S7	24.94 ± 4.99	17.34 ± 4.16	308.20 ± 17.56	10.37 ± 3.22
S8	26.24 ± 5.12	33.28 ± 5.77	419.84 ± 20.49	11.06 ± 3.33
S9	26.63 ± 5.16	22.90 ± 4.79	332.07 ± 18.22	6.51 ± 2.55
S10	23.08 ± 4.80	25.87 ± 5.09	398.80 ± 19.97	9.83 ± 3.14
S11	24.02 ± 4.90	31.40 ± 5.60	384.24 ± 19.60	2.92 ± 1.71
S12	14.06 ± 3.75	19.74 ± 4.44	306.60 ± 17.51	8.99 ± 3.00
S13	17.60 ± 4.20	19.71 ± 4.44	429.99 ± 20.74	8.75 ± 2.96
S14	17.80 ± 4.22	21.24 ± 4.61	352.60 ± 18.78	9.80 ± 3.13
S15	37.19 ± 6.10	26.09 ± 5.11	449.20 ± 21.19	12.28 ± 3.50
S16	26.10 ± 5.11	34.80 ± 5.90	388.80 ± 19.72	9.44 ± 3.07
S17	27.43 ± 5.24	26.48 ± 5.15	384.25 ± 19.60	10.74 ± 3.28
S18	28.10 ± 5.30	27.57 ± 5.25	427.80 ± 20.68	11.07 ± 3.33
S19	26.65 ± 5.16	29.14 ± 5.40	460.42 ± 21.46	9.32 ± 3.05
S20	14.92 ± 3.86	23.68 ± 4.87	308.60 ± 17.57	11.30 ± 3.36
S21	15.08 ± 3.88	21.76 ± 4.66	285.30 ± 16.89	6.49 ± 2.55
S22	19.62 ± 4.43	29.04 ± 5.39	309.60 ± 17.60	10.95 ± 3.31
S23	23.10 ± 4.81	24.16 ± 4.92	381.30 ± 19.53	9.67 ± 3.11
S24	29.89 ± 5.47	26.32 ± 5.13	380.65 ± 19.51	7.62 ± 2.76
S25	19.51 ± 4.42	28.44 ± 5.33	345.13 ± 18.58	8.14 ± 2.85
S26	14.77 ± 3.84	17.13 ± 4.14	333.36 ± 18.26	4.84 ± 2.20
S27	25.34 ± 5.03	28.76 ± 5.36	435.80 ± 20.88	5.18 ± 2.28
S28	24.63 ± 4.96	32.25 ± 5.68	409.06 ± 20.23	11.75 ± 3.43
S29	17.30 ± 4.16	26.39 ± 5.14	343.40 ± 18.53	10.88 ± 3.30
S30	20.30 ± 4.51	22.10 ± 4.70	361.70 ± 19.02	5.55 ± 2.36
S31	20.14 ± 4.49	24.51 ± 4.95	315.30 ± 17.76	8.54 ± 2.92
S32	20.22 ± 4.50	25.04 ± 5.00	388.14 ± 19.70	6.88 ± 2.62
S33	19.72 ± 4.44	26.96 ± 5.19	385.47 ± 19.63	4.21 ± 2.05
S34	12.01 ± 3.47	23.91 ± 4.89	289.90 ± 17.03	11.52 ± 3.39
S35	20.75 ± 4.56	26.80 ± 5.18	341.60 ± 18.48	9.97 ± 3.16
S36	24.71 ± 4.97	25.63 ± 5.06	357.10 ± 18.90	5.46 ± 2.34
S37	22.41 ± 4.73	31.30 ± 5.59	370.22 ± 19.24	8.57 ± 2.93
Average	21.83 ± 4.64	25.29 ± 5.01	363.47 ± 19.02	8.72 ± 2.92
Global Limit [10,14]	35	30	400	14.8

The highest value of specific activity of (^{232}Th) was found in (S16) sample (An agricultural area close to the high-pressure Towers) region, which is equal to (34.80 ± 5.90 Bq.kg^{-1}), while the lowest value of specific activity of (^{232}Th) was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (14.05 ± 3.75 Bq.kg^{-1}), with an average value of (25.29 ± 5.01 Bq.kg^{-1}).

The highest value of specific activity of (^{40}K) was found in (S3) sample (Stores of the Center for Research AL-Tuwaitha) region, which is equal to (490.95 ± 22.16 Bq.kg^{-1}), while the lowest specific activity concentration of (^{40}K) was found in (S21) sample (Department liquefaction water near AL-Tuwaitha N.R.C.) regions which is equal to (285.30 ± 16.89 Bq.kg^{-1}), with an average value of (363.47 ± 19.02 Bq.kg^{-1}).

The highest value of specific activity of (^{137}Cs) was found in (S4) sample (Stores of the Center for Research AL-Tuwaitha) region, which is equal to (15.20 ± 3.90 Bq. kg^{-1}), while the lowest value of specific activity of (^{137}Cs) was found in (S11) sample (End AL-Tuwaitha N.R.C.) regions which is equal to (2.92 ± 1.71 Bq. kg^{-1}), with an average value of (8.72 ± 2.92 Bq. kg^{-1}).

From **Table 4** it can be noticed that the highest value of radium equivalent activity (Ra_{eq}) was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) Region, which is equal to (109.09 ± 10.44 Bq. kg^{-1}), while the lowest value of radium equivalent activity was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (57.60 ± 7.59 Bq. kg^{-1}), with an average value of (85.97 ± 9.24 Bq. kg^{-1}).

The highest value of the absorbed gamma dose rate (Dɣ) was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to (51.67 nGy. h^{-1}), while the lowest value of the absorbed gamma dose rate was found in (S2) sample (Taha mosque near rotated Salman) region which is equal to (27.70 nGy. h^{-1}), with an average value of (40.51 nGy. h^{-1}).

The highest value of the absorbed gamma dose rate (Dɣ) for Cs-137 was found in (S4) sample (Stores of the Center for Research AL-Tuwaitha) region, which is equal to (2.58 nGy. h^{-1}), while the lowest value of the absorbed gamma dose rate was found in (S11) sample (End AL-Tuwaitha N.R.C.) regions which is equal to (0.50 nGy. h^{-1}), with an average value of (1.48 nGy. h^{-1}).

The highest value of indoor annual effective dose rate $(AEDE)_{in}$ was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to (0.25 mSv.y^{-1}), while the lowest value of indoor annual effective dose rate was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (0.14 mSv.y^{-1}), with an average value of (0.20 mSv.y^{-1}).

The highest value of outdoor annual effective dose rate $(AEDE)_{out}$ was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to (0.06 mSv.y^{-1}), while the lowest value of outdoor annual effective dose rate was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (0.03 mSv.y^{-1}), with an average value of (0.05 mSv.y^{-1}).

The highest value of internal hazard index (H_{in}) was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to (0.4), while the lowest value of internal hazard index was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (0.19), with an average value of (0.29).

The highest value of external hazard index (H_{ex}) was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to (0.29), while the lowest value of external

hazard index was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (0.16), with an average value of (0.23).

Table 4: (Ra_{eq}), (D), AEDE (in and out), (H_{in}) and (H_{ex}), and (I_{γ}) for soil samples of the surrounding regions of Al- Tuwaitha nuclear research center in Iraq.

Sample Code	Ra_{eq} (Bq.Kg^{-1})	D (nGy.h^{-1})	D (nGy. h^{-1}) for Cs-137	$(AEDE)_{in}$ (mSv. y^{-1})	$(AEDE)_{out}$ (mSv. y^{-1})	I_{γ}	H_{in}	H_{ex}
S1	85.43 ± 9.24	40.21	1.88	0.20	0.05	0.63	0.30	0.23
S2	57.60 ± 7.59	27.70	0.90	0.14	0.03	0.44	0.19	0.16
S3	98.14 ± 9.91	47.11	0.93	0.23	0.06	0.74	0.34	0.27
S4	93.13 ± 9.65	43.27	2.58	0.21	0.05	0.69	0.31	0.25
S5	69.13 ± 8.31	32.54	1.23	0.16	0.04	0.52	0.22	0.19
S6	73.15 ± 8.55	34.29	1.69	0.17	0.04	0.54	0.25	0.20
S7	73.47 ± 8.57	34.85	1.76	0.17	0.04	0.55	0.27	0.20
S8	106.16 ± 10.30	49.73	1.88	0.24	0.06	0.79	0.36	0.29
S9	84.95 ± 9.22	39.98	1.11	0.20	0.05	0.63	0.30	0.23
S10	90.78 ± 9.53	42.92	1.67	0.21	0.05	0.68	0.31	0.25
S11	98.51 ± 9.93	46.09	0.50	0.23	0.06	0.73	0.33	0.27
S12	65.90 ± 8.12	31.20	1.53	0.15	0.04	0.50	0.22	0.18
S13	78.89 ± 8.88	37.97	1.49	0.19	0.05	0.60	0.26	0.21
S14	75.32 ± 8.68	35.76	1.67	0.18	0.04	0.57	0.25	0.20
S15	109.09 ± 10.44	51.67	2.09	0.25	0.06	0.81	0.40	0.29
S16	105.80 ± 10.29	49.29	1.60	0.24	0.06	0.78	0.36	0.29
S17	94.88 ± 9.74	44.69	1.83	0.22	0.05	0.70	0.33	0.26
S18	100.47 ± 10.02	47.47	1.88	0.23	0.06	0.75	0.35	0.27
S19	103.77 ± 10.19	49.11	1.58	0.24	0.06	0.78	0.35	0.28
S20	72.54 ± 8.52	34.06	1.92	0.17	0.04	0.54	0.24	0.20
S21	68.16 ± 8.26	32.01	1.10	0.16	0.04	0.51	0.22	0.18
S22	84.99 ± 9.22	39.51	1.86	0.19	0.05	0.63	0.28	0.23
S23	87.01 ± 9.33	41.17	1.64	0.20	0.05	0.65	0.30	0.23
S24	96.84 ± 9.84	45.58	1.30	0.22	0.06	0.72	0.34	0.26
S25	86.75 ± 9.31	40.58	1.38	0.20	0.05	0.64	0.29	0.23
S26	64.93 ± 8.06	31.07	0.82	0.15	0.04	0.49	0.22	0.18
S27	100.02 ± 10.00	47.25	0.88	0.23	0.06	0.75	0.34	0.27
S28	102.25 ± 10.11	47.92	2.00	0.24	0.06	0.76	0.34	0.28
S29	81.48 ± 9.03	38.25	1.85	0.19	0.05	0.61	0.27	0.22
S30	79.75 ± 8.93	37.81	0.94	0.19	0.05	0.60	0.27	0.22
S31	79.47 ± 8.91	37.26	1.45	0.18	0.05	0.59	0.27	0.21
S32	85.91 ± 9.27	40.65	1.17	0.20	0.05	0.64	0.29	0.23
S33	87.95 ± 9.38	41.47	0.72	0.20	0.05	0.66	0.29	0.24
S34	68.52 ± 8.28	32.08	1.96	0.16	0.04	0.51	0.22	0.19
S35	85.38 ± 9.24	40.02	1.69	0.20	0.05	0.63	0.29	0.23
S36	88.86 ± 9.43	41.79	0.93	0.20	0.05	0.66	0.31	0.24
S37	95.68 ± 9.78	44.70	1.46	0.22	0.05	0.71	0.32	0.26
Average	85.97 ± 9.24	40.51	1.48	0.20	0.05	0.64	0.29	0.23
Global Limit [10]	370	55		1	1	1	1	1

The highest value of the gamma Index (Iɣ) was found in (S15) sample (Towers high-pressure behind the AL-Tuwaitha N.R.C.) region, which is equal to (0.81), while the lowest value of the activity

concentration index was found in (S2) sample (Taha mosque near rotated Salman) region, which is equal to (0.44), with an average value of (0.64).

CONCLUSIONS

1- The average of the specific activity of ^{238}U , ^{232}Th , ^{40}k and ^{137}CS for soil samples in the studied regions was lower than the value of the global limit which is equal to (35 Bq. kg^{-1}), (30 Bq. kg^{-1}), (400 Bq. kg^{-1}) and (14.8 Bq. kg^{-1}), respectively [10,14].

2- The values of Radium equivalent activity, absorbed gamma dose rate, indoor annual effective dose rate $(AEDE)_{in}$ and outdoor annual effective doses $(AEDE)_{out}$, gamma Index (I_γ) and the hazard indices (H_{in}) and (H_{ex}) for the soil samples in the studied regions were lower than the value of the global limit which is equal to (370 Bq. kg^{-1}), (55 nGy. h^{-1}), (1 mSv. y^{-1}), (1 mSv. y^{-1}), (1), (1) and (1), respectively [10].

3- The levels of natural radioactivity are confirming the absence of any unusual nuclear activities within the region during the last period.

REFERENCES

1. M.F. L'Annunziata, Radioactivity: Introduction and History, Elsevier, 2007.
2. R.E. Lapp and H.L. Andrews, nuclear radiation physics, Englewood Cliffs, 1956.
3. B. Smodis & *et al.*, Assessment of TENORM sources in Slovenia in naturally occurring radioactive material (NORM V), Proceedings of an international symposium, Posters, 2008.
4. V. Ramasamy & *et al.*, Evaluation of natural radionuclide content in river sediments and excess lifetime cancer risk due to gamma radioactivity, Research Journal of Environmental and Earth Sciences, 2009, 1(1), 6-10.
5. R.E. White, Principles and practice of soil science: the soil as a natural resource, John Wiley & Sons, 2013.
6. H. Taskin & *et al.*, Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli Turkey, Journal of environmental radioactivity, 2009, 100(1), 49-53.
7. P.E. Abiama & *et al.*, High background radiation investigated by gamma spectrometry of the soil in the southwestern region of Cameroon, Journal of environmental radioactivity, 2010, 101(9), 739-743.
8. R. Mehra, Use of Gamma Ray Spectroscopy Measurements for Assessment of the Average Effective Dose from the Analysis of ^{226}Ra, ^{232}Th, and ^{40}K in Soil Samples, Indoor and Built Environment, 2009, 18 (3), 270-275.
9. M. Belivermis & *et al.*, The effects of physicochemical properties on gamma emitting natural radionuclide levels in the soil profile of Istanbul, Environmental monitoring and assessment, 2010, 163 (1-4), 15-26.
10. (UNSCEAR) United Nations Scientific Committee on the Effect of Atomic Radiation, Sources and effects of ionizing radiation sources, (Annex B). United Nations Publications. 2000, 1, 84.

11. (IAEA) International Atomic Energy Agency, Guidelines for radioelement mapping using gamma ray spectrometry data. International Atomic Energy Agency Publication IAEA-TECDOC-1363, Vienna, Austria. 2003.
12. A. Kadum & *et al.* , Natural Radioactivity in Red Clay Brick Manufactured in Tlemcen-Algeria, Using Well-Shape NaI (Tl) Detector. Advances in Physics Theories and Applications. 2013, 25, 120-128.
13. A. Faanu & *et al.*, Natural radioactivity levels in soils, rocks and water at a mining concession of Perseus gold mine and surrounding towns in Central Region of Ghana. Springer Plus. 2016, 5 (1), 1.
14. (UNSCEAR) United Nations Scientific Committee on the Effect of Atomic Radiation, Report to the General Assembly. "Sources and effects of Ionizing Radiation", New York, 1993.

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