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Natural Radioactivity and Risk Assessment in Soil Samples of Tuzkhormato District Salahd in Governorate-Iraq

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Abstract: The specific activities of naturally occurring radioactive material (NORM) includes ^{238}U, ^{232}Th and ^{40}K in soil samples collected across the District Tuzkhormato of Salahdin Governorate-Iraq at 2016, have been measured by gamma spectroscopy using NaI(Tl) detector. The specific activity of ^{226}Ra in the soil ranged from 20.8Bq/kg to 353.9Bq/kg with mean 151.94Bq/kg, ^{214}pb ranged from 34Bq/kq to 99.3Bq/kg with mean 70.25Bq/kg and ^{214}Bi ranged from 4Bq/kg to 114.6Bq/kg with mean 42.37 Bq/kg. The specific activities of ^{238}U ranged from 32.63 to 127.36 with mean 88.26 Bq/kg, ^{228}Ac ranged from MDL to 170.6Bq/kg with mean 85.56Bq/kg and ^{40}K ranged from 60.9Bq/kg to 1202.1Bq/kg with mean 395.7Bq/kg. The average value of specific activities of present study, for ^{238}U, ^{232}Th and ^{40}K are higher than the world average value of 35Bq/kg, 30Bq/kg and 400Bq/kg respectively. Radium equivalent, absorbed gamma dose rate, annual effective dose equivalent, the external hazard index, internal hazard index andthe representative level index were calculated and comparable with other global radioactivity measurements and found to be safe for public and environment.
Keywords: Natural Radioactivity, Specific Activity, Soil, Radiation hazards, NaI(Tl) Detector.

1 Introduction

Radionuclides have been present always in every environment of the earth's surface. Only nuclides with half-lives comparable to the age of the earth or their corresponding decay products, existing in terrestrial materials, can still be found today on earth, e.g. ^{40}K, and the radionuclides from the Uranium and Thorium series [1]. These naturally occurring radioactive materials include radionuclides which belong to the uranium and thorium decay chains and natural radioactive potassium (^{40}K) are present in at least trace amounts in most geological materials in the earth's crust. They have long half-life and present at the beginning of the earth's formation. ^{238}U, ^{235}U and ^{232}Th are the most important primary origin natural radionuclide and also they give continuously secondary radionuclides which are radioactive and decay to their other products and it can be consider as radioactive decay chain. The first member of each series has a very long half-life and has a gas member also the final product of each series is a stable isotope of lead [2-3]. Gamma radiation arising from these radionuclides is the main source of natural background, external exposure to human beings [4-5].

There are some human activities which can enhance radioactivity from NORM indirectly, such as the use of building materials that contain elevated levels of activity concentration in building dwellings and workplace (commission European, 1999 [6].

The global effective dose rate of public exposure from soil with weighted mean activity concentrations of 30 Bq/kg, 35 Bq/kg, and 400 Bq/kg for ^{238}U, ^{232}Th, and ^{40}K respectively is 0.460 mSv/y [7].

The aim of this study is to determine the specific activities of ^{238}U, ^{232}Th and ^{40}K insurface soil of Tuzkhormato of Salahdin Governorate-Iraq. Also, the average radium equivalent activity (Raeq), the total absorbed dose rate (D), the external hazard index (Hex) and the annual effective dose equivalent (AEDE) that are related to the externalgamma dose rate have been estimated and compared with the recommended limits from UNSCEAR data [8].

2 Material and Methods

2.1 Collection and Preparation of Samples

A total of 15 surface soil samples were collected from some

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selected regions in Tuzkhormato of Salahdin Governorate, the study location is shown on Figure 1. Each soil sample was dried under the laboratory condition until constant weight was achieved. The samples were crushed, homogenized and sieved through 300 µmmesh.1kg of each samples packaged in a Marinelli beaker.The sealed Marinellibeaker were kept for one month before measurements in order to achieve the secular equilibrium for ^{238}U and ^{232}Th with their respective progenies [9-11].

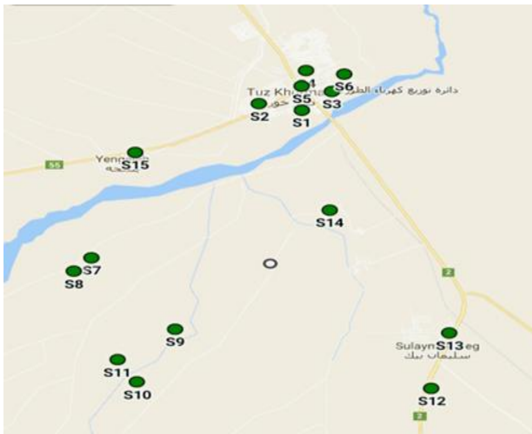

Figure 1. locations of the samples in region under study

2.2 Radioactivity Measurement

The specific activity of the natural radioactivity (^{226}Ra, ^{232}Th and ^{40}K) in soil samples were determined using NaI(Tl)3"x 3"coupled to PC-MCA (4096 channel)model (Canberra, USA),was used to measure the natural radioactivity in soil samples. Spectral data from the detector was analyzed by using computer software (GINE-2000).

The detector was surrounded by a lead shielding to reduce the background radiation.

Energy calibration and efficiency calibration of gamma spectrometer were carriedout using standard source (radionuclides mixed).

The background spectra distribution due to naturally occurring radionuclides in the environment around the detector, an emptyMarinelli beakerwas counted in the same manner as the samples.

The minimum detectable activity (MDA) was calculated for each radionuclide according to equation [7],

$$MDA = \frac{LD}{T \times Eff\,(E) \times P\gamma\,(E) \times M} \quad (1)$$

where LD is the detection limit calculated using the following equation [7]:

$$LD = LC + K\,\sigma D \quad (2)$$

where LC is the critical level below which no signal can be detected, σD is the standard deviation, and K is the error probability.

The activity concentration of^{238}U was evaluated by using the most abundant gamma rays from the^{226}Ra at energies 186keV,lead^{214}Pb at 351.92keV and ^{214}Bi at 609.31keVrespectively. Similarly, theactivity concentration of ^{232}Th was determined from^{228}Acat 338.4, 911.1keV. The activity concentration of^{40}K was determined from the energy of 1460.83keV.The expression used for the calculation of the activityconcentrations is given by the following equation inBq/kg [8,9]:

$$A_s\,Bq/kg = \frac{C_n}{\varepsilon \times I_\gamma \times T \times m} \quad (3)$$

where: A_s is the specific activity in Bq/kg, $C_n$is the net gamma counting rate (counts per second), I_γ is the gamma-ray emission probability at each energy, T is the time for counting (sec), m is the mass of sample (kg).

3 Results and Discussion

3.1 Activity Concentration in Soil Samples

The specific activity of ^{238}U series includes radionuclides ^{226}Ra, ^{214}Pb and^{214}Bi have been shown in Table 1.The specific activity of ^{226}Ra in the soil ranged from 20.8Bq/kg in sample S15 to 353.9Bq/kg in sample S9 with mean 151.94Bq/kg, ^{214}pb ranged from 34Bq/kqin sample S1to 99.3Bq/kg in sample S13 with mean 70.25Bq/kg and^{214}Bi ranged from 4Bq/kg in sample S2 to 114.6Bq/kg in sample S9 with mean 42.37 Bq/kg.

Table 1. Specific Activities (Bq/kg) of ^{226}Ra, ^{214}Pb and ^{214}Bi in Soil Samples from Tuzkhormato of Salahdin Governorate.

Location	^{226}Ra (Bq/kg)	^{214}Pb (Bq/kg)	^{214}Bi (Bq/kg)
S1	202.1	34.0	74.1
S2	36.3	85.0	4.0
S3	123.4	54.9	20.2
S4	119.8	75.3	52.5
S5	268.2	63.6	38.8
S6	190.1	67.9	31.8
S7	218.6	44.4	12.2
S8	120.1	45.3	39.8
S9	353.9	91.6	114.6
S10	30.7	58.4	8.8
S11	62.7	69.6	65.9
S12	229.9	86.1	66.1
S13	55.3	99.3	18.5
S14	247.2	83.9	44.4
S15	20.8	94.5	47.6
Mean	151.94	70.25	42.37

The specific activities of ^{238}U,^{228}Ac and ^{40}K in soil samples have been shown in

Table 2.,show that the specific activity of ^{238}U ranged from 32.63 in sample S10 to 127.36 in sample S12 with mean 88.26 Bq/kg,^{228}Ac ranged from MDAin sample S10 to 170.6Bq/kg in sample S8 with mean 85.56Bq/kg and ^{40}K ranged from 60.9Bq/kgin sample S6 to 1202.1 in sample S2Bq/kg with mean 395.7Bq/kg. The average value of specific activities of present study, for ^{238}U,^{232}Th and^{40}Karehigher than theworld average value of 35Bq/kg,30Bq/kg and 400Bq/kg respectively[12-13].The specific activity of ^{238}U, ^{228}Ac and ^{40}K (Bq/kg) in soil samples for various locations in the study area have been shown in Figure 2.

The mean specific activity of ^{238}U, ^{228}Ac and ^{40}K (Bq/kg) in soil for various locations in the study area have been shown in Figure 3.

Table 2. Specific Activities (Bq/kg) of ^{238}U, ^{228}Ac and ^{40}K in Soil Samples from Tuzkhormato of Salahdin Governorate.

Location	^{238}U (Bq/kg)	^{228}Ac (Bq/kg)	^{40}K (Bq/kg)
S1	103.36	80.3	286.9
S2	41.76	71.1	1202.1
S3	66.16	88.7	215.3
S4	82.53	93.6	586.0
S5	123.53	48.2	142.2
S6	96.6	50.1	60.9
S7	91.73	60.6	205.6
S8	68.4	170.6	546.8
S9	186.7	166.8	263.9
S10	32.63	MDA	708.1
S11	66.06	99.2	963.4
S12	127.36	75.6	396.6
S13	57.7	77.4	154.3
S14	125.16	112.8	129.8
S15	54.3	27.9	73.6
Mean	88.26	85.56	395.7

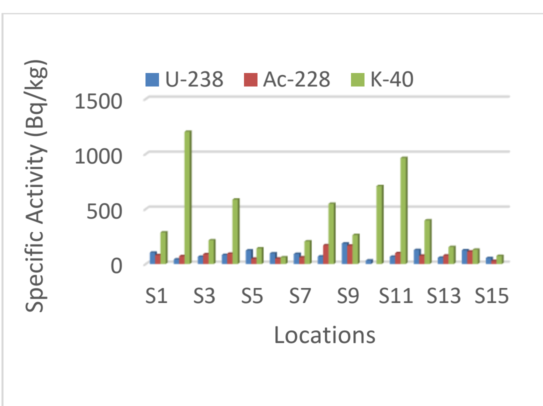

Figure 2. Specific activity of ^{238}U, ^{228}Ac and ^{40}K (Bq/kg) in soil samples for various Locations in the study area.

The variations in the specific activates in the soil of the various locations in Tuzkhormato of Salahdin Governorate depend on the geological and geographical conditions of the area and the extent of fertilizer applied to the agriculture regions [12].

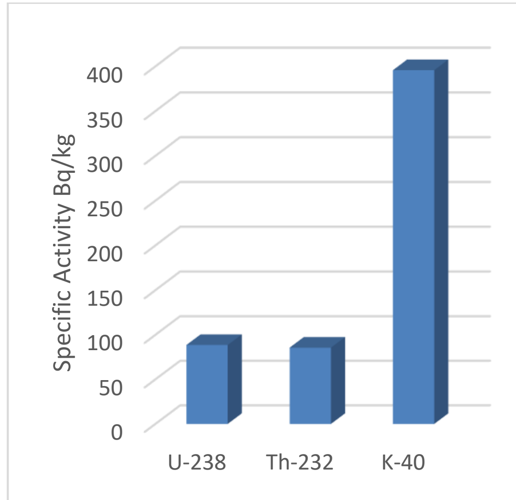

Figure 3. Mean Specific Activity of ^{226}Ra, ^{228}Ac and ^{40}K (Bq/kg) in soil for various Locations in the study area.

4 Radiological Parameters

4.1 Radium Equivalent Activities (Raeq)

The radium equivalent activity $Ra_{eq}$is given by the following equation in Bq/kg [14]

$$Ra_{eq}\ (Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad (4)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg respectively.

The formula is based on the assumption that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th and 481 Bq/kg of^{40}K produce the same gamma-ray dose rate [7]. A value of 370 Bq/kg corresponds to 1 mSv/y. The results ofradium equivalent activity are shown in Table 3 and graphically in Figure 4. The Raeq values ranged from 66.36 Bq/kg in sample (S15) to 612.74 Bq/kg in sample (S9) with mean298.98Bq/kg, The maximum value ofRaeq in soil samples is higher than the world average value of 370 Bq/kg [10,11].

4.2 Absorbed Gamma Dose Rate(D)

The absorbed gamma dose rates D ($nG \cdot h^{-1}$) in air at 1 m above the ground surface for radionuclides were calculated by the following equation,UNSCEAR, 2000[5].

$$D\ (nG \cdot h^{-1}) = 0.427A_{Ra} + 0.623A_{Th} + 0.043A_K \qquad (5)$$

Table 3 and Fig.5 show the results of absorbed gamma dose rate. It is observed that the absorbed dose rate ranges from

30 nGy/h in sample S15 to 278.1 nGy/hin Sample S9 with an average 137.32nG/h.The maximum and the mean values of absorbed dose rate is higher than the world average value of 55 nGy/h [14].

4.3 The Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent (AEDE) was calculated from the absorbed dose by applying the dose conversionfactor of 0.7 $Sv \cdot Gy^{-1}$ with an outdoor occupancy factor of 0.2 and 0.8 for indoor UNSCEAR, 2000 [7].

$$AEDE_{out}(mSv/y)=ADRA(nGy/h)\times 0.7\times 0.2\times 8760\ h/y \quad (6)$$

$$AEDE_{in}(mSv/y)=ADRA(nGy/h)\times 0.7\times 0.8\times 8760\ h/y \quad (7)$$

The annual effective dose equivalent (AEDE) indoor ranges from 0.15 mSv/y to 1.36 mSv/y with mean value0.67 mSv/y as shown in Table 4 and Figure 6.
The annual effective dose equivalent (AEDE) outdoor ranges from 0.0.04 mSv/yto 0.34 mSv/y with an average 0.16 mSv/y.The maximum and the mean valuesarelower than the world average value of 1mSv/y [15-17].

4.4 Hazard Index (H)

The external hazard index for soil samples is given by the following equation [18-19]

$$Hex = A_{Ra}/370\ Bq/kg + A_{Th}/259\ Bq/kg + A_K/4810\ Bq/kg \quad (8)$$

The values of outdoor radiation hazard index Hex ranged from 0.18 to 1.65 with a mean value of 0.8as shown in Table 4. whichall values are less than the critical value of unity, we can conclude that there is no health hazard from the soil of Tuzkhormatoregion.
The population internal exposure associated with the natural radionuclides in the soil, the internalhazard index (Hin) was calculated according to the following equation [14]:

$$Hin = A_{Ra}/185 + A_{Th}/259 + A_K/4810 < 1 \quad (9)$$

The values of indoor radiationhazard index (Hin) vary from 0.23 to 2.61 with a mean value of 1.2, the maximum and the mean values were higher than the criticalvalue of unity and are presented in Table 4 and Figure 6.

4.5 Representative Level Index

The representative level index, $I\gamma$ for soil samples were calculated by the following equation[1].

$$I\gamma = (1/150)C_{Ra} + (1/100)C_{Th} + (1/1500)C_K \quad (10)$$

$I\gamma$varies from 0.47 to 4.2 with a mean value of 2.09 as shown in Table 3.

Table 3. Radiological hazards (Ra_{eq},air-absorbed dose rates $I\gamma$), in soil from Tuzkhormato of Salahdin Governorate.

Location	Ra_{eq}(Bq/kg)	D ($nG \cdot h^{-1}$)	$I\gamma$
S 1	339.02	155.20	2.34
S 2	230.53	111.05	1.75
S 3	266.82	121.07	1.85
S 4	298.77	137.91	2.13
S 5	348.07	159.77	2.36
S 6	266.43	121.48	1.81
S 7	321.09	147.2	2.2
S 8	406.16	184.23	2.87
S 9	612.74	278.09	4.20
S 10	85.22	43.71	0.67
S 11	278.74	130.74	2.05
S 12	368.55	169.7	2.55
S 13	177.86	80.05	1.25
S 14	418.5	189.7	2.8625
S 15	66.36	30.0	0.47
Mean	298.98	137.32	2.08

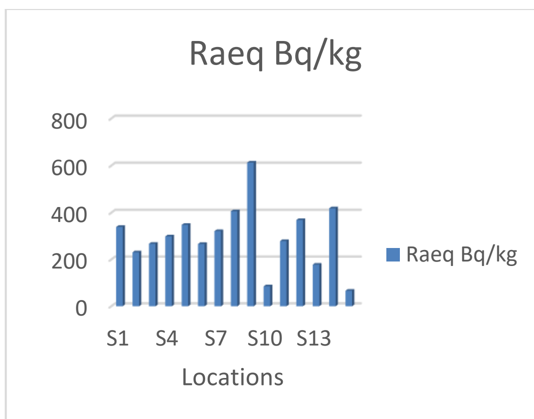

Figure 4. Radium Equivalent Activities (Bq/kg) for various Locations in the Study area.

5 Conclusion

The mean concentrations of ^{238}U and ^{228}Ac radionuclides in all analyzed soil samples were higher than the world average value of 35Bq/kg, 30Bq/kg respectively.
The mean concentration of ^{40}K radionuclide in all analyzed soil samples were within the world average value of 400 Bq/kg.
For uranium, thorium series and ^{40}K, the low levels of ^{226}Ra, ^{214}Pb,^{214}Bi, ^{228}Ac and ^{40}K radionuclides has been determined in samples S15, S1, S2, S10 and S6

respectively.The higher levels of ^{226}Ra, ^{214}Pb,^{214}Bi, ^{228}Ac and ^{40}K radionuclides has been determined in samples S9, S13, S9, S8 and S2 respectively, were higher than the world average.

The mean value of Ra_{eq} activity was found to be less than the world average value of 370 Bq/kg.

The mean values of annual effective dose and the external hazard indices were found to beless than the acceptable limit of unity.

The mean value of total absorbed dose rate was found to be higher than the world average value of 55 nGy/h.

This data may provide ageneral background level for the studied area and may also serve as a guideline for future measurement and assessment of possible radiological risks to human health in this region.

Table 4. Radiological hazards annual effective doses, H_{ex} and H_{in}.

Location	$AEDE_{out}$(mSv/y)	$AEDE_{in}$(mSv/y)	H_{ex} Bq/kg	H_{in}Bq/kg
S 1	0.19	0.76	0.92	1.46
S 2	0.13	0.54	0.62	0.72
S 3	0.15	0.59	0.72	1.05
S 4	0.17	0.67	0.81	1.13
S 5	0.17	0.78	0.94	1.66
S 6	0.15	0.59	0.72	1.23
S 7	0.18	0.72	0.87	1.46
S 8	0.23	0.90	1.1	1.42
S 9	0.34	1.36	1.65	2.61
S 10	0.05	0.21	0.23	0.31
S 11	0.16	0.64	0.75	0.92
S 12	0.21	0.83	0.99	1.62
S 13	0.1	0.39	0.48	0.63
S 14	0.23	0.93	1.13	1.8
S 15	0.04	0.15	0.18	0.23
Mean	0.16	0.67	0.80	1.2

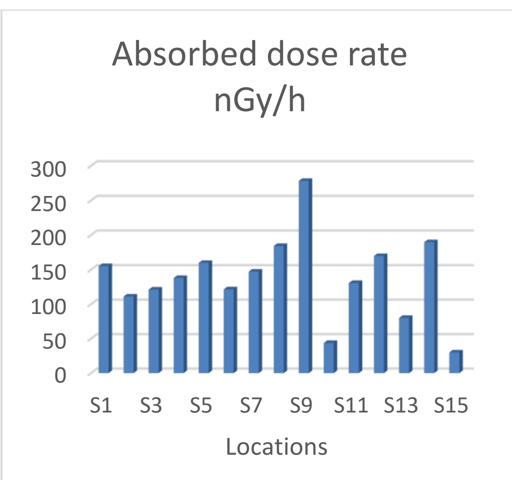

Figure 5. Absorbed dose rate (nGy/h) for various Locations in theStudy area.

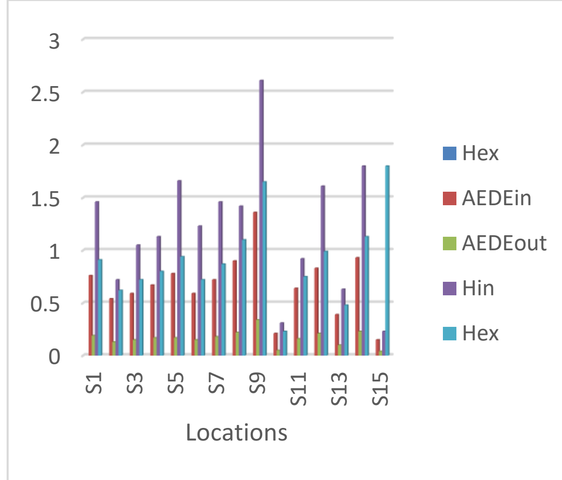

Figure 6. Annual effective dose, External hazard Index and internal hazard index for various Locations in the study area.

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