Natural Radioactivity Level in Agricultural Soil for ^{226}Ra, ^{232}Th and ^{40}K

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Abstract

In this study, natural radioactivity was measured for the following isotopes: radium ^{226}Ra, thorium ^{232}Th and potassium ^{40}K in agricultural soil in Oyoun al-Jawa in Qassim region, Saudi Arabia, at soil level and depth of 1.5m. The radiometric parameters associated with these isotopes, such as the absorbed dose and the radium equivalent, were also calculated. Also in the present study the radiological hazard were calculated and the current results were compared with the results of the natural radioactivity in different Regions in Saudi Arabia and to world average values.

Keyword: Soil, NaI Detector, Radioactivity concentration, Radium equivalent activities, Absorbed dose rate, Oyoun al-Jawa, Saudi Arabia

1-Introduction

Humans and organisms are constantly exposed to natural radiation from natural sources, such as cosmic rays, radiation from the Earth's crust, soil, and radon. It is also exposed to additional doses resulting from the scientific development in which radioisotopes have been used in many modern technologies in medicine, agriculture and industry, which can contain industrial radioactive sources. In this study, we will measure the natural radioactivity of Agricultural soil samples in Oyoun Al-Jawa in the Qassim region by measuring the level of natural radiation represented by measuring the radioactivity ,the absorbed dose, the radium equivalent for radium and the radiological hazard indices for ^{226}Ra and thorium ^{232}Th and potassium ^{40} K for the number of seven samples, including three on the surface of the soil and Four at a depth of 1.5m in different directions. The current results have also been compared to those measured in other regions of the world.

2- Sampling and preparation of samples

A total of seven Agricultural soil samples were collected from Ayyoun al-Jawa region in Qassim with an area of 6.5Km^2 from all directions (north-south-east and west) each sample is 1km away. The first four samples were on the surface and the other samples were deep of 1.5m as given in Table 1. The samples were placed in polyethylene bags for one month until the radiological balance was obtained and any traces of radon were eliminated in the sample and then dried by an oven also filtered until homogeneous samples were obtained and placed in special packages. The natural radioactivity concentration of the samples is measured using a gamma ray spectrometer (ɣ-ray spectroscopy) with a sodium iodide detector with thalium NaI (Tl).

Table (1): Description of samples

the sample code	Direction	Notes
S1	South	on the surface
S2	East	on the surface
S3	West	on the surface
S4	North	on the surface
S5	South	at a depth of 1.5m
S6	East	at a depth of 1.5m
S7	West	at a depth of 1.5m

3- Method

a. calculation of natural radioactivity Concentration

for Calculation of radium concentration ^{226}Ra the following energies were used:

Lead ^{214}pb at 351KeV and bismuth ^{214}Bi at 609.3Kev and 1120.3KeV and 1764.5KeV.

The mean value of the count rate for all gamma lines was calculated in Bq or c/s unit.

1- for Calculation the concentration of thorium ^{232}Th the following energies were used: ^{212}pb at 238.6KeV, and ^{228}Ac at 911.1KeV. The mean count value of all gamma lines in Bq or c/s unit was calculated.

2- for Calculation of ^{40}K Potassium concentration the count rate for single gamma at 1460 Kev energy was used.

The following equation was used for calculation of the natural radioactivity concentration A_s in (Bq / Kg) unit [1,2,3,4]:

$$A_s = \frac{C_s}{\epsilon P_r M_s} \qquad (1)$$

Where:

Cs The net count in the second unit (Bq), ε is the detector efficiency of the radioactive element, Pr is the abundance of the isotope and M_s is the weight of the sample in (Kg) unit [1,2,3,4].

In Table (2) gamma energy, abundance and gamma efficiency for the calculation of radium, thorium and calcium concentrations are given

Table (2): Gamma energy, abundance and gamma efficiency for the calculation of radium, thorium and calcium concentrations

Nuclide	Isotopes	Energy(KeV)	Measured Efficiency for gamma-ray peak (ε)	Abundance of gamma peak in radionuclide (P_r)
^{226}Ra	^{214}pb	351.9	37	0.21
	^{214}Bi	609.3	46	0.12
	^{214}Bi	1120.3	15	0.08
	^{214}Bi	1764.5	15.9	0.067
^{232}Th	^{228}Ac	911.10	29	0.09
	^{212}pb	238.60	44	0.25
^{40}K	^{40}K	1460.00	11	0.07

b- **Calculation of Absorbed Dose Rale (DR):**

Is the amount expressed in the outdoor dose of radiation emitted from the radioisotope concentration in the environment and is considered an important parameter for the assessment of health risks and is measured in (nGy/h) unit. Its value can be estimated using the following equation.

DR (nGy / h) = 0.427 A_{Ra} + 0.683A_{Th} + 0.043 A_K (2)

Where: A_{Ra}, A_{TH} and A_K are the concentrations of radium, thorium and potassium, respectively in (Bq / Kg) unit. [5].

c- Calculation of Radium Equivalent Activities (Raeq):

Radiation risk from gamma-ray isotopes is expressed by a number of parameters, the most important and the most widely used radium equivalent of radiation, which is the sum of the weighted total radiation from the three sources. It is based on the calculation that 370 Bq /Kg of radium ^{226}Ra, Bq /Kg 259 of thorium ^{232}Th, 481 Bq /Kg of potassium ^{40}K gives the same rates of gamma ray dose and is measured in Bq /Kg unit and can be estimated by the following relationship:

$$R_{eaq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \qquad (3)$$

The radium equivalent should not exceed 370 Bq / Kg, which is determined by the International Atomic Energy Agency (IAEA) [6,7].

d- Hazard Index

The external hazard index for samples under study is given by the following equation [8]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (4)$$

Where A is the natural radioactivity concentration A_s in (Bq / Kg) unit

To estimate the population internal exposure associated with the natural radio nuclides in the soil the internal hazard index (H_{in}) was calculated by the following equation [9]:

$$H_{ex} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (5)$$

e- Representative Level Index

The radiation hazards due to radioactive nuclides were assessed by an other idex called representative level index (I_r) and is calculated by the following equation:

$$H_{ex} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \qquad (6)$$

4-Results

Table (3): Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K

Samples	Concentration (Bq/Kg)			Average of Concentration (Bq/Kg)
	^{226}Ra	^{232}Th	^{40}K	
S_1	0.68	10.82	44.36	18.62
S_2	1.24	11.9	121.06	44.73
S_3	1.22	9.81	20.75	10.59
S_4	0.08	7.43	64.09	23.87
S_5	0.26	12.91	138.31	50.49
S_6	5.39	14.65	86.62	35.55
S_7	0.316	8.56	24.20	11.02

Table (4): Absorbed Dose Rale (DR) of ^{226}Ra, ^{232}Th and ^{40}K

Samples	**Absorbed Dose Rale (DR)** (nGy/h)			
	^{226}Ra	^{232}Th	^{40}K	Average
S_1	0.29	6.74	1.9	2.98
S_2	0.52	7.41	5.2	4.37
S_3	0.52	6.11	0.89	2.51
S_4	0.03	4.62	2.75	2.46
S_5	0.11	8.04	5.94	4.69
S_6	2.3	9.13	3.72	5.05
S_7	0.13	5.33	1.04	2.16

Table (5): Radium Equivalent Activities (Raeq) of ^{226}Ra, ^{232}Th and ^{40}K

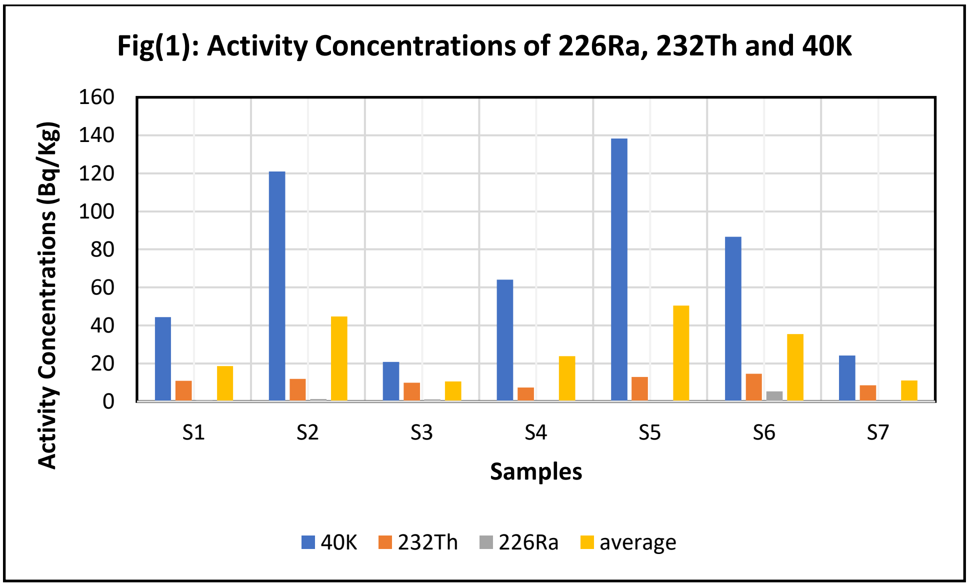
Samples	Radium Equivalent Activities			
	^{226}Ra	^{232}Th	^{40}K	Average
S_1	0.68	15.47	3.42	6.52
S_2	1.24	17.02	9.32	9.19
S_3	1.22	14.03	1.60	5.61
S_4	0.08	10.62	4.93	5.21
S_5	0.26	18.46	10.65	9.79
S_6	5.39	20.94	6.67	10.99
S_7	0.32	12.24	1.86	4.81

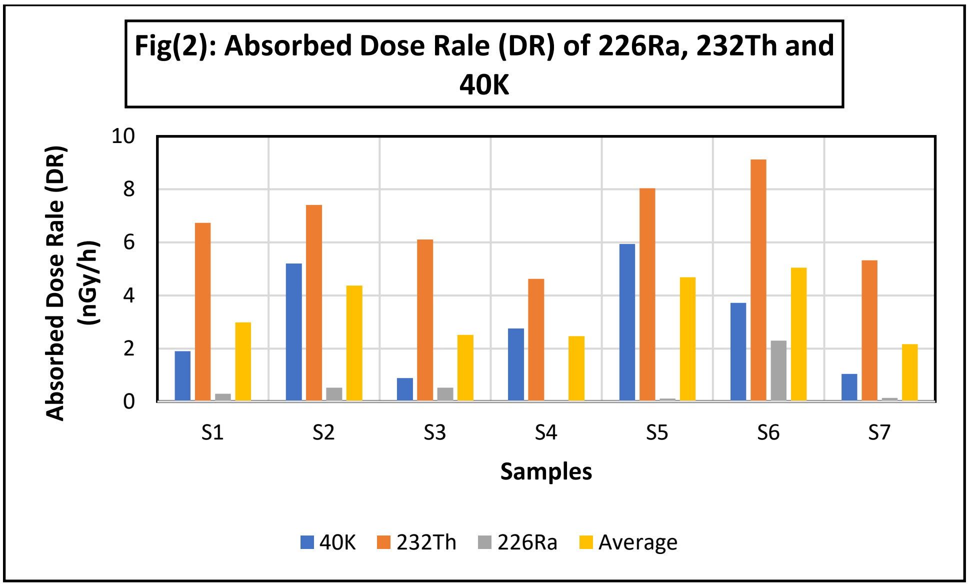
Table (6): Radiological Hazard

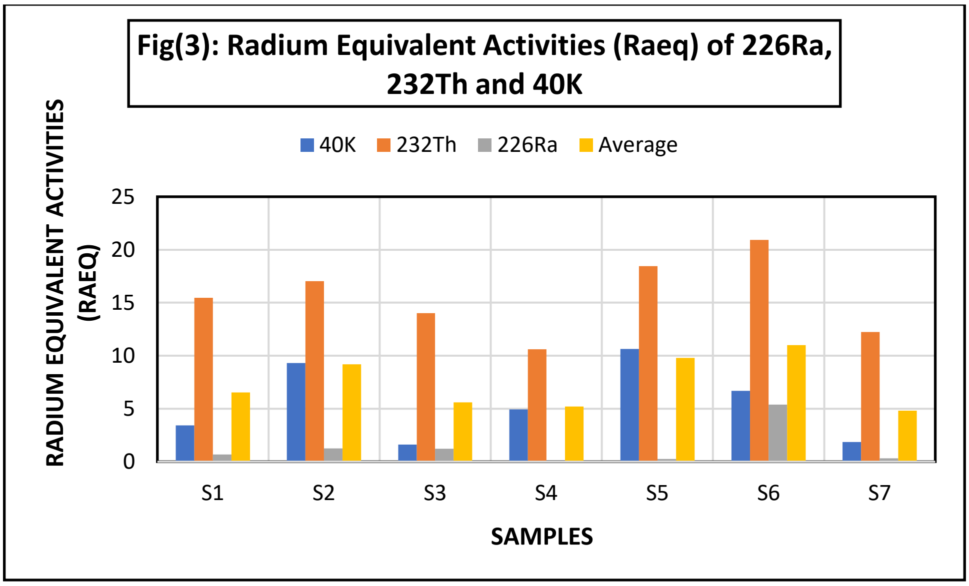
External Hazard index (H_{ex})	Internal Hazard index (H_{in})	Representative Level Index (I_r)
0.053	**0.055**	**0.14**
0.074	0.078	0.21
0.045	0.049	0.12
0.042	0.042	0.12
0.079	0080	0.22
0.089	0.104	0.24
0.039	0.04	0.10

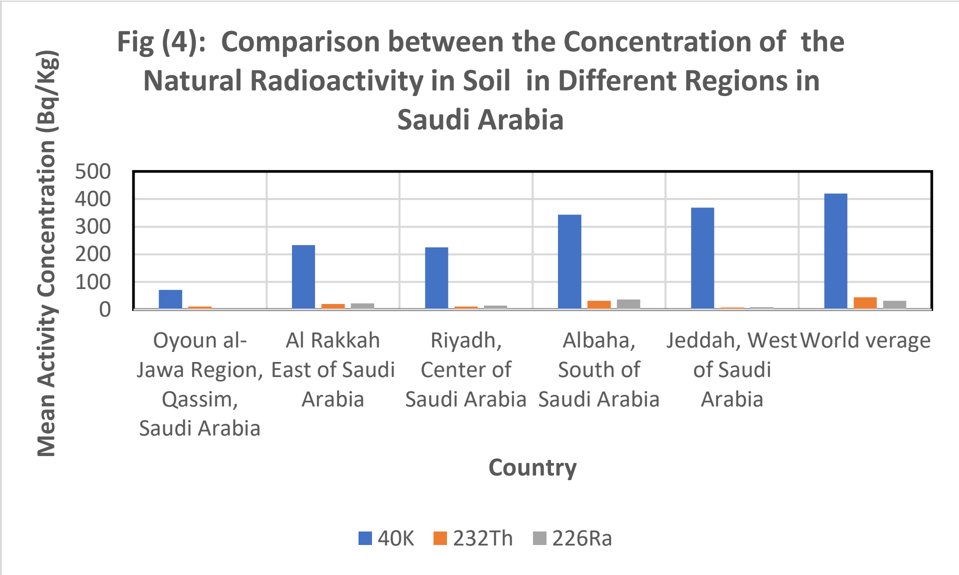
Table (7): Comparison between the Concentration of the Natural Radioactivity in Soil in Different Regions in Saudi Arabia

Country	Mean Activity Concentration (Bq/Kg)			References
	^{40}K	^{232}Th	^{226}Ra	
Oyoun al-Jawa Region, Qassim, Saudi Arabia	71.34	10.86	1.31	Present Study
Al Rakkah East of Saudi Arabia	233	20	23	10
Riyadh, Center of Saudi Arabia	225	11	14.5	11
Albaha, South of Saudi Arabia	343	32	37	12
Jeddah, West of Saudi Arabia	369	7.4	9.3	13
World verage	420	45	32	5




Fig(2): Absorbed Dose Rale (DR) of 226Ra, 232Th and 40K
Absorbed Dose Rale (DR) (nGy/h)
10
8
6
4
2
0
S1
S2
S3
S4
S5
S6
S7
Samples
40K
232Th
226Ra
Average


Fig(3): Radium Equivalent Activities (Raeq) of 226Ra, 232Th and 40K
40K
232Th
226Ra
Average
RADIUM EQUIVALENT ACTIVITIES (RAEQ)
25
20
15
10
5
0
S1
S2
S3
S4
S5
S6
S7
SAMPLES



Conclusion

It is very important to determine the radiation background for some agricultural regions in order to know the amount of natural radiation that may be transmitted to humans through food and may affect its health. Therefore, in this study, the soil of Oyoun al-Jawa Region Qassim, Saudi Arabia was chosen as an agricultural area.

We note that the ^{226}Ra concentration in the soil of Oyoun al-Jawa Region, Qassim, Saudi Arabia is very low compared to other regions in the Kingdom of Saudi Arabia such as Riyadh, Jeddah and Al-Baha, and it is considered an advantage of the soil of Oyoun al-Jawa Region, Qassim, Saudi Arabia where the activity concentration of radium ^{226}Ra reached 1.39Bq/Kg. Also, it was observed that the activity concentration of ^{232}Th and ^{40}K is low compared to other regions in Saudi Arabia and to world average values. Also the radiological hazard is calculated using the external and internal and representative level indices. The values of these indices were found to be less than the acceptable limit of unity. Therefore the area under study is with in the zone of the normal radiation level.

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