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Measurement of Radioactivity in Soil Samples for Selected Regions in Thi-Qar Governorate-Iraq

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Abstract: In the present work, we have been specific activity concentrations in five soil samples for selected regions in Thi-Qar governorate by using high purity germanium (HPGe) detector. The results indicated that, the specific activity, for ^{238}U was ranged from (33.67±5.8 Bq/kg) in AL-refai region to (23.92±4.8 Bq/kg) in Suq-AL- shuyukh region, for ^{232}Th was ranged from (27.56±5.2 Bq/kg) in AL- refai region to (18.27±4.2 Bq/kg) in Suq-AL- shuyukh region, for ^{40}K was ranged from (376.32±19.3 Bq/kg) in AL- refai region to (236.84±15.3 Bq/kg) in Suq-AL- shuyukh region, and for ^{137}Cs was ranged from (4.2±2.0 Bq/kg) in AL-refai region to (B.D.L) in (Suq-AL-shuyukh),[AL-nasiriyah (Sayed dakhil)] and (AL- hmmar) regions, respectively, with an average values of (29.2±5.1 Bq/kg) , (22.7±4.1 Bq/kg), (304.6±69.1 Bq/kg) and (3.15±1.05 Bq/kg), for ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs, respectively. In order to asses the radiological hazards of the radioactivity in soil, radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose equivalent, external annual effective dose, activity concentration index and both (external and internal) hazard indicies have been determined, and were found to be less than the allowed values given by (UNSCEAR reports).

Keywords: (HPGe) detector, soil, specific activity, radionuclides, hazards indicies, Thi-Qar governorate**.**

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], Gamma radiation emitted from naturally occurring radioisotopes, such as K-40 and the radionuclides from the Th-232 and U-238 series and their decay products (also called terrestrial background radiation), which exist as trace levels in all ground formations, represents the main external source of irradiation to the human body [2,3].

External exposure to radiation arises from natural and man-made radioactivity. Natural background radiation exposure is mainly caused by primordial radioactivity and cosmic radiation. Primordial radioactivity is mainly due to the presence of Uranium and Thorium series radionuclides and ^{40}K in the earth's crust. Cosmic radiation comes through the earth's atmosphere, from the sun and galaxies. The primary cosmic radiation interacts with the atmospheric matter and produces cosmogenic radionuclides also known as secondary cosmic radiation [4-6].

Thi-Qar governorate situated in the south east of Iraq, and it is lies in the heart of Iraqi's marshland areas. It is bordered by Wassit governorate to the north, Al-Qadissiya governorate to the northwest, Al-Muthanna governorate to the west, Basrah governorate to the south, and Missan governorate to the northeast . Its largest city is Al-Nasiriyah, with location of latitude (30.33º-32.20º N), and longitude (45.37º -47.12º E). It is located about (4-9 m) above the sea level, with a total area of about (12900 km^2) [7].

The aim of the present work is to determine the specific activity concentrations of (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs), and the associated radiation hazards such as radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose equivalents, external annual effective dose, activity concentration index, internal and external hazard indicies in surface soil samples for some selected regions in Thi-Qar governorate by using high

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purity germanium (HPGe) detector.

2 Materials and Methods

2.1 Collection and Preparation of the samples

Surface soil samples (0-5 cm) were taken from different locations in Thi-Qar governorate. The samples were crushed to small pieces then to fine powder by using electrical mill, then (1 kg) of about(300 µm) grain size of the samples were obtained by using special sieves (mesh).The samples were dried at (60 °C) for 2 hours and they were packaged in a (1 litter) Marinelli beaker, the sealed Marinelli beaker were kept for one month before measurements in order to achieve secular equilibrium for ^{238}U and ^{232}Th with their respective progenies [8,9].

2.2 High Purity Germanium (HPGe) Detector

In the present study, (HPGe) detector (CANBERA-model 7229N, USA) with an efficiency of 40% and energy resolution of (2.6 keV) at energy of (1332.6 keV) for ^{60}Co was used. The (HPGe) detector is kept cold by immersing it in a liquid-nitrogen vessel at (-196 ˚C) to reduce the leakage current to acceptable levels. The detector is surrounded by lead shield of about 10 cm in thickness in order to reduce the background radiation.

2.3 Energy Calibration

An essential requirement for the measurement of gamma emitter is the exact identity of photo peaks present in a spectrum produced by the detector system. The energy calibration of germanium detector system was made by measuring the standard sources of known radionuclide with well-defined energies with the energy of interest. The Energy calibration source should be counted long enough to produce well-defined photo peaks.

The energy calibration was performed by using a standard source of 1 litter capacity of Marinelli beaker of Europium (^{152}Eu), which has been prepared in this work with energies (121.8, 244.7, 344.3, 411.1, 444.6, 778.9, 964.0, 1085.8, 1112.0 and 1408.0 keV), as shown in Figure (1) .

$$Ra_{eq}(Bq/kg)=A_U+1.43A_{Th}+0.077A_K \quad (2)$$

Where, AU, A_{Th} and A_K are the specific activity concentrations of ^{238}U,^{232}Th and ^{40}K in (Bq/kg) respectively.

2.4 Specific activity concentrations of radionuclides

The specific activity concentrations of radionuclides in soil samples were obtained by using the equation [10]:

$$A=(Net\ \ Area-B.G)/M\times I_\gamma(E_\gamma)\times eff\times T \quad \ldots\ldots(1)$$

where:

B.G: Background activity.

A: The specific activity concentration of radionuclides measured in (Bq/kg).

M: mass of the soil sample (kg).

eff: The efficiency of the detectors at energy E_γ.

$I_\gamma(E_\gamma)$: is the abundance at energy E_γ.

T: The time of measurement which was equal to (7200 s).

2.4 Gamma Radiation Parameters (Radiation hazard indicies)

2.4.1 Radium Equivalent Activity (Ra_{eq})

To represent the activity concentrations of ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index is called radium equivalent activity (Ra_{eq}) which is used to ensure the uniformity in the distribution of natural radionuclides ^{238}U, ^{232}Th and ^{40}K and is it given by the expression [11,12]:

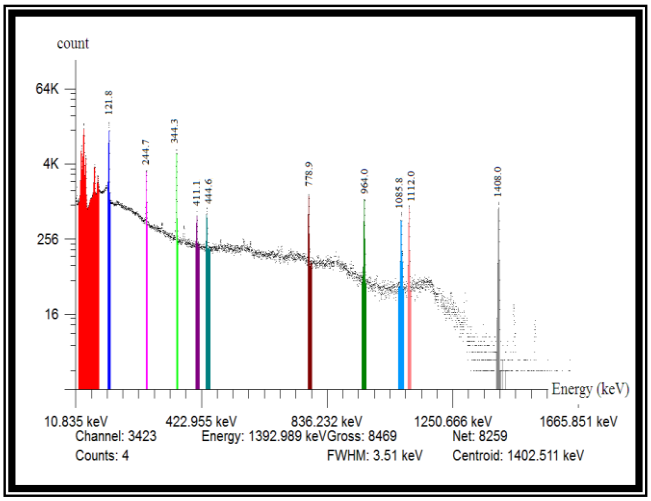

Figure (1) ^{152}Eu spectrum of the prepared standard source.

2.4.2 Absorbed Gamma Dose Rate (D_γ)

Outdoor air absorbed gamma dose rate (D_γ) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface was determined from the specific activities of A_U, A_{Th} and A_K for ^{238}U, ^{232}Th and ^{40}K respectively in (Bq/kg) units using the following relation [13]:

$$D_\gamma\ (nGy/h) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \quad (3)$$

2.4.3 Annual Effective Dose Equivalent

The estimated annual effective dose equivalent received by humans was determined using a conversion factor of (0.7

Sv/Gy), which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20 % and 80 % for indoors by using the following relations [14,15]:

$$(AED)_{in}(mSv/y)=D(nGy/h)\times10^{-6}\times8760\ h/y\times0.80\times0.7Sv/Gy \quad (4)$$

$$(AED)_{out}(mSv/y)=D_{\gamma}(nGy/h)\times10^{-6}\times8760h/y\times0.20\times0.7Sv/Gy \quad (5)$$

2.4.4 External Annual Effective Dose (EAD)

The external annual effective dose was determined by using the following relation [16]:

$$EAD=(0.92A_U+1.1A_{Th}+0.08A_K)\times(10^{-9}\,Gy/h)\times(0.7\ Sv/Gy)\times(24\times365)\ h/y\times0.8 \quad (6)$$

2.4.5 Activity gamma Index (I_γ)

The activity gamma index (I_γ) for soil samples was determined by using the following relation [16]:

$$I_\gamma=\frac{A_U}{150}+\frac{A_{Th}}{100}+\frac{A_K}{1500} \quad (7)$$

2.4.6 External (H_{ex}) and Internal (H_{in}) Hazard Indicies

Beretka and Mathew [17] defined two other indicies that represent internal and external radiation hazards. The external hazard index is obtained from (Ra_{eq}) expression through the supposition that its allowed maximum value (equal to unity) correspond to the upper limit of Ra_{eq} (370 Bq/kg) . The external hazard index (H_{ex}) can then be defined as:

$$H_{ex}=\frac{A_U}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \quad (8)$$

Internal exposure to radon ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) and it is given by the relation [18]:

$$H_{in}=\frac{A_U}{185}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \quad (9)$$

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

3 Results and Discussion

The results of the present work are summarized in Tables (1) and (2).

From Table (1), it can be noticed that:

The highest value of specific activity of (^{238}U) was found in (AL- refai) region which was equal to (33.67±5.8 Bq/kg), while the lowest value of specific activity of (^{238}U) was found in (Suq-AL- shuyukh) region which was equal to (23.92±4.8 Bq/kg) ,with an average value of (29.2±5.1 Bq/kg). The present results have shown that values of specific activity of (^{238}U) for the studied regions in Thi-Qar governorate were less than the recommended value of (35 Bq/kg) for the specific activity of (^{238}U) given by (UNSCEAR , 2000), [19].

The highest value of specific activity of (^{232}Th) was found in (AL- refai) region which was equal to (27.56±5.2 Bq/kg), while the lowest value of specific activity of (^{232}Th) was found in (Suq-AL- shuyukh) region which was equal to (18.27±4.2 Bq/kg), with an average value of (22.7±4.1 Bq/kg). The present results have shown that values of specific activity of (^{232}Th) for the studied regions in Thi-Qar governorate were less than the recommended value of (30 Bq/kg) for the specific activity of (^{232}Th) given by (UNSCEAR,2000).

The highest value of specific activity of (^{40}K) was found in (AL- refai) region which was equal to (376.32±19.3 Bq/kg), while the lowest value of specific activity of (^{40}K) was found in (Suq-AL- shuyukh) region which was equal to (236.84±15.3 Bq/kg), with an average value of (304.6±69.1 Bq/kg). The present results have shown that values of specific activity of (^{40}K) for the studied regions in Thi-Qar governorate were less than the recommended value of (400 Bq/kg) for the specific activity of (^{40}K) given by (UNSCEAR , 2000) , see Figure (2).

Table (1) Specific activity concentrations of (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs) , in soil samples for selected regions in Thi-Qar governorate.

Region	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)
AL- refai	33.67±5.8	27.56±5.2	376.32±19.3	4.2±2.0
AL-fajr	27.41±5.2	24.43±4.9	287.22±16.9	2.1±1.4
Suq-AL- shuyukh	23.92±4.8	18.27±4.2	236.84±15.3	B.D.L
AL-nasiriyah (Sayed dakhil)	29.64±5.4	20.32±4.5	265.07±16.2	B.D.L
AL- hammar	31.32±5.5	22.86±4.7	357.50±18.9	B.D.L
Average	**29.2±5.1**	**22.7±4.1**	**304.6±69.1**	**3.15±1.05**
Global limit [UNSCEAR, 2000]	**35**	**30**	**400**	**14.8** [United Nations Scientific, 1993]

B.D.L: below detection limit

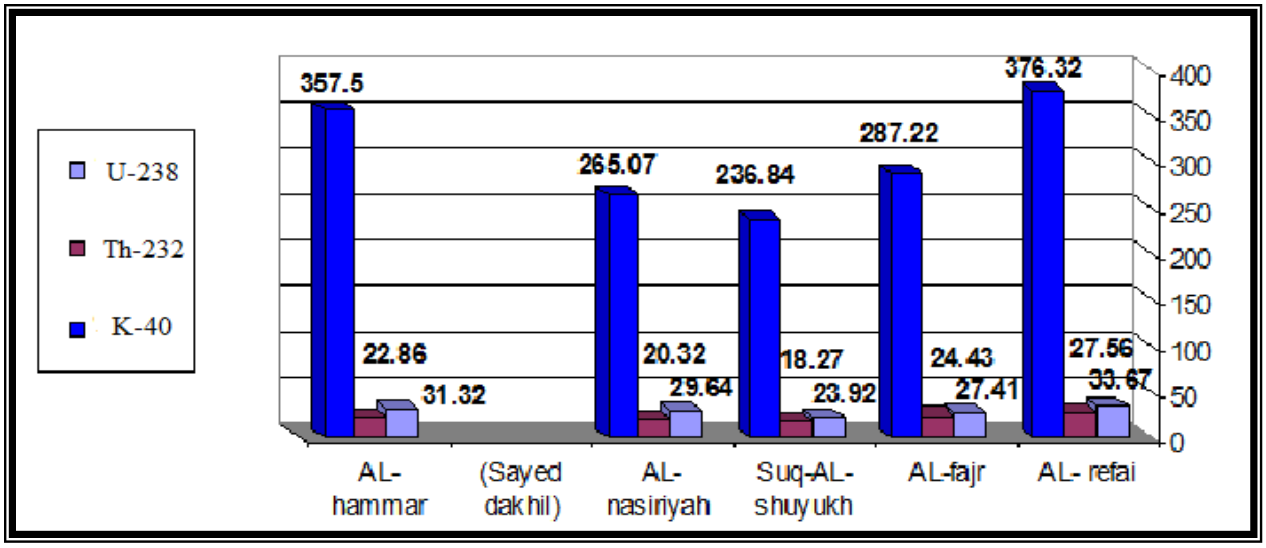

Figure (2) specific activity of (^{238}U, ^{232}Th and ^{40}K) for the studied regions in Thi-Qar governorate.

The highest value of specific activity of (^{137}Cs) was found in (AL- refai) region which was equal to (4.2±2.0 Bq/kg) , while the lowest value of specific activity of (^{137}Cs) was found in (Suq-AL- shuyukh), [AL-nasiriyah (Sayed dakhil)] and (AL-hammar) regions respectively which were (B.D.L) ,with an average value of (3.15±1.05 Bq/kg). The present results shown that values of specific activity of (^{137}Cs) for the studied regions in Thi-Qar governorate were less than the recommended value of (14.8 Bq/kg) for the specific activity of (^{137}Cs) given by (United Nations Scientific, 1993).

From Table (2), it can be noticed that:

The highest value of radium equivalent activity (Ra_{eq}) was found in (AL- refai) region which was equal to (102.06 Bq/kg), while the lowest value of radium equivalent activity was found in (Suq-AL- shuyukh) region which was equal to (68.28 Bq/kg) ,with an average value of (85.09±9.3 Bq/kg). The present results have shown that values of radium equivalent activity for the studied regions in Thi-Qar governorate were less than the recommended value of (370 Bq/kg) for the radium equivalent activity given by (UNSCEAR , 2000).

Table (2) Radium equivalent activity (Ra_{eq}) , absorbed gamma dose rate (D_γ), annual effective dose equivalents (AED) $_{in}$ and (AED) $_{out}$, external annual effective dose (EAD), activity concentration index (I_γ) , internal hazard index (H_{in}) and external hazard index (H_{ex}) in soil samples for selected regions in Thi-Qar governorate

region	Ra_{eq} (Bq/kg)	D_γ (nGy/h)	Annual effective dose equivalent (mSv/y)		EAD (mSv/y)	I_γ	Hazard index	
			Indoor (AED) $_{in}$	Outdoor (AED) $_{out}$			H_{in}	H_{ex}
AL- refai	102.06	47.89	0.235	0.059	0.448	0.751	0.367	0.276
AL-fajr	84.46	39.39	0.193	0.048	0.368	0.619	0.302	0.228
Suq-AL- shuyukh	68.28	31.96	0.157	0.039	0.299	0.500	0.249	0.184
AL- nasiriyah (Sayed dakhil)	79.11	37.02	0.181	0.045	0.347	0.578	0.294	0.214
AL- hammar	91.54	43.18	0.211	0.052	0.405	0.676	0.332	0.247
Average	**85.09±9.3**	**39.9±4.5**	**0.2±0.02**	**0.05±0.005**	**0.37±0.04**	**0.63±0.07**	**0.31±0.03**	**0.23±0.02**
Global limits [19]	**370**	**55**	**1**	**1**	**1.5**	**1**	**1**	**1**

The highest value of absorbed gamma dose rate (D_Y) was found in (AL- refai) region which was equal to (47.89 nGy/h) , while the lowest value of absorbed gamma dose rate was found in (Suq-AL- shuyukh) region which was equal to (31.96 nGy/h), with an average value of (39.9±4.5 nGy/h). The present results have shown that values of absorbed gamma dose rate for the studied regions in Thi-Qar governorate were less than the recommended value of (55 nGy/h) for the absorbed gamma dose rate given by (UNSCEAR , 2000).

The highest value of indoor annual effective dose equivalent $(AED)_{in}$ was found in (AL- refai) region which was equal to (0.235 mSv/y), while the lowest value of indoor annual effective dose equivalent was found in (Suq-AL- shuyukh) region which was equal to (0.157 mSv/y) ,with an average value of (0.2±0.02 mSv/y). The present results have shown that the indoor annual effective dose equivalent for the studied regions in Thi-Qar governorate were less than the recommended value of (1mSv/y) for the indoor annual effective dose equivalent given by (UNSCEAR, 2000).

The highest value of outdoor annual effective dose equivalent$(AED)_{out}$ was found in (AL- refai) region which was equal to (0.059 mSv/y) , while the lowest value of outdoor annual effective dose equivalent was found in (Suq-AL- shuyukh) region which was equal to (0.039 mSv/y), with an average value of (0.05±0.005 mSv/y). The present results have shown that values of outdoor annual effective dose equivalent for the studied regions in Thi-Qar governorate were less than the recommended value of (1 mSv/y) for the outdoor annual effective dose equivalent given by (UNSCEAR,2000).

The highest value of external annual effective dose (EAD) was found in (AL- refai) region which was equal to (0.448 mSv/y) , while the lowest value of external annual effective dose was found in (Suq-AL- shuyukh) region which was equal to (0.299 mSv/y) ,with an average value of (0.37±0.04 mSv/y). The present results have shown that values of external annual effective dose for the studied regions in Thi-Qar governorate were less than the recommended value of (1.5 mSv/y) for the external annual effective dose given by (UNSCEAR, 2000).

The highest value of activity concentration index (I_γ) was found in (AL- refai) region which was equal to (0.751) , while the lowest value of activity concentration index was found in (Suq-AL- shuyukh) region which was equal to (0.500) ,with an average value of (0.63±0.07). The present results have shown that values of activity concentration index for the studied regions in Thi-Qar governorate were less than the recommended value of (1) for the activity concentration index given by (UNSCEAR, 2000).

The highest value of internal hazard index(H_{in}) was found in (AL- refai) region which was equal to (0.367) , while the lowest value of internal hazard index was found in (Suq-AL- shuyukh) region which was equal to (0.249) ,with an average value of (0.31±0.03). The present results have shown that values of internal hazard index for the studied regions in Thi-Qar governorate were less than the recommended value of (1) for the internal hazard index given by (UNSCEAR, 2000).

The highest value of external hazard index (H_{ex}) was found in (AL- refai) region which was equal to (0.276) , while the lowest value of external hazard index was found in (Suq-AL- shuyukh) region which was equal to (0.184) , with an average value of (0.23±0.02). The present results have shown that values of external hazard index for the studied regions in Thi-Qar governorate were less than the recommended value of (1) for the external hazard index given by (UNSCEAR, 2000).

4 Conclusions

The results of the present work concerning values of the specific activity concentrations for (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs) and the parameters [radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose equivalent, external annual effective dose, the gamma index, internal and external hazard indicies] ,all were found to be lower than their corresponding allowed values given by (UNSCEAR ,1993 and 2000), and hence will pose relatively none series health risk.

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