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Natural Radioactivity in Soil Samples For Selected Regions in Baghdad Governorate

Nada Fathil Tawfiq [1*], Hazim Louis Mansour[2] Mahmood Salim Karim[2]
[1] *Department of Physics, College of Science, Al-Nahrain University, Iraq*
[2] *Department of Physics, College of Education, Al-Mustansiriyah University, Iraq*
E-mail : nadafathil@yahoo.com

Abstract -Specific activity concentrations in five soil samples of selected regions in Baghdad governorate were analyzed for the natural radioactivity of ^{226}Ra, ^{232}Th and ^{40}K using γ-ray spectroscopy system based on high-purity germanium detector with an efficiency of 40 %. The activity concentrations of the natural radionuclide's ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs were found to range from (20.20±4.4 Bq/kg) in AL-Zafraniya region to (9.21±3.0 Bq/kg) in AL-Shaab region, (16.40±4 Bq/kg) in AL-Zafraniya region to (7.23±2.7 Bq/kg) in AL-Shaab region, (160.32±12.6 Bq/kg) in AL-Zafraniya region to (B.D.L) in (AL-Taji) and (AL-Dora) regions, and (6.32±2.5 Bq/kg) in AL-Zafraniya region to (B.D.L) in (AL-Habibiya) and (AL-Dora) regions respectively. With an average values of (14.09±3.3 Bq/kg), (11.53±3.2 Bq/kg), (104.26±37.3 Bq/kg), (4.02±1.5 Bq/kg), for ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs, respectively. The radium equivalent activities (Raeq), absorbed gamma dose rate, (D□), annual effective dose rate (AED) $_{in}$ and (AED) $_{out}$ annual effective doses, external annual effective dose rate (EAD), the gamma Index (I□) and hazard indices(H_{in}) and (H_{ex}) associated with the natural radionuclides were calculated. The Raeq values of all soil samples are lower than the limit of 370 Bq kg^{-1}, equivalent to a γ-dose of 1.5 mSv yr^{-1}. The values of Hex and Hin are less than unity, all the obtained results were found to be less than the allowed limits given by (UNSCEAR, 2000).

Keywords- Natural radioactivity, γ-spectrometry, Radium-equivalent activities, External hazard index, Internal hazard index, annual effective dose rate (AED)

I. INTRODUCTION

It is well known that people are exposed to ionizing radiation from the radionuclides that are present in different types of natural sources. Human exposure to ionizing radiation is one of the scientific subjects that attract most public attention [1]. Since natural radiation is responsible for most of the total radiation exposure of the human population, knowledge of the dose received from natural radioactivity, is very important in the discussion of effect on health [2]. Natural occurring radionuclides materials is known to be present in rocks and soil [3]. The natural radionuclides of concern are mainly of ^{238}U, ^{232}Th or its progenies and ^{40}K [4]. The knowledge of radionuclide distribution levels in the environment is important for assessing the effect of radiation exposure due to both terrestrial and cosmogenic sources .Terrestrial radiation is due to radioactive nuclei present in varying amounts in, for example, soil, building materials, water and rocks. The transference of some radio nuclides from these sources to man was happened through food chain or inhalations. The particular importance of evaluation of gamma radiation dose from natural sources comes from largest contributor of natural radiation to the external dose of world population [5].

Baghdad governorate is the capital of Iraq and located on a vast plain bisected by the river Tigris. The Tigris splits Baghdad in half, with the eastern half being called Al-Risafa and the Western half known as Al-Karkh . The land on which the city is built is almost entirely flat and low-lying, being of alluvial origin due to the periodic large floods which have been occurred by the river, with location of latitude (31.30º-33.10º N), and longitude (44.32º-44.10º E). It is located about (32 m) above the sea level, with a total area of nearly (4555 km^2) [6].

The aim of the present work is to determine the specific activity concentrations of (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs), radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose rates, external annual effective dose, activity concentration index, internal and external hazard indices in surface soil samples in some selected regions in Baghdad governorate by using high purity germanium (HPGe) detector.

II. MATERIALS AND METHODS

A- Collection and Preparation of samples

Surface soil samples were taken from some selected regions in Baghdad governorate. The samples were crushed to small pieces then to fine powder by using electrical mill. (1 kg) of about (300 µm) grain size of surface soil samples were obtained using special sieves (mesh). The samples were dried at (60 °C) for 2 hours and they were packaged in a marinelli beaker, the sealed marinelli beaker were kept for one month before measurements in order to achieve the secular equilibrium for ^{238}U and ^{232}Th with their respective progenies [7].

B- High Purity Germanium (HPGe) Detector

In the present work (HPGe) detector (CANBERA-model 7229N, USA) with an efficiency of 40% and energy resolution (2.6 keV) at energy (1332.6 keV) for ^{60}Co. The high purity N-type semiconductor detector with physical characteristics of geometry closed-end coaxial, (3×3 inch) was used. The (HPGe) detector is kept cold by immersing it in a liquid-nitrogen vessel at (-196 $^{\circ}$C) to reduce the leakage current to acceptable levels. The detector is surrounded by lead shield of about 10 cm in thickness to reduce the background radiation.

C- 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 a well-defined energies with the energy of interest. The Energy calibration source should be counted long enough to produce a well-defined photo peaks. The energy calibration by using the standard source of a capacity of one litter marinelli beaker of Europium ($^{152}_{63}Eu$), 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), is shown in Figure (1).

D- Specific activity concentrations of radionuclides

The specific activity concentrations of radionuclides in soil samples were measured by the equation [8]:

A = (Net area under the photo peak at energy (E) – B.G) / (M × I(E) ×□(E) ×T) (1)

Where,

B.G: Background activity.

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

M: Mass of the soil sample (kg).

I (E): is the abundance at energy (E) (the number of gamma rays per disintegration of nuclide at energy (E).

□(E): The detector efficiency at energy (E) .

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

E- Gamma Radiation Parameters

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 given by the expression [9]:

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

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

2. Absorbed Gamma Dose Rate (D□)

Outdoor air gamma absorbed dose rate (D□) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface which can be computed from specific activities A_U, A_{Th} and A_K of ^{238}U, ^{232}Th and ^{40}K in (Bq/kg) respectively using the following relation [10]:

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

3. Annual Effective Dose Rate (AED)

The estimated annual effective dose equivalent received by a member was calculated by 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 [11]:

$(AED)_{in}$ (mSv/y)= D_γ (nGy/h)×10^{-6}×8760 h/y×0.80×0.7Sv/Gy (4)

$(AED)_{out}$ (mSv/y)= D_γ (nGy/h)×10^{-6}×8760 h/y×0.20×0.7Sv/Gy (5)

4. External Annual Dose (EAD)

The external annual effective dose was calculated by using the following equation [12]:

EAD= $(0.92A_U+1.1A_{Th}+0.08A_K)$ × (10^{-9} Gy/h) × (0.7 Sv/Gy) × (24×365) h/y×0.8 (6)

5. The Gamma Index (I_γ)

The gamma index (I_γ) for soil samples was calculated by using the following equation [12]:

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \qquad (7)$$

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

Beretka and Mathew [13] 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:

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

Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) as given below [14]:

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

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

III. RESULTS AND DISCUSSION

From Table I it can be noticed that the highest value of specific activity concentration of (^{238}U) was found in (AL-Zafraniya) region which was equal to (20.20±4.4 Bq/kg), while the lowest value of specific activity concentration of (^{238}U) was found in (AL-Shaab) region which was equal to (9.21±3.0 Bq/kg), with an average value of (14.09±3.3 Bq/kg) .The present results have shown that values of specific activity concentrations of (^{238}U) in the studied regions in Baghdad governorate were lower than the value of the specific activity concentration of (^{238}U) global limit which is equal to (35 Bq/kg) [15].

The highest value of specific activity concentration of (^{232}Th) was found in (AL-Zafraniya) region which was equal to (16.40±4 Bq/kg), while the lowest value of specific activity concentration of (^{232}Th) was found in (AL-Shaab) region which was equal to (7.23±2.7 Bq/kg), with an average value of (11.53±3.2 Bq/kg). The present results have shown that values of specific activity concentrations of (^{232}Th) in the studied regions in Baghdad governorate were lower than the value of the specific activity concentration of (^{232}Th) global limit which is equal to (30 Bq/kg) [15].

The highest value of specific activity concentration of (^{40}K) was found in (AL-Zafraniya) region which was equal to (160.32±12.6 Bq/kg), while the lowest specific activity concentration of (^{40}K) was found in (AL-Taji) and (AL-Dora) regions which were B.D.L, with an average value of (104.26±37.3 Bq/kg). The present results have shown that values of specific activity concentrations of (^{40}K) in the studied regions in Baghdad governorate were lower than the value of the specific activity concentration of (^{40}K) global limit which is equal to (400 Bq/kg) [15].

The highest value of specific activity concentration of (^{137}Cs) was found in (AL-Zafraniya) region which was equal to (6.32±2.5 Bq/kg), while the lowest value of specific activity concentration of (^{137}Cs) was found in (AL-Habibiya) and (AL-Dora) regions which were B.D.L, with an average value of (4.02±1.5 Bq/kg). The present results have shown that values of specific activity concentrations of (^{137}Cs) in the studied regions in Baghdad governorate were lower than the value of the specific activity concentration of (^{137}Cs) global limit which is equal to (14.8 Bq/kg) [15].

From Table II it can be noticed that the highest value of radium equivalent activity (Ra_{eq}) was found in

(AL-Zafraniya) region which was equal to (55.99 Bq/kg) , while the lowest value of radium equivalent activity was found in (AL-Shaab) region which was equal to (25.12 Bq/kg), with an average value of (35.40±9.1 Bq/kg). The present results have shown that values of radium equivalent activity in studied the regions in Baghdad governorate were lower than the value of the radium equivalent activity global limit which is equal to (370 Bq/kg) [15].

The highest value of absorbed gamma dose rate (D_{γ}) was found in (AL-Zafraniya) region which was equal to (25.92 nGy/h) , while the lowest value of absorbed gamma dose rate was found in (AL-Shaab) region which was equal to (11.64 nGy/h), with an average value of (16.08±4.11 nGy/h). The present results have shown that values of absorbed gamma dose rate in the studied regions in Baghdad governorate were lower than the value of the absorbed gamma dose rate global limit which is equal to (55 nGy/h) [15].

The highest value of indoor annual effective dose rate $(AED)_{in}$ was found in (AL-Zafraniya) region which was equal to (0.127 mSv/y) , while the lowest value of indoor annual effective dose rate was found in (AL-Shaab) region which was equal to (0.057 mSv/y), with an average value of (0.07±0.02 mSv/y) . The present results have shown that values of indoor annual effective dose rate in the studied regions in Baghdad governorate were lower than values of the indoor annual effective dose global limit which is equal to (1 mSv/y) [15].

The highest value of outdoor annual effective dose rate $(AED)_{out}$ was found in (AL-Zafraniya) region which was equal to (0.031 mSv/y) ,while the lowest value of outdoor annual effective dose rate was found in (AL-Shaab) region which was equal to (0.014 mSv/y), with an average value of (0.01±0.005 mSv/y) . The present results have shown that values of outdoor annual effective dose rate in the studied regions in Baghdad governorate were lower than the value of the outdoor annual effective dose rate global limit which is equal to (1 mSv/y) [15].

The highest value of external annual effective dose (EAD) was found in (AL-Zafraniya) region which was equal to (0.40 mSv/y) , while the lowest value of external annual effective dose was found in (AL-Shaab) region which was equal to (0.18 mSv/y), with an average value of (0.24±0.06 mSv/y). The present results have shown that values of the external annual effective dose in the studied regions in Baghdad governorate were lower than the value of the outdoor annual effective dose global limit which is equal to (1.5 mSv/y) [15].

The highest value of the gamma Index (I_{γ}) was found in (AL-Zafraniya) region which was equal to (0.322) , while the lowest value of activity concentration index was found in (AL-Shaab) region which was equal to (0.144), with an average value of (0.19±0.05). The present results have shown that values of activity concentration index in the studied regions in Baghdad governorate were lower than the value of the activity concentration index global limit which is equal to (1) [15].

The highest value of internal hazard index (H_{in}) was found in (AL-Zafraniya) region which was equal to (0.399) , while the lowest value of internal hazard index was found in (AL-Shaab) region which was equal to (0.178), with an average value of (0.25±0.07). The present results have shown that values of internal hazard index in the studied regions in Baghdad governorate were lower than the value of the internal hazard index global limit which is equal to unity [13].

The highest value of external hazard index (H_{ex}) was found in (AL-Zafraniya) region which was equal to (0.247) ,while the lowest value of external hazard index was found in (AL-Shaab) region which was equal to (0.110), with an average value of (0.15±0.03). The present results have shown that values of external hazard index in the studied regions in Baghdad governorate were lower than the value of the external hazard index global limit which is less than unity [13].

IV. CONCLUSIONS

The results of the present work concerning values of the specific activity concentrations of (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs), radium equivalent activity, indoor and outdoor annual effective dose rates, external annual effective dose, the gamma index, internal and external hazard indicies, all were found to be lower than their corresponding allowed limits.

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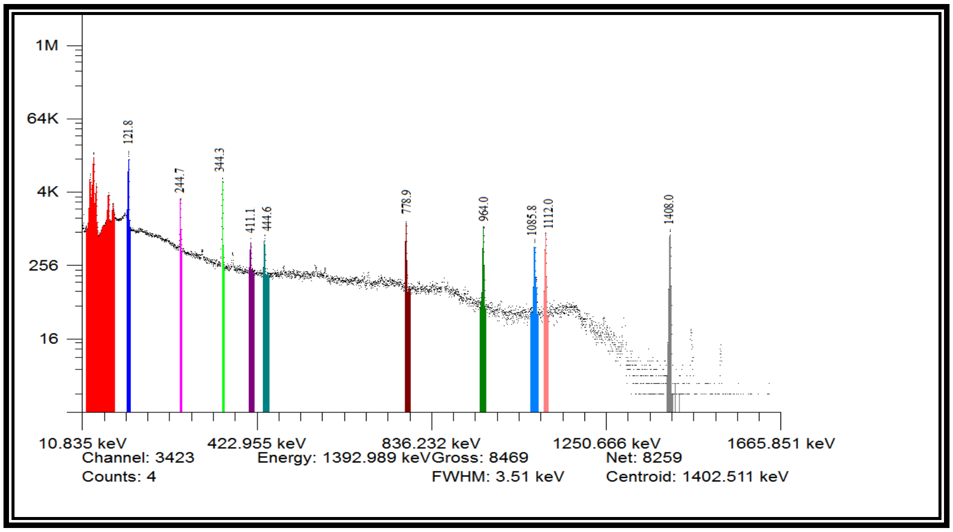

Figure (1) ^{152}Eu spectrum of the prepared standard source.

Table I

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

region	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)
AL-Shaab	9.21±3.0	7.23±2.7	72.43±8.5	2.31±1.5
AL-Habibiya	10.60±3.2	7.91±2.8	80.04±8.9	B.D.L
AL-Taji	14.12±3.7	11.43±3.3	B.D.L	3.43±1.8
AL-Dora	16.32±4.0	14.72±3.8	B.D.L	B.D.L
AL-Zafraniya	20.20±4.4	16.40±4.0	160.32±12.6	6.32±2.5
Average	14.09±3.3	11.53±3.2	104.26±37.3	4.02±1.5
Global limit [15]	35	30	400	14.8 [11]

B.D.L: Below Detection Limit

Table II

Radium equivalent activity (Ra_{eq}) , absorbed gamma dose rate (D□), annual effective dose rate $(AED)_{in}$ and $(AED)_{out}$ annual effective doses, external annual effective dose rate (EAD), the gamma Index (I□) and hazard indices(H_{in}) and (H_{ex}) for soil samples in selected regions in Baghdad governorate.

region	Ra_{eq} (Bq/kg)	D□ (nGy/h)	Annual effective dose rate (mSv/y)		EAD (mSv/y)	I□	Hazard index	
			Indoor $(AED)_{in}$	Outdoor $(AED)_{out}$			H_{in}	H_{ex}
AL-Shaab	25.12	11.64	0.057	0.014	0.18	0.144	0.178	0.110
AL-Habibiya	28.07	13.01	0.063	0.015	0.20	0.159	0.198	0.123
AL-Taji	30.46	13.42	0.065	0.016	0.19	0.158	0.208	0.126
AL-Dora	37.36	16.43	0.080	0.020	0.24	0.198	0.285	0.157
AL-Zafraniya	55.99	25.92	0.127	0.031	0.40	0.322	0.399	0.247
Average	35.40±9.1	16.08±4.11	0.07±0.02	0.01±0.005	0.24±0.06	0.19±0.05	0.25±0.07	0.15±0.03
Global limit [15]	370	55	1	1	1.5	1	1	1