Pollution, 3(1): 47-53, Winter 2017
DOI: 10.7508/pj.2017.01.006
Print ISSN 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

Evaluation of natural radioactivity of soil samples from different regions of Wassit governorate

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Received: 17 May 2016 Accepted: 3 Aug. 2016

ABSTRACT: The present paper measures natural radioactivity in different areas of Wassit governorate, using (HPGe) detector. Gamma spectrum analysis for each sample along with caululated specific activity show that the average concentrations of U-238, Th-232, and K-40 have been 19.420±4.7 Bq/kg, 18.487±5.05 Bq/kg, and 204.266±46.9 Bq/kg respectively, which is lower than the worldwide average value. While the average value of Radium equivalent, absorbed dose, indoor and outdoor annual effective dose, activity index, and internal and external hazard index for each sample have been found to be 85.182 Bq/kg, 39.962 nGy/h, 0.196 mSv/y, 0.049 mSv/y, 0.374, 0.313, 0.309, and 0.230 respectively, all of them are lower than the permissibility limit value.

Keyword: hazard indices, HPGe detector, natural radioactivity, radium equivalent, soil, Wassit governorate.

INTRODUCTION

The natural radioactive chains from ^{238}U, ^{235}U, and ^{232}Th produce a group of radionuclides with half-lives. Most of the radioisotopes are alpha emitters, so when they are ingested or inhaled, they contribute significantly to the radiation dose that people receive (Mireles et al., 2003). On the other hand, considering the fact that uranium and thorium are ever present in the soil, their gamma radiation causes external exposures to the consequently-absorbed doses (Colmenero et al., 2004).

The study of natural soil radioactivity (background radiation) is one of the most important topics, taught by researchers aligned with the subject of the importance of environmental impact on human health, especially if we take into account areas with high concentrations of natural radioactive isotopes due to their geological composition, where the focus is on natural chains of Uranium-238 and Thorium-232 in addition to Potassium-40, regarded as the most important factors to increase the radiation dose, absorbed by human, while the average global concentrations of these isotopes in the Earth's crust are up to 35Bq/kg, 30Bq/kg, and 400Bq/kg respectively (Abusini et al., 2008).

One of the most important natural isotopes is Potassium-40, making up to 0.012% of natural minerals with a lifespan of 1.28×10^9 year (Alsagii, 1999). Another isotope is Radon-222, one of the noble gases, colorless, tasteless, and scarcely toxic, resulting in radioactive decay of

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radium (Ra-226), which consists of Radium as a result of Uranium radioactive decay chain (Gordon, 2008).

Natural environmental radioactivity and the associated external exposure, as a result of gamma radiation, depend primarily on the geological and geographical conditions and appear at different levels in the soil samples of any region of the world. The specific levels of terrestrial environmental radiation are related to the composition of each lithologically-separated area, not to mention to the content of the rock from which the soil has originated. There are many types of soils, depending on their physical and chemical composition (UNSCEAR, 2000).

Human beings have always been exposed to natural radiations in their surroundings. Exposure to ionizing radiations from natural sources happens, as a result of naturally-occurring radioactive elements in the soil and rocks, the cosmic rays entering the earth's atmosphere from outer space, and the internal exposure from radioactive elements through food, water, and air. Hence assessment of gamma radiation dose from natural sources is of particular account as natural radiation contributes the most to the external dose of the world population (SOP, 1999).

The present work aims to determine the specific activity of ^{238}U, ^{232}Th, and ^{40}K, as well as radium-equivalent activity, rate of absorbed gamma dose, indoor and outdoor annual effective dose rates, external annual effective dose, activity concentration index, and internal and external hazard indices in surface soil samples at some selected regions in Wassit Governorate by means of High Purity Germanium (HPGe) detector.

EXPERIMENTAL PROCEDURE

Description of the study area

Wassit Governorate is located in eastern Iraq, at the border with Iran. The Baramadad border passing through Wassit connects the two countries. Wassit shares internal boundaries with the governorates of Diyala, Baghdad, Babil, Qadissiya, Thi-Qar, and Missan (Fig. 1). It is intersected by the Tigris River, along which runs a ribbon of irrigated farmland, giving way to a dry desert landscape to the northeast. Wassit has a dry, desert climate, with its temperature easily exceeding 40°C in summer. Rainfall is scarce and concentrated during winter months (Salim and Klis, 2010).

Fig. 1. Sketch map showing locations of the studied sites in Wassit governorate

Sample collection and preparation

Surface soil samples were taken from different locations in Wassit governorate. They were crushed to small pieces, then to fine powder by an electrical mill. Finally about 1 kg of the grain samples, 300 µm in size, was obtained, using special sieves (mesh). The samples got dried at 50°C for 2 h and were packaged in a 1-liter Marinelli beaker, which was sealed and kept for one month prior to the measurements in order to achieve the secular equilibrium for ^{238}U and ^{232}Th with their respective progenies.

Activity concentration

Since all the elements of radioactive chains are influential on late balance, it is possible to calculate the concentration of an element in the series in terms of another one's concentration. This has been effectiveness focus for a series of Uranium ^{238}U type and Radium ^{226}Ra. The nuclide Bismuth ^{214}Bi (1764 keV), as well as Thorium ^{232}Th series has been the focus of effectiveness of the radioactive nuclide Thallium ^{208}Tl (2614 keV), which represents the concentration of thorium ^{232}Th type, Afterwards, the concentration of Potassium ^{40}K type's radioactive nuclide (1460 keV) can calculated by Equation (1) (Dia et al., 2008).

$$A = \frac{NET}{\varepsilon * I_{\gamma} * m * t} \tag{1}$$

where

A: activity concentrations of the sample units Bq/kg

ε : Energy efficiency

m: mass of sample units kg

t: time measurement (7200 sec.).

High Purity Germanium (HPGe) detector

The present study uses an HPGe detector, the efficiency and energy resolution of which is 40% and 2.6 keV respectively at an energy rate of 1332.6 keV for ^{60}Co. What is more, the detector is high purity N-type semiconductor with physical characteristics of geometry closed-end coaxial, (3×3 inch).

The HPGe detector is kept cold through immersion into a liquid-nitrogen vessel at (-196°C) to reduce the leakage current to acceptable levels. It is surrounded by a lead shield, about 10 cm thick in order to reduce the background radiation.

Energy calibration

An essential step for measuring gamma emitter is to exactly identify photo peaks present in a spectrum, produced by the detector system. The energy calibration of germanium detector system has been done by measuring the standard sources of known radionuclide with well-defined energies. The Energy calibration source should be counted long enough to produce well-defined photo peaks.

The energy has been calibrated via the standard source of 1-liter marinelli beaker of Europium (^{152}Eu), which has been prepared in the present research with energies (121.8, 244.7, 344.3, 411.1, 444.6, 778.9, 964.0, 1085.8, 1112.0 and 1408.0 keV; Fig. 2).

Radium equivalent

Radium equivalent is calculated from Equation (2) (Dia et al., 2008).

$$Ra_{eq}(Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \tag{2}$$

where A_k, A_{Th}, A_{Ra} represent activity concentration of a series of Radium and a series of Thorium and Potassium, respectively. Equation (2) assumes that 10 Bq/kg of Radium and 7 Bq/kg of Thorium and 130 Bq/kg of Potassium produce an equal dose of radiation (Shawkat, 2000).

The rate of absorbed dose

The total rate of the absorbed dose in the air is calculated in terms of the concentrations of Radium, Thorium, and Potassium through Equation (3) (Shawkat, 2000).

$$D_{\gamma} = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{K} \tag{3}$$

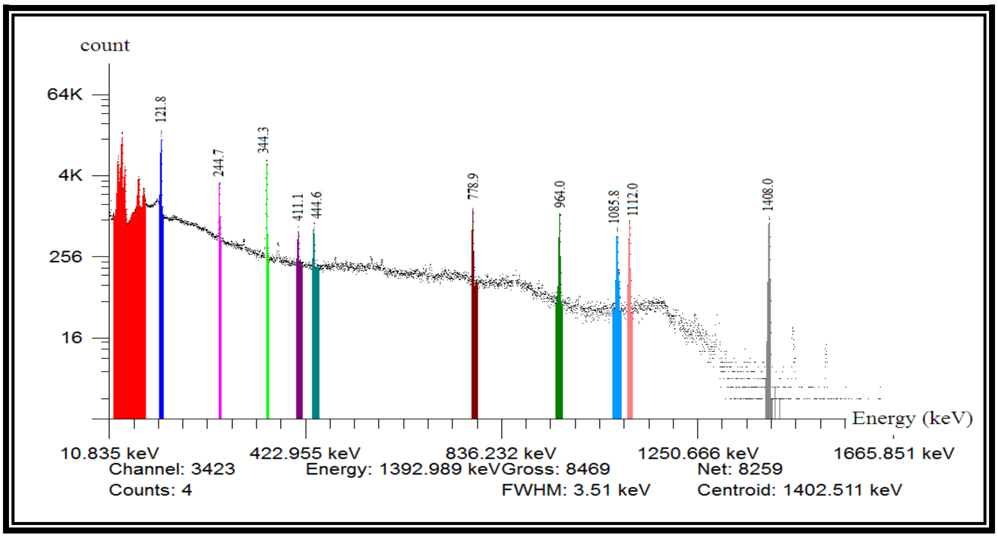

Fig. 2. ^{152}**Eu spectrum of the prepared standard source**

The annual effective dose

In order to calculate, the annual effective dose must take the following into consideration: first, the conversion factor of absorbed dose to effective dose and second, the internal occupation factor. Use the factor of 0.7Sv as a conversion factor from absorbed dose in the air to the annual effective received by the adult dose and put 0.8 as the internal occupation (which is the ratio of time spent at home) and 0.2 as the ratio of time spent outside. The annual effective dose is calculated as follows (El-Arabi, 2005).

$$E_{in}(mSv/y) = D\,(nGy.h^{-1}) \times 10^{-6} \times 8760(h/y) \times 0.80 \times 0.7(SvGy^{-1}) \quad (4)$$

$$E_{out}(mSv/y) = D\,(nGy.h^{-1}) \times 10^{-6} \times 8760(h/y) \times 0.20 \times 0.7(SvGy^{-1}) \quad (5)$$

where the 8760 refers to the number of hours a year. The global average annual effective dose is 0.48 mSv.

External hazard index

The external guide is a hazard assessment of natural gamma radiation risk and is calculated from Equation (6) (Al-Taher and Makhluf, 2010).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (6)$$

where this factor must be less than one; otherwise (being equal to or greater than one) it indicates the presence of radiation risk.

Gamma index (I_γ)

The activity index (I_γ) for soil samples has been calculated by Equation (7) (Al-Taher and Makhluf, 2010).

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

Internal hazard index

The internal exposure is caused by the inhalation of radon gas and its relevant examples which can be expressed in terms of the internal hazard index and calculated with Equation (8) (Arman, 2007).

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (8)$$

It should be added that this factor must be less than one so that it is placed within the allowable universally border.

RESULTS AND DISCUSSIONS

Table 1 summarizes the results of the present work from which it can be noticed that:

- The highest value of specific activity for ^{238}U was found in Al-Wahda region, being equal to 29.220 Bq/kg, while the lowest value of specific activity of ^{238}U was found in Zorbatya region, equal to 11.150 Bq/kg with an average value of 19.420±4.7 Bq/kg. The present results have shown that values of specific activity for ^{238}U in Wassit governorate were less than its recommended value (equal to 35 Bq/kg), given by UNSCEAR (2000).
- The highest value of specific activity of ^{232}Th was in Al-Hai region, with a value equal to 27.620 Bq/kg, while its lowest value belonged to Nuamaniya region, being equal to 11.350 Bq/kg, with an average value of 18.487±5.05 Bq/kg. The present results have shown that values of specific activity for ^{232}Th in Wassit governorate were less than its recommended value of 30 Bq/kg, given by UNSCEAR (2000).
- As for specific activity of ^{40}K, its highest value (equal to 307.810 Bq/k) was in Al-Wahda region, g, while the lowest value of specific activity of ^{40}K was found in Sheek Saad region, being equal to 122.450 Bq/kg, with an average value of 204.266±46.9 Bq/kg. The present results have shown that values of specific activity for ^{40}K in Wassit governorate were less than its recommended value of 400 Bq/kg given by UNSCEAR (2000).
- The highest value of radium equivalent activity was in Al-Wahda region, which was 85.182 Bq/kg, whereas the lowest value of radium equivalent activity was found in Al-Azezia region, being equal to 42.667 Bq/kg, with an average value of 61.585±14.0 Bq/kg. The present results have shown that values of radium equivalent activity in Wassit governorate were less than the recommended value of 370 Bq/kg for this entry, given by UNSCEAR (2000).
- The highest value of absorbed dose rate (D_γ) was found in Al-Wahda region which was equal to 39.962 nGy/h, while its lowest value belonged to Al-Azezia region, being 19.992 nGy/h, with an average value of 28.656± 6.45 nGy/h. Based on the present results, values of absorbed gamma dose rate in Wassit governorate were less than its recommended value of 55 nGy/h, given by UNSCEAR (2000).
- The highest value of indoor annual effective dose equivalent belonged to Al-Wahda region which was equal to 0.196 mSv/y, while the lowest rate of this variant was in Al-Azezia region, being equal to 0.098 mSv/y, with an average of 0.141±0.03 mSv/y. The present results have shown that the indoor annual effective dose equivalent in Wassit governorate were less than the recommended value of (1 mSv/y) given by UNSCEAR (2000).
- As for the outdoor annual effective dose equivalent, the highest value was in Al-Wahda region, equal to 0.049 mSv/y, whereas its lowest value belonged to Al-Azezia region, which was equal to 0.025 mSv/y with an average value of 0.035± 0.007 mSv/y. Based on the present results, values of outdoor annual effective dose equivalent in Wassit governorate were less than the recommended value of 1 mSv/y, given by UNSCEAR (2000).
- The highest value of external annual effective dose was found in Al-Wahda region which was equal to 0.374 mSv/y, while the lowest value of external annual effective dose was in Al-Azezia region, being equal to

0.187 mSv/y with an average value of 0.268± 0.06 mSv/y. Results from the present have shown that values of external annual effective dose in Wassit governorate were less than its recommended value of 1.5 mSv/y, given by UNSCEAR (2000).

- The highest value of activity concentration index belonged to Al-Wahda region which was equal to 0.313, whereas its lowest value was in Al-Azezia region, equal to 0.157 with an average value of 0.225±0.05. Results have shown that values of activity concentration index in Wassit governorate were less than its recommended value of 1, given by (UNSCEAR, 2000).
- The highest value of internal hazard index was found in Al-Wahda region, with a value equal to 0.309, whereas the lowest value belonged to Al-Azezia region, being equal to 0.155 with an average value of 0.219±0.05. Based on the present results, values of internal hazard index in Wassit governorate were less than the recommended value of 1 given by UNSCEAR (2000).
- And as for the external hazard index, the highest value belonged to Al-Wahda region, equal to 0.230, whereas its lowest value was found in Al-Azezia region, equal to 0.115, with an average value of 0.166±0.03. The present results have shown that values of external hazard index in Wassit governorate were less than the recommended value of 1 given by UNSCEAR (2000).

Table 1. Specific activities of radionuclides with some other parameters in soil samples in Wassit governorate

Location	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Ra_{eq} (Bq/kg)	D_γ (nGy/h)	(A.E.D) (mSv/y) Indoor E_{in}	(A.E.D) (mSv/y) Outdoor E_{out}	EAD (mSv/y)	I_γ	Hazard index H_{in}	Hazard index H_{ex}
Al-Azezia	14.530	11.490	152.030	42.667	19.992	0.098	0.025	0.187	0.157	0.155	0.115
Al-Suwira	18.020	15.410	123.240	49.546	22.772	0.112	0.028	0.213	0.178	0.183	0.134
Zorbatya	11.150	14.470	221.340	48.885	23.121	0.113	0.028	0.215	0.183	0.162	0.132
Badra	24.040	23.760	271.740	78.941	36.789	0.180	0.045	0.343	0.290	0.278	0.213
Kut	15.320	14.430	206.720	51.872	24.414	0.120	0.030	0.228	0.192	0.182	0.140
Jassan	27.710	22.330	184.540	73.851	33.985	0.167	0.042	0.318	0.266	0.274	0.199
Nuamaniya	18.460	11.350	210.240	50.879	24.151	0.118	0.030	0.227	0.188	0.187	0.137
Sheek Saad	15.510	21.450	122.450	55.612	25.228	0.124	0.031	0.234	0.200	0.192	0.150
Al-Hai	20.240	27.620	242.550	78.413	36.148	0.177	0.044	0.336	0.286	0.266	0.212
Al-Wahda	29.220	22.560	307.810	85.182	39.962	0.196	0.049	0.374	0.313	0.309	0.230
Ave.	19.420±4.7	18.487± 5.05	204.266±46.9	61.585± 14.0	28.656± 6.45	0.141± 0.03	0.035± 0.007	0.268± 0.06	0.225±0.05	0.219±0.05	0.166±0.03
Min.	11.150	11.350	122.450	42.667	19.992	0.098	0.025	0.187	0.157	0.155	0.115
Max.	29.220	27.620	307.810	85.182	39.962	0.196	0.049	0.374	0.313	0.309	0.230
worldwide average (SOP, 1999)	35	30	400	370	55	1	1	1.5	1	1	1

CONCLUSIONS

The results of the present work concerning values of the specific activity for (^{238}U, ^{232}Th, and ^{40}K) and determination parameters such as Ra_{eq} ,$D_γ$, $(AED)_{in}$, $(AED)_{out,}$ EAD, $I_{γ}$, H_{in}, and H_{ex} have been found to be lower than their corresponding allowed limits, hence they will pose relatively no serious health risk.

ACKNOWLEDGMENTS

The authors would like to thank the residents of the studied areas for their co-operation during the fieldwork, and care for the samples during the studied period.

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