

Jamal K. Alsaedi, Nada M. Hasan\*, Ali A. Abdulhasan

*Directorate of Nuclear Research and Applications,  
Ministry of Higher Education, Science and Technology, Baghdad, Iraq*

\*Corresponding author: nada66\_altai@yahoo.com

## NATURAL RADIOACTIVITY IN SOIL SAMPLES FROM SELECTED AREAS IN NINEVEH GOVERNORATE, IRAQ

The activity distribution of natural radionuclides  $^{232}\text{Th}$ ,  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  were determined in soil samples. The samples were collected from four different regions in Nineveh governorate north-west of Iraq (Tall Kayf, Badush, Al-Hamdaniya, Hammam Al-alil) and measured by the gamma-ray spectrometry with high purity germanium (HPGe) detector with relative efficiency 50 %. The specific radioactive activity of the samples was in the range of 1.75 - 45.56, 8.63 - 43.72, 147.92 - 502.49 and MDL - 69.32 Bq/kg, respectively, at the selected areas. The calculated hazard indices that estimate the potential radiological health risk such as radium equivalent activity ( $Ra_{eq}$ ) were in the range 40.33 - 122.12 Bq/kg. The absorbed dose rate in the air was also calculated for the samples and it was in the range 20.51 - 56.72 nGy/h. External hazard index ( $H_{ex}$ ) is in the range 0.11 - 0.33, internal hazard index ( $H_{in}$ ) is in the range 0.13 - 0.4 and gamma index was 0.32 - 0.89. The annual effective dose equivalent (AEDE), annual gonadal dose equivalent (AGDE), and excess lifetime cancer risk (ELCR) were also calculated and their ranges were 25.15 - 69.56, 151.63 - 396.05 and  $0.09 \cdot 10^{-3}$  -  $0.24 \cdot 10^{-3}$  respectively. This study showed that there is no radiation hazard to the public due to natural radionuclides in the selected areas.

*Keywords:* activity concentrations, gamma-ray spectrometry, hazard indices, natural radioactivity, HPGe detector.

### 1. Introduction

Natural environment components such as soils, rocks, plants, and water contain some of the natural radioactive materials. Nearly 60 radioactive nuclides have been identified, which contribute to radiation doses received by humans and other mammals [1]. The most important of these radioactive isotopes are from the  $^{238}\text{U}$ ,  $^{235}\text{U}$  and  $^{232}\text{Th}$  series and the  $^{40}\text{K}$  [2]. In addition to the natural radioactive isotopes, artificial radionuclides such as  $^{137}\text{Cs}$  that results from the use of nuclear applications in different areas cause an increase in the radiation dose [3]. Modern scientific and technological activities also contribute to radiation levels in the environment. Therefore, the improper use of the natural environment may cause an increase in the rates of natural radioactivity [4, 5].

Humans are exposed to natural radiation activity continuously and without intervention. It cannot be controlled or reduced so it is important to study the natural radiation activity and its impact on human health. Gamma rays emitted from radionuclides represent the main external radiation source and known as the background radiation [6]. It is represented at different levels depending on the geological structure of the area such as the surface of the earth, rocks,

water, plants and even the air and geographical conditions of each region [7]. Therefore, the radioactive levels have a different effect on human health [8, 9].

The monitoring and the measurement of natural radioactivity are crucial to ensure that the background levels dose not exceeds the recommended limits. It is a precautionary and necessary process to retain data as a reference for subsequent measurements and to observe possible changes in the radiological environment resulting from nuclear, industrial activities and other possible causes [10, 11]. These measurements and the complete survey of the areas are of great importance in the research fields and have an important role in the radiation protection programs [12, 13].

The aim objective of the present work is to determine the specific activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in surface soil samples in some selected districts in Nineveh province in Iraq using the gamma spectrometry with HPGe detector. The results can serve as a database in the monitoring of any radioactivity variation in the environment. It is very important to assess the health impact of radionuclides to the human population, by calculation of radium equivalent activity, absorbed gamma dose rate, external and internal hazard indices, annual effective doses equivalent (AEDE), annual gonadal dose equivalent (AGDE), and excess lifetime cancer risk (ELCR).

## 2. Materials and methods

**The study areas.** Nineveh is located at 465 km from Baghdad to the northwest of Iraq. This study was carried out for this area. Six samples from four areas have been selected, these areas are (Tall Kayf,

Badush, Al-Hamdaniya, and Hammam Al-alil). The coordinates are 36°29'22"N 43°7'9"E, 36°24'55.0"N 42°58'17.0"E, 35°35'17"N 42°43'6"E, 36°09'29.2"N 43°15'33.8"E in Tall Kayf, Badush, Hamdaniya, and Hammam Al-alil respectively. Fig. 1 depicted the four areas the samples were collected from.



Fig. 1. The areas where the samples were selected.

**Samples preparation.** Four regions were selected from Nineveh governorate, and six samples were collected from each region at 25 cm depth from the ground surface. The samples were stamped, stored and preserved for at least one month to allow the radioactive equilibrium among the daughter products of  $^{222}\text{Ra}$ ,  $^{220}\text{Rn}$  to decay their short-lived isotopes [14]. An electric agate mill was used to crush the samples converting them to a fine powder with approximately 200  $\mu\text{m}$  particle size to obtain homogenize samples to reduce the error due to the preparation of the samples. The samples then were dried in an oven at a constant temperature of 200 °C for 2 h to ensure the moisture is removed from the samples. The weight of each sample was fixed at 500 g using Marinelli beaker model 533 N.

**The measurement system.** Gamma-ray spectrometry analysis of the soil samples for natural radioactivity was carried out by using the HPGe detector attached to the digital spectrum analyzer model (DSA-2000) (Canberra Industries, USA). The system was controlled via a personal computer through the Ethernet. The data were collected and saved for further analysis via the Genie-2000 software (Canberra Industries, USA). The background radiation levels were reduced by shielding the detector with lead bricks. The energy resolution of the detector is 2.0 keV at the 1332 keV gamma emission of  $^{60}\text{Co}$ , with a relative efficiency 50 %. The system was calibrated using standard radioactive sources  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  with energies 661, 1172 and 1332 keV. The

relative efficiency of the system was calibrated using the area under the full energy peak from standard Marinelli beaker calibration. The standard source contains  $^{241}\text{Am}$ ,  $^{57}\text{Co}$ ,  $^{60}\text{Co}$ ,  $^{85}\text{Sr}$ ,  $^{88}\text{Y}$ ,  $^{109}\text{Cd}$ ,  $^{137}\text{Cs}$ ,  $^{139}\text{Ce}$  and  $^{203}\text{Hg}$ . The linearity and the reliability of the system were checked by measuring and analyses of the standard source (MG651095), which contained a mixed radionuclide of  $^{241}\text{Am}$ ,  $^{109}\text{Cd}$ ,  $^{57}\text{Co}$ ,  $^{139}\text{Ce}$ ,  $^{203}\text{Hg}$ ,  $^{113}\text{Sn}$ ,  $^{85}\text{Sr}$ ,  $^{137}\text{Cs}$ ,  $^{88}\text{Y}$  and  $^{60}\text{Co}$  with total activity 1.1  $\mu\text{Ci}$ . The comparison results between experimental data and the certificate data proof that the HPGe unit is reliable for such measurements. The collected samples were placed over the detector and the measured dead time was approximately 0.08 - 0.3 %. The counting time was fixed at 7200 s for each sample.

The activity concentration of  $^{226}\text{Ra}$  was determined by measuring the energy peak 351.9 keV from  $^{214}\text{Pb}$ , and 609.2 keV from  $^{214}\text{Bi}$ . The activity concentration of  $^{232}\text{Th}$  was determined by measuring the energy peak of 583.1 keV from  $^{208}\text{Tl}$  and 911.1 keV from  $^{228}\text{Ac}$ . The activity concentration of  $^{40}\text{K}$  and  $^{137}\text{Cs}$  was determined using a single peak of 1460 and 661 keV respectively [15].

The concentration of natural radionuclide of  $^{238}\text{U}$  series,  $^{232}\text{Th}$  series and  $^{40}\text{K}$  in four soil sample was estimated using the following equation [16]:

$$A \left( \frac{\text{Bq}}{\text{kg}} \right) = \frac{\sum N - \sum B.G}{\text{eff } I t m}, \quad (1)$$

where  $A$  – the active concentration;  $\sum N$  – net peak area

at corresponding energy;  $\Sigma B.G$  – net peak area of  $B.G$ ;  $eff$  – the detectors' efficiency;  $I$  – the absolute intensity;  $t$  – the counting time;  $m$  – the weight of the sample.

**Calculation of radiological effects.**

*Radium equivalent activity.* The term radium equivalent activity ( $Ra_{eq}$ ) is used to the purpose of uniform the distribution of radioactivity of radionuclides which is not uniform in soil. Total radiation exposure represents the equivalent radiation activity and it is calculated by the equation [17]:

$$Ra_{eq} \left( \frac{Bq}{kg} \right) = A_{Ra} + 1.43A_{Th} + 0.077A_K, \quad (2)$$

where  $A_{Ra}$ ,  $A_{Th}$ ,  $A_K$  are the specific activities concentration of  $^{226}Ra$ ,  $^{232}Th$ ,  $^{40}K$  in Bq/kg. The highest allowable value of  $Ra_{eq}$  is 370 Bq/kg corresponding to the annual dose of 1.5 mGy. This item is very useful to determine the standards of radiation safety for the public [13].

*Radiation hazard indices.* The external gamma radiation dose is the external hazard index ( $H_{ex}$ ). It is assumed that 370 Bq/kg of  $^{226}Ra$ , 259 Bq/kg of  $^{232}Th$  and 4810 Bq/kg of  $^{40}K$  produce the same gamma-ray dose rate. The external hazard index was calculated from equation [18]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}. \quad (3)$$

Normally,  $H_{ex}$  should be  $\leq 1$ . The maximum value of  $H_{ex}$  equal to unity corresponds to the upper limit of  $Ra_{eq}$  (370 Bq/kg).

*The internal exposure.* Radon and its daughter products are quantified as the internal hazard index ( $H_{in}$ ) which is given by the equation [19]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}. \quad (4)$$

Normally,  $H_{in}$  should be  $\leq 1$ .

*Gamma index.* The gamma index ( $I_\gamma$ ) for soil samples is calculated using the equation [20]:

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500}. \quad (5)$$

The values of the hazard indices and gamma index should be less than unity to keep the radiation hazard to be negligible [21].

*Gamma absorbed dose rate (D).* The total air absorbed dose rate in nGy/h at 1 m above the ground surface due to the activity concentrations of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  (Bq/kg) can be calculated using the equation [22]:

$$D \left( \frac{nGy}{h} \right) = 0.462A_{Ra} + 0.621A_{Th} + 0.041A_K. \quad (6)$$

*Annual effective dose equivalent (AEDE).* The AEDE in the air was calculated using the equation [20]:

$$AEDE \left( \frac{\mu Sv}{yr} \right) = D \left( \frac{nGy}{h} \right) \cdot 8760 h \cdot 0.7 \left( \frac{Sv}{Gy} \right) \cdot 0.2 \cdot 10^{-3}. \quad (7)$$

*Annual gonadal dose equivalent (AGDE).* Gonadal and bone marrow have a significant effect on human life and genetic changes of living cells. Therefore, to calculate the AGDE due to the radioactivity of  $^{226}Ra$ ,  $^{232}Th$ ,  $^{40}K$  is necessary to the population of the study area using the equation [23]:

$$AGDE \left( \frac{\mu Sv}{y} \right) = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_K. \quad (8)$$

*Excess lifetime cancer risk (ELCR).* The probability of cancer is determined by the indicators of AEDE, life-span exposure 70 years (LS) and hazard factor (HF)  $0.05 Sv^{-1}$ . This index can be calculated using this equation [24]:

$$ELCR = AEDE LS HF. \quad (9)$$

**3. Results and discussion**

The activity concentration of the natural radionuclides of the  $^{226}Ra$ ,  $^{232}Th$ ,  $^{40}K$  and the artificially occurring  $^{137}Cs$  in four soil samples from Nineveh governorate were calculated. The results are given in Fig. 2 and Table 1. The activity concentration values were in the range 8.63 - 43.72, 1.75 - 45.56 and 147.92 - 502.49 Bq/kg for  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  respectively. These radioactivity concentration values obtained in this study are below the international range of 11 - 64, 17 - 60 and 140 - 850 Bq/kg for  $^{232}Th$ ,  $^{226}Ra$  and  $^{40}K$  respectively.  $^{137}Cs$  does not exist in natural radioactivity, but its existence is due to the nuclear weapon tests conducted by several countries in addition to the Chernobyl Nuclear Power Plant accident that occurred in April 1986 [25]. The artificially occurring  $^{137}Cs$  were in the range MDL - 69.32, where MDL is the minimum detection limit; the mean values of  $^{137}Cs$  are lower than the world's average values in all selected soil samples except Al-Hamdaniya. The average as shown in Table 2 shows the activity concentration of  $^{226}Ra$ ,  $^{232}Th$ ,  $^{40}K$ , and  $^{137}Cs$  in soil samples compared with the other soil samples in Iraq and other countries.

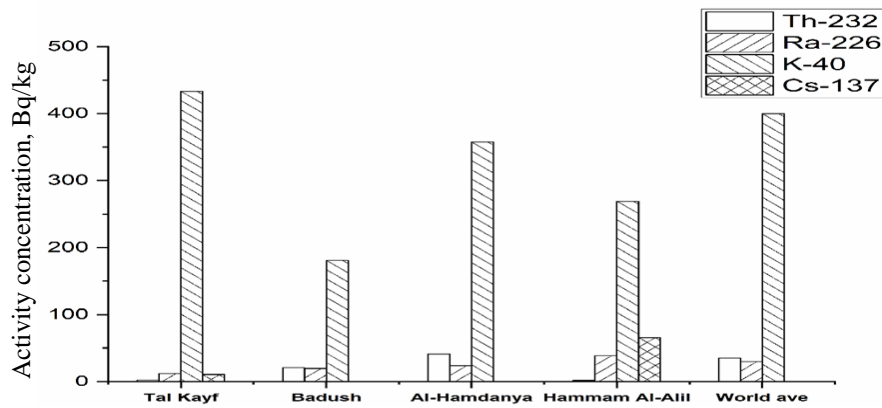


Fig. 2. The average value of the concentration of activity and comparison with the global average.

Table 1. The activity concentration of the natural radionuclides of the <sup>226</sup>Ra, <sup>232</sup>Th, <sup>40</sup>K, and <sup>137</sup>Cs in four soil samples from Nineveh governorate, Bq/kg

Sample code	Code No.	<sup>226</sup> Ra	<sup>232</sup> Th	<sup>40</sup> K	<sup>137</sup> Cs
Tall Kayf	S-1	13.42 ± 0.61	2.91 ± 0.11	395.64 ± 20.63	8.73 ± 0.53
	S-2	8.63 ± 0.41	1.75 ± 0.07	440.42 ± 22.63	9.94 ± 0.62
	S-3	12.94 ± 0.62	3.11 ± 0.15	502.49 ± 26.61	8.25 ± 0.51
	S-4	9.45 ± 0.42	2.11 ± 0.09	361.82 ± 20.11	13.29 ± 1.21
	S-5	14.18 ± 0.81	1.91 ± 0.09	453.79 ± 22.89	12.43 ± 1.11
	S-6	12.32 ± 0.71	2.15 ± 0.09	445.82 ± 22.21	9.63 ± 0.73
	Range	8.63 - 14.18	1.75 - 3.11	361.82 - 502.49	8.25 - 13.29
	Average	11.82	2.32	433.33	10.38
Badush	M-1	22.16 ± 1.52	14.74 ± 0.81	221.23 ± 10.52	B.D.L.
	M-2	17.87 ± 1.21	24.31 ± 1.24	218.65 ± 10.31	B.D.L.
	M-3	18.93 ± 1.07	23.53 ± 1.56	147.92 ± 7.85	B.D.L.
	M-4	21.34 ± 1.21	21.45 ± 1.22	163.48 ± 8.41	B.D.L.
	M-5	25.34 ± 1.26	19.47 ± 0.95	178.93 ± 9.11	B.D.L.
	M-5	12.64 ± 0.74	22.11 ± 1.42	155.62 ± 7.83	B.D.L.
	Range	12.64 - 25.34	14.74 - 24.31	221.23 - 147.92	-
	Average	19.7	20.93	180.97	-
Hamdaniya	R-1	20.61 ± 1.09	35.86 ± 2.56	341.42 ± 17.65	B.D.L.
	R-2	19.98 ± 0.95	38.98 ± 2.86	333.29 ± 17.15	B.D.L.
	R-3	22.69 ± 1.41	44.23 ± 3.52	393.84 ± 20.22	B.D.L.
	R-4	25.36 ± 1.72	42.31 ± 3.26	325.63 ± 16.84	B.D.L.
	R-5	26.16 ± 1.78	39.96 ± 3.11	363.54 ± 18.95	B.D.L.
	R-6	27.04 ± 1.83	45.56 ± 3.87	388.73 ± 20.13	B.D.L.
	Range	19.98 - 27.04	35.86 - 45.56	341.42 - 393.84	-
	Average	23.64	41.15	357.74	-
Hammam Al-alil	N-1	36.63 ± 2.96	2.21	308.45 ± 15.73	62.44 ± 1.31
	N-2	32.41 ± 2.62	1.28	294.51 ± 15.63	62.83 ± 1.52
	N-3	40.51 ± 3.11	1.97	236.61 ± 12.94	69.43 ± 2.37
	N-4	43.72 ± 3.51	1.53	240.53 ± 13.52	69.32 ± 3.11
	N-5	39.94 ± 3.11	2.14	265.47 ± 13.73	65.34 ± 1.84
	N-6	39.23 ± 3.11	1.57	270.6 ± 14.41	65.14 ± 1.83
	Range	32.41 - 43.72	1.28 - 2.21	236.61 - 308.45	62.44 - 69.32
	Average	38.744	1.78	269.36	65.75

B.D.L. – Below detection limits.

Table 2. Activity concentrations of <sup>232</sup>Th, <sup>226</sup>Ra, and <sup>40</sup>K measured in Iraq and compared with surrounding countries, Bq/kg

Country	<sup>232</sup> Th	<sup>226</sup> Ra	<sup>40</sup> K	<sup>137</sup> Cs	Ref.
Egypt	12.53 ± 0.91 - 32.81 ± 2.39	6.98 ± 0.51 - 26.01 ± 1.89	383.90 ± 27.95 - 711.98 ± 51.83	0.36 ± 0.03 - 9.73 ± 0.71	[26]
Iran	27.3 ± 0.5 - 57.1 ± 1.1	30.5 ± 0.6 - 45.4 ± 0.9	328.0 ± 4.6 - 768.5 ± 13.4	0.8 - 7.43	[27]

Continuation of Table 2

Country	<sup>232</sup> Th	<sup>226</sup> Ra	<sup>40</sup> K	<sup>137</sup> Cs	Ref.
Qatar	0.8 ± 0.1 - 7.6 ± 0.2	7.5 ± 0.5 - 63.3 ± 3.2	13.6 ± 1.5 - 179.5 ± 9.1	0 - 3.7 ± 0.3	[28]
Saudi Arabia	7.4 ± 1.0 - 21.4 ± 2.9	10.8 ± 1.3 - 25.3 ± 3.4	98 ± 13 - 320 ± 44	0.8 - 3.1	[29]
Yemen	19.00 ± 0.48 - 112.4 ± 5.62	17.6 ± 0.88 - 76.36 ± 1.64	110.5 ± 5.525 - 555.18 ± 18.41	-	[30]
Turkey	9.5 ± 0.6 - 170.8 ± 10.2	7.9 ± 0.8 - 79.8 ± 9.1	157.8 ± 89.7 - 320.7 ± 105.2	0 - 154.3 ± 4.7	[31]
Syria	18.43 ± 5	22.2 ± 9	247 ± 100	-	[32]
Gordon	6.3 - 85.5	1.8 - 76.4	84 - 516.7	-	[33]
Najaf	5.94 ± 0.76 - 14.29 ± 0.76	19.28 ± 3.91 - 1118.16 ± 23.13	223.49 ± 11.46 - 655.25 ± 34.99	-	[34]
Baghdad	7.23 ± 2.7 - 16.40 ± 4.0	9.21 ± 3.0 - 20.20 ± 4.4	B.D.L. - 104.26 ± 37.3	B.D.L. - 6.32 ± 2.5	[35]
Present work	1.79 - 41.15	11.82 - 38.74	180.97 - 433.30	B.D.L. -71.32	-
World's range	11 - 64	17 - 60	140 - 850	-	[36]
World's average	30	35	400	51	[31]

Calculated assessment of radiation hazards in this work are shown in Table 3. Owing to activity concentration of <sup>232</sup>Th, <sup>226</sup>Ra and <sup>40</sup>K, presents Ra<sub>eq</sub> natural radionuclides from all sites varies in the range 40.33 - 122.12 Bq/kg which is much less than the threshold value of 370 Bq/kg. External and internal radiation hazard indices (H<sub>ex</sub>, H<sub>in</sub>) and gamma index (I<sub>γ</sub>) are 0.11

- 0.33, 0.13 - 0.4 and 0.32 - 0.89 respectively. Mean value of air absorbed gamma radiation dose rate (D) and AEDE are 20.51 - 56.72 nGy/h and 25.15 - 69.56 μSv/y respectively. AGDE and ELCR were also calculated and their range are 151.63 - 396.05 μSv/y and 0.09·10<sup>-3</sup> - 0.24·10<sup>-3</sup> respectively.

Table 3. Radium equivalent (Ra<sub>eq</sub>), external hazard index (H<sub>ex</sub>), internal hazard index (H<sub>in</sub>), gamma Index (I<sub>γ</sub>), gamma absorbed dose rate (D), annual effective dose equivalent (AEDE), annual gonadal dose equivalent (AGDE), excess lifetime cancer risk (ELCR)

Sample code	Code No.	Ra <sub>eq</sub> , Bq/kg	H <sub>ex</sub>	H <sub>in</sub>	I <sub>γ</sub>	D, nGy/h	AEDE, μSv/y	AGDE, μSv/y	ELCR
Tall Kayf	S-1	48.04	0.13	0.16	0.38	24.23	29.71	177.86	0.10·10 <sup>-3</sup>
	S-2	45.04	0.12	0.14	0.36	23.13	28.37	172.27	0.10·10 <sup>-3</sup>
	S-3	56.08	0.15	0.18	0.45	28.51	34.96	210.76	0.12·10 <sup>-3</sup>
	S-4	40.33	0.11	0.13	0.32	20.51	25.15	151.63	0.09·10 <sup>-3</sup>
	S-5	51.85	0.14	0.18	0.42	26.34	32.31	194.29	0.11·10 <sup>-3</sup>
	S-6	49.71	0.13	0.16	0.40	25.30	31.03	187.01	0.11·10 <sup>-3</sup>
	min.	40.33	0.11	0.13	0.32	20.51	25.15	151.63	0.09·10 <sup>-3</sup>
	max.	56.08	0.15	0.18	0.45	28.51	34.96	210.76	0.12·10 <sup>-3</sup>
ave.	48.51	0.13	0.16	0.39	24.67	30.26	182.30	0.10·10 <sup>-3</sup>	
Badush	M-1	60.27	0.16	0.22	0.44	28.46	34.90	199.55	0.12·10 <sup>-3</sup>
	M-2	69.47	0.19	0.23	0.51	32.31	39.63	225.49	0.14·10 <sup>-3</sup>
	M-3	63.97	0.17	0.22	0.46	29.42	36.08	203.29	0.13·10 <sup>-3</sup>
	M-4	64.60	0.17	0.23	0.46	29.88	36.64	206.93	0.13·10 <sup>-3</sup>
	M-5	66.96	0.18	0.25	0.48	31.13	38.18	215.86	0.13·10 <sup>-3</sup>
	M-6	56.24	0.15	0.18	0.41	25.95	31.82	180.34	0.11·10 <sup>-3</sup>
	min.	56.24	0.15	0.18	0.41	25.95	31.82	180.34	0.11·10 <sup>-3</sup>
	max.	69.47	0.19	0.25	0.51	32.31	39.63	225.49	0.14·10 <sup>-3</sup>
ave.	63.58	0.17	0.22	0.46	29.52	36.21	205.24	0.13·10 <sup>-3</sup>	
Hamdaniya	R-1	98.18	0.26	0.32	0.72	45.79	56.15	320.78	0.19·10 <sup>-3</sup>
	R-2	101.38	0.27	0.33	0.74	47.10	57.76	329.32	0.20·10 <sup>-3</sup>
	R-3	116.26	0.31	0.37	0.85	54.10	66.34	378.65	0.23·10 <sup>-3</sup>
	R-4	110.93	0.29	0.37	0.81	51.34	62.96	357.46	0.22·10 <sup>-3</sup>
	R-5	111.29	0.30	0.37	0.81	51.81	63.53	362.02	0.22·10 <sup>-3</sup>
	R-6	122.12	0.33	0.40	0.89	56.72	69.56	396.05	0.24·10 <sup>-3</sup>
	min.	98.18	0.26	0.32	0.72	45.79	56.15	320.78	0.19·10 <sup>-3</sup>
	max.	122.12	0.33	0.4	0.89	56.72	69.56	396.05	0.24·10 <sup>-3</sup>
ave.	110.02	0.29	0.36	0.80	51.14	62.71	357.38	0.22·10 <sup>-3</sup>	



Sample code	Code No.	R <sub>a</sub> <sub>eq</sub> , Bq/kg	H <sub>ex</sub>	H <sub>in</sub>	I <sub>γ</sub>	D, nGy/h	AEDE, μSv/y	AGDE, μSv/y	ELCR
Hammam Al-alil	N-1	63.54	0.17	0.27	0.47	30.94	37.95	219.27	0.13·10 <sup>-3</sup>
	N-2	56.92	0.15	0.24	0.42	27.84	34.14	197.97	0.12·10 <sup>-3</sup>
	N-3	61.54	0.16	0.27	0.45	29.64	36.35	207.70	0.13·10 <sup>-3</sup>
	N-4	64.43	0.17	0.29	0.47	31.01	38.03	217.01	0.13·10 <sup>-3</sup>
	N-5	63.44	0.17	0.28	0.46	30.66	37.61	215.71	0.13·10 <sup>-3</sup>
	N-6	62.31	0.19	0.27	0.46	30.19	37.03	212.75	0.13·10 <sup>-3</sup>
	min.	56.92	0.15	0.24	0.42	27.84	34.14	197.97	0.12·10 <sup>-3</sup>
	max.	64.43	0.19	0.29	0.47	31.01	38.03	219.27	0.13·10 <sup>-3</sup>
ave.	62.03	0.17	0.27	0.45	30.04	36.85	211.73	0.13·10 <sup>-3</sup>	
World's average		370 <sup>(a)</sup>	<1 <sup>(a)</sup>	<1 <sup>(a)</sup>	<1 <sup>(a)</sup>	55 <sup>(a)</sup>	67 <sup>(b)</sup> , 70 <sup>(a)</sup>	270 <sup>(b)</sup> , <300 <sup>(a)</sup>	0.29·10 <sup>-3(a)</sup>

<sup>(a)</sup> Ref. 36.

<sup>(b)</sup> Calculated.

#### 4. Conclusions

The measurement of radioactivity in the environment is of great importance to monitor and control the levels of radiation to which man is exposed directly or indirectly. Humans are affected by the environmental radioactivity and ionizing radiation from the air. Hazard indices have been calculated to assess the potential radiological health risk in soil. The activity concentration of <sup>232</sup>Th, <sup>226</sup>Ra, <sup>40</sup>K and <sup>137</sup>Cs in Bq/kg in soil sample in Nineveh showed that the levels are relatively low and uniformly distributed in soil except for the <sup>137</sup>Cs activity concentrations in one place which are higher than the global limit. This can be attributed to the Chernobyl Nuclear Power Plant accident and the atmospheric nuclear weapon tests

conducted by several countries. The R<sub>a</sub><sub>eq</sub> is less than the acceptable limit 370 Bq/kg. The average absorbed dose rate value also less than the acceptable limit of 55 nG/h. The H<sub>ex</sub>, H<sub>in</sub> and I<sub>γ</sub> of soil samples were less than unity. It was concluded that no harmful radiation effects may pose to the population who live in the study areas. The repeating of similar studies periodically to conduct measurements of natural and artificial radioactivity resulting from nuclear accidents is very important in terms of monitoring the area of human health.

The authors would like to acknowledge the support of the Iraqi Ministry of Science and Technology in supporting this work.

#### REFERENCES

- I. Sert et al. Estimation of sediment accumulation rates using naturally occurring <sup>210</sup>Pb models in Gul-bahce Bay, Aegean Sea. *J. Environ. Rad.* 107 (2012) 1.
- G. Alzubaidi, F.B.S. Hamid, I. Abdul Rahman. Assessment of Natural Radioactivity Levels and Radiation Hazards in Agricultural and Virgin Soil in the State of Kedah, North of Malaysia. *Sci. World J.* (2016) 6178103.
- R. Mehra, S. Surinder. Use of Gamma-Ray Spectroscopy Measurements for Assessment of the Average Effective Dose from the Analysis of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K in Soil Samples. *Indoor Built Environ.* 18(3) (2009) 270.
- M.C.A. Alvarez, M.T.D. Vivero. Natural radionuclide contents in Spanish coals of different rank. *Fuel* 77(13) (1998) 1427.
- Ch.H. Lakehal, M. Randhane, A. Boucenna. Natural radionuclide concentration in two phosphate ores of east Algeria. *J. Environ. Rad.* 101(5) (2010) 377.
- A.H. Taqi, L.A.A. Al-Ani, A.M. Ali. Assessment of the natural radioactivity levels in the Kirkuk oil field. *J. Radiat. Res. Appl. Sci.* 9(3) (2016) 337.
- R.M. Yousuf, K.O. Abdullah. Measurement of natural radioactivity in soil collected from the eastern of Sulaiman governorate in Kurdistan-region, Iraq. *ARNP J. Sci. Techn.* 7 (2013) 749.
- R. Kapsimalis, S. Landsberger, N. Reguigui. Measurement of uranium in small quantities in phosphates by use of gamma-ray spectrometry and the 1001 keV peak of <sup>234m</sup>Pa. *J. Radioanal. Nucl. Chem.* 280(2) (2009) 293.
- A.P. Yousaf et al. External gamma radiation levels and natural radioactivity in the soil around a phosphate fertilizer plant at Mumbai. *J. Radioanal. Nucl. Chem.* 300 (2014) 23.
- S. Harb et al. Activity concentration for surface soil samples collected from Armant, Qena, Egypt. In: *Proc. of the 4-th Environmental Physics Conference, Hurghada, Egypt, 2010*, p. 49.
- A. El-TaHER, J.H. Al-Zahrán. Radioactivity measurement and radiation dose assessment in the soil of Al-Qassim region, Saudi Arabia. *Indian Journal of Pure & Applied Physics* 52 (2014) 147.
- B.A. Almayahi. Gamma Spectroscopic of Soil Samples from Kufa in Najaf Governorate, Iraq. *World Applied Sciences Journal* 31(9) (2014) 1582.

13. A.M. Saleh, A.H. Al-Mashhadani, M.A. Siyah. Natural Radioactivity Concentration and Estimation of Radiation Exposure in Environmental Soil Samples from Al-Sader City, Iraq. *International Journal of Computer Engineering and Technology* 4 (2014) 2902.
14. R. Veiga et al. Measurement of natural radioactivity in Brazilian beach sands. *Radiat Meas.* 41 (2006) 189.
15. D.A.E. Darwish, K.T.M. Abul-Nasr, A.M. El-Khayatt. The assessment of natural radioactivity and its associated radiological hazards and dose parameters in granite samples from South Sinai, Egypt. *J. Radiat. Res. Appl. Sci.* 8(1) (2015) 17.
16. A.A. Al-Hamidawi, H.H. Al-Gazaly, L.A. Al-Alasadi. Determination of natural radiation contamination for some types of legumes available in the Iraqi markets. *Adv. Appl. Sci. Res.* 4(5) (2013) 245.
17. A.O. Taiwo et al. Determination of radium equivalent activity from naturally occurring radionuclide around a superphosphate fertilizer factory in Nigeria. *Archives of Applied Science Research* 6(1) (2014) 28.
18. H.M. Diab et al. Evaluation of natural radioactivity in a cultivated area around a fertilizer factory. *J. Nucl. Rad. Phys.* 3(1) (2008) 53.
19. E.O. Agbalagba, G.O. Avwiri, Y.E. Chad-Umoreh.  $\gamma$ -Spectroscopy measurement of natural radioactivity and assessment of radiation, hazard indices in soil samples from oil fields environment of Delta State, Nigeria. *J. Environ. Rad.* 109 (2012) 64.
20. A.K. Ademola, A.K. Bello, A.C. Adejumbi. Determination of natural radioactivity and hazard in soil samples in and around the gold mining area in Itagunmodi, South-Western, Nigeria. *J. Radiat. Res. Appl. Sci.* 7(3) (2014) 249.
21. I.F Al-Hamarneh, M. Awadallah. Soil radioactivity levels and radiation hazard assessment in the high lands of northern Jordan. *Radiat. Meas.* 44 (2009) 102.
22. B.G. Jagadeesha, Y. Narayana. Natural radionuclide concentration in Hassan district of South India. *Radiation Protection and Environment* 41(1) (2018) 37.
23. N. Zaim, H. Atlas. Assessment of radioactivity levels and radiation hazards using gamma spectrometry in soil samples of Edirne, Turkey. *J. Radioanal. Nucl. Chem.* 310(3) (2016) 959.
24. R.D. Senthilkumar, R. Narayanaswamy. Assessment of radiological hazards in the industrial effluent disposed soil with statistical analysis. *J. Rad. Res. Appl. Sci.* 9 (2016) 449.
25. K.R.S. Dizman, F.K. Gorur. Determination of radioactivity levels of soil samples and the excess of lifetime cancer risk in Rize province, Turkey. *Int. J. Radiat. Res.* 14(3) (2016) 237.
26. S. Harb et al. Radioactivity Levels and Soil-to-Plant Transfer Factor of Natural Radionuclides from Protectorate Area in Aswan, Egypt. *World Journal of Nuclear Science and Technology* 4 (2014) 7.
27. A. Osouli, F. Abbasi, M. Naseri. Measurement of  $^{137}\text{Cs}$  in soils of Tehran province, Iran. *Int. J. Radiat. Res.* 7(3) (2009) 141.
28. T. Nasir, H. Al-Sulaiti, H.R. Patrick. Assessment of Radioactivity in Some Soil Samples of Qatar by Gamma-Ray Spectroscopy and the Derived Doses Rate. *Pakistan Journal of Scientific and Industrial Research. Series A: Physical Sciences* 55(3) (2012) 128.
29. A.S. Alaamer. Characterization of  $^{137}\text{Cs}$  in Riyadh Saudi Arabia Soil Samples. *World Journal of Nuclear Science and Technology* 2 (2012) 161.
30. S. Harb et al. Natural Radioactivity of soil samples from some areas of Aden governorate, south of Yemen Region. *Int. J. Curr. Microbiol. App. Sci.* 3(11) (2014) 640.
31. A. Durusoy, M. Yildirim. Determination of radioactivity concentrations in soil samples and dose assessment for Rize Province, Turkey. *J. Radiat. Res. Appl. Sci.* 10 (2017) 348.
32. I.O.T. Yassine. Natural radioactivity in the Syrian environment. *J. Sci. Total. Environ.* 170(1) (1995) 119.
33. O. Abu-Haija. Determination of Natural Radionuclides Concentrations in Surface Soil in Tafila, Jordan. *Mod. Appl. Sci.* 6(3) (2012) 87.
34. H.H. Al-Gazaly et al. Natural radioactivity in the soil at regions around the uranium mine in Abu-Skhair Najaf Province, Iraq. *J. Adv. Appl. Sci. Res.* 5(1) (2014) 13.
35. N.F. Tawfiq, H.L. Mansour, M.S. Karim. Natural Radioactivity in Soil Samples for Selected Regions in Baghdad Governorate. *International Journal of Recent Research and Review* 8(1) (2015) 1.
36. United Nations Scientific Committee on the Effects of Atomic Radiation. *UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes. Vol. 1. Sources and Effects of Ionizing Radiation (New York, United Nations, 2000).*

Джамаль К. Альсааді, Нада М. Хасан\*, Алі А. Абдулхасан

Управління ядерних досліджень та програм  
Міністерства вищої освіти, науки та технологій, Багдад, Ірак

\*Відповідальний автор: nada66\_altai@yahoo.com

### ПРИРОДНА РАДІОАКТИВНІСТЬ ЗРАЗКІВ ҐРУНТУ У ВИБРАНИХ РАЙОНАХ ПРОВІНЦІЇ НІНЕВІЯ, ІРАК

Активність природних радіонуклідів  $^{232}\text{Th}$ ,  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  та  $^{137}\text{Cs}$  була визначена за допомогою гамма-спектрометрії у зразках ґрунту з чотирьох регіонів у провінції Ніневія на північному заході Іраку (Tall Kayf, Badush, Al-Hamdaniya, Hammam Al-alil). Використовувався детектор із германію високої чистоти (HPGe) з відносною ефективністю 50 %. Питома радіоактивність зразків знаходилася в межах 1,75 - 45,56, 8,63 - 43,72, 147,92 - 502,49

i MDL - 69,32 Бк/кг відповідно, на вибраних ділянках. Обчислені індекси потенційних радіологічних ризиків для здоров'я; еквівалентна активність радію ( $Ra_{eq}$ ) знаходилася в межах 40,33 - 122,12 Бк/кг. Інтенсивність поглиненої дози в повітрі також була розрахована для зразків; вона була в межах 20,51 - 56,72 нГр/год. Індекс зовнішнього ризику ( $H_{ex}$ ) знаходиться в діапазоні 0,11 - 0,33, індекс внутрішнього ризику ( $H_{in}$ ) – у межах 0,13 - 0,4, а гамма-індекс – 0,32 - 0,89. Також було розраховано річну еквівалентну ефективну дозу (AEDE), річний еквівалент гонадної дози (AGDE) та надлишковий ризик раку (ELCR); їхні діапазони становили 25,15 - 69,56, 151,63 - 396,05 та  $0,09 \cdot 10^{-3}$  -  $0,24 \cdot 10^{-3}$  відповідно. Дане дослідження показало, що радіаційної небезпеки для населення, зумовленої природними радіонуклідами в обраних районах, не існує.

*Ключові слова:* концентрація активності, гамма-спектрометрія, індекси ризику, природна радіоактивність, детектор HPGe.

**Джамаль К. Альсаади, Нада М. Хасан\* Али А. Абдулхасан**

*Управление ядерных исследований и программ  
Министерства высшего образования, науки и технологий, Багдад, Ирак*

\*Ответственный автор: nada66\_altai@yahoo.com

### **ЕСТЕСТВЕННАЯ РАДИОАКТИВНОСТЬ ОБРАЗЦОВ ГРУНТА В ВЫБРАННЫХ РАЙОНАХ ПРОВИНЦИИ НИНЕВИЯ, ИРАК**

Активность природных радионуклидов  $^{232}\text{Th}$ ,  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  и  $^{137}\text{Cs}$  была определена с помощью гамма-спектрометрии в образцах почвы из четырех регионов в провинции Ниневия на северо-западе Ирака (Tall Kayf, Badush, Al-Namdaniya, Hammam Al-alil). Использовался детектор из германия высокой чистоты (HPGe) с относительной эффективностью 50 %. Удельная радиоактивность образцов находилась в пределах 1,75 - 45,56, 8,63 - 43,72, 147,92 - 502,49 и MDL - 69,32 Бк/кг соответственно, на выбранных участках. Вычислены индексы потенциальных радиологических рисков для здоровья; эквивалентная активность радия ( $Ra_{eq}$ ) находилась в пределах 40,33 - 122,12 Бк/кг. Интенсивность поглощенной дозы в воздухе также была рассчитана для образцов; она была в пределах 20,51 - 56,72 нГр/ч. Индекс внешнего риска ( $H_{ex}$ ) находится в диапазоне 0,11 - 0,33, индекс внутреннего риска ( $H_{in}$ ) – в пределах 0,13 - 0,4, а гамма-индекс – 0,32 - 0,89. Также была рассчитана годовая эквивалентная эффективная доза (AEDE), годовой эквивалент гонадной дозы (AGDE) и избыточный риск рака (ELCR); их диапазоны составляли 25,15 - 69,56, 151,63 - 396,05 и  $0,09 \cdot 10^{-3}$  -  $0,24 \cdot 10^{-3}$  соответственно. Данное исследование показало, что радиационной опасности для населения, обусловленной природными радионуклидами в выбранных районах, не существует.

*Ключевые слова:* концентрация активности, гамма-спектрометрия, индексы риска, естественная радиоактивность, детектор HPGe.

Надійшла/Received 07.08.2019