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NATURAL RADIOACTIVITY AND RADIOLOGICAL EFFECTS IN SOIL SAMPLES OF THE MAIN ELECTRICAL STATIONS AT BABYLON GOVERNORATE

The natural radionuclides namely ^{238}U, ^{232}Th and ^{40}K for soil samples collected from locations of Alexandria and Musayyib electrical stations were measured. In addition, the radiological effects were calculated for all samples chosen in this study. The technique used in this study was gamma-ray spectrometry to estimate the natural radioactivity of twenty samples at the study area of the above-mentioned electrical stations. The results show that the specific activity of Alexandria samples of ^{238}U were varied from 13.3 - 17.2 Bq/kg with an average of 15.4 ± 0.5 Bq/kg, ^{232}Th were varied from 5.0 - 9.6 Bq/kg with an average of 6.2 ± 0.4 Bq/kg and ^{40}K were varied from 244.3 - 330.5 Bq/kg with an average of 293.0 ± 8.4 Bq/kg. But in Musayyib, the results of ^{238}U, ^{232}Th and ^{40}K were varied from 10.0 - 18.7 Bq/kg with an average of 13.9 ± 0.9 Bq/kg, from 4.8 - 7.4 Bq/kg with an average of 6.0 ± 0.3 Bq/kg and from 207.5 - 294.2 Bq/kg with an average of 269.5 ± 8.6 Bq/kg respectively. Also, it is found that the average of radiological effects like the radium equivalent (Ra_{eq}), the absorbed dose Rate (D_r), external hazard index (H_{ex}), internal hazard index (H_{in}), representative gamma hazard index (I_γ), the total annual effective dose equivalent (AEDE) and the excess lifetime cancer risk (ELCR) due to natural radioactivity in soil samples of Alexandria stations were 46.82 ± 2.10 Bq/kg, 23.27 ± ± 0.673 nGy/h, 0.126 ± 0.005, 0.167 ± 0.004, 0.359 ± 0.01, 0.142 ± 0.005 mSv/y and 0.499 ± 0.018 · 10^{-3} respectively, while for Musayyib were 43.29 ± 2.51 Bq/kg, 21.52 ± 0.719 nGy/h, 0.116 ± 0.004, 0.154 ± 0.006, 0.332 ± 0.011, 0.132 ± 0.005 mSv/y and 0.462 ± 0.019 · 10^{-3} respectively. When comparing the results in the study area with the world mean values specified by the UNSCEAR, OECD and ICRP, it can be concluded that no health risk may threaten the workers in the center of these locations due to these radionuclides in the soil of the study area.

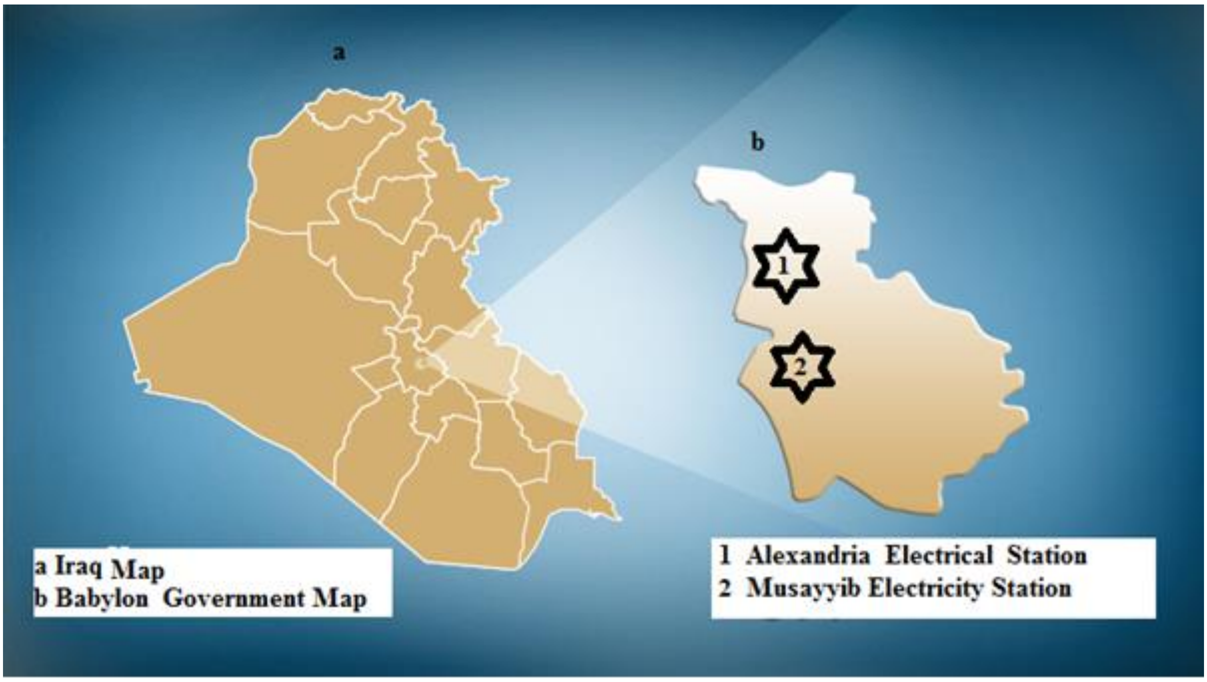
Keywords: natural radioactivity, electrical stations, Babylon Governorate, gamma spectrometer.

1. Introduction

Natural radioactivity is the source of continuous exposure to human beings which contributed about 80 % from radiation exposure of the population in world [1]. It is a gift within the human environment because of the presence of cosmogenic and early radionuclides in the earth's crust [2]. There are several sources of radiation within the environment like gamma ray, which is emitted from naturally occurring radionuclides, also known as terrestrial background. These radiations form the most external supply of radiation to the human body [3, 4]. Natural environmental radioactivity and also the associated external exposure because of gamma ray rely totally on the geological and geographical conditions, and seem at totally different levels within the soil of every region in the world. Terrestrial background radiations were shaped by the method of nucleo-synthesis [5]. The radioactive chemicals that originate on earth are called "terrestrial radiation" and may be found in igneous and sedimentary rock around the globe. Terrestrial radiation includes the series of radionuclides produced when ^{238}U and ^{232}Th decay, as well as ^{40}K [6]. Natural radioactivity is widespread and present in different geological formations in the earth. Studies on natural radioactivity are necessary not only for the impact of radiation but because they have a great interest and importance in health physics. Therefore, studies on measurement of natural radioactivity in soil are very important to determine the amount of change in the natural background activity with the passage of time as a result of the spread of radioactivity [5]. Soil is one of the sources of human food and it is the most important contributor to radiation exposure. It is necessary to know the distribution of radioactivity in the soil [6]. The study of NORM is necessary as a result of naturally occurring radioactive materials will serve pretty much as good organic chemistry and geochemical tracers in environment just in case of earth science events like earthquakes and eruptions volcanic [7]. Many studies worldwide have measured the specific activity of natural radioactivity in soil samples to ascertain the levels of contamination [8 - 13]. The present study aims to investigate the natural radioactivity (^{238}U, ^{232}Th, and ^{40}K), as well as to evaluate the radiological effects in soil samples collected from two locations in Babylon Governorate; these are Alexandria and Musayyib electrical stations.

2. Area of study

Babylon Governorate lies in the center of Iraq between 32 to 33.25° North latitude and between 44 to 45° East longitude [14]. It occupies about 5,119 km^2. The provincial capital is the city of Hillah, which lies near the ancient city of Babylon, on the Euphrates [15]. Babylon Governorate has two electrical stations, the first lies in Alexandria city and the second in Musayyib. Figure shows the geographic location of the states of the Babylon Governorate, in addition to the locations of Alexandria and Musayyib electrical stations. As for the areas under study, no surveys of natural radioactivity in soil samples have been carried out so far and no baselines of concentration of natural and anthropogenic radioisotopes have been reported. Therefore, this study can be considered the first in this respect. In addition, so many workers are working in more than 18 hours. In this context, cancer incident cases have been reported with some of the fore mentioned workers. Consequently, we believe that this study can be used as a baseline for further research.



Babylon administrative map.

3. Experimental procedure

In autumn 2015, twenty soil samples at depth 15 cm in two locations were collected from Babylon Governorate. These locations are Alexandria and Musayyib electrical stations. Samples were collected from within the electrical station region. This collection was guided by IAEA recommended standards. To illustrate, no less than ten samples were collected from no less than 10 m^2 taken into account four corners for each site. In this context, the studied area can be estimated to be around 4 km^2 The samples after collection were transferred to the environmental laboratory located in the Physics Department at the College of Education for Pure Sciences in University of Babylon for crushing and cleaning from exotic material such as pieces of stones and gravel. Some of these samples were dried in an oven at 100 °C for 1 hour to ensure that any significant moisture was removed. After that, a sieve with diameter holes 300 μm was used to obtain a homogeneous powder and then weighed by 0.75 kg each one. Then the samples were packed into one cubic decimeter polyethylene plastic Marinelli beakers of constant volume to ensure geometric homogeneity around the detector. These of the plastic Marinelli beakers were sealed with a tape and stored for concerning one month before investigating to permit secular equilibrium to be earned between ^{222}Rn and its parent ^{226}Ra in uranium chain. Radioactivity measurements were performed by gamma ray spectrometry which it is consists of NaI(Tl) detector (“3 × 3”) and multi-channel analyzer (with range of 4096 channel) joined with analog to digital convertor unit, through interface and desperation energy (FWHM) in the peak 1.33 keV for ^{60}Co is 7.9 %. The radioactive background decrease for different radiations using shield by ORTEC cylindrical chamber (diameter of 22 cm) which consist of two parts, the first part of stainless steel with width 20 cm and the second part is lead with width 5 cm. The spectrometer was calibrated for energy by acquiring a spectrum from radioactive standard sources of known energies and gamma-ray 1 μCi such as ^{137}Cs, ^{60}Co and ^{22}Na the energy calibration curve that it found in present study. Energy efficiency of gamma spectrometer were carried out using same calibration sources in one liter Marinelli beaker covering the energy from 500 to 2500 keV. The standard source put over the detector with a geometric match exactly to the geometrical sample form and with same distance between the sample and the detector. The sample was put in the middle of room shield with period about 5 hours according to radioactivity. The specific activity of ^{238}U and ^{232}Th were determined from the energy 1764.49 keV gamma transition energy of ^{214}Bi (15.96 % possibility) and from the 2614 keV gamma transition energy of ^{208}Tl, (99 % possibility) which are in secular equilibrium with them respectively, while ^{40}K activity is determined using the 1460 keV gamma ray line (11 % possibility).

4. Theoretical calculations

4.1. The specific activity

The specific activity of the gamma emission in the measured samples was computed using the following relation [16, 17]

$$C\left(\frac{Bq}{kg}\right)=\frac{C_a}{I\cdot\varepsilon_{ff}\cdot M_s}\pm\frac{\sqrt{C_a}}{I\cdot\varepsilon_{ff}\cdot M_s}, \quad (1)$$

where C_a – net gamma counting rate (counts per second); ε_{ff} – efficiency of the detector; I – intensity of the gamma-line in a radionuclide; M_s – mass of the sample, kg.

4.2. Radiological effects

In the present study, there are many radiological effects parameter were calculated as the following.

4.2.1. The radium equivalent activity (*Ra_{eq}*)

The radium equivalent activity can be calculated by [18]

$$Ra_{eq}=C_U+(1.43C_{Th})+(0.077C_K), \quad (2)$$

where C_U, C_{Th} and C_K – average the specific activity in the sample in Bq/kg of ^{232}U, ^{232}Th and ^{40}K respectively.

4.2.2. The absorbed dose rate

The absorbed dose rate can be calculated by [19, 20]

$$D_r\left(\frac{\text{nGy}}{\text{h}}\right)=\text{DCF}_{Ra}\cdot C_U+\text{DCF}_{Th}\cdot C_{Th}+\text{DCF}_K\cdot C_K, \quad (3)$$

where DCF_U (0.427), DCF_{Th} (0.662) and DCF_K (0.043) – dose conversion factors for, ^{238}U, ^{232}Th and ^{40}K in nSv/h per Bq/kg [21, 22].

4.2.3 The external, internal and representative gamma hazard index

The external, internal and representative gamma hazard Index can be calculated by [18]

$$H_{ex}=\frac{C_U}{370}+\frac{C_{Th}}{259}+\frac{C_K}{4810}\le 1, \quad (4)$$

$$H_{in}=\frac{C_U}{185}+\frac{C_{Th}}{259}+\frac{C_K}{4810}, \quad (5)$$

$$I_\gamma=\frac{C_U}{150}+\frac{C_{Th}}{100}+\frac{C_K}{1500}, \quad (6)$$

where, H_{ex}, H_{in} and I_γ – external, internal, representative gamma hazard index due to the emitted gamma-rays of the soil.

4.2.4. Total annual effective dose equivalent

The values of annual effective dose can be calculated by [20]

$$\text{AEDE}\left(\frac{\text{mSv}}{\text{y}}\right)=\text{AEDE}_{\text{outdoor}}+\text{AEDE}_{\text{indoor}}, \quad (7)$$

$$\text{AEDE}_{\text{outdoor}}(\text{mSv/y})=$$

$$=[D_r(\text{mGy/h})\cdot 8760\text{ h}\cdot 0.2\cdot 0.7\text{ Sv/Gy}]\cdot 10^{-6}, \quad (8)$$

$$\text{AEDE}_{\text{indoor}}(\text{mSv/y})=$$

$$=[D_r(\text{mGy/h})\cdot 8760\text{ h}\cdot 0.8\cdot 0.7\text{ Sv/Gy}]\cdot 10^{-6}, \quad (9)$$

where AEDE – total annual effective dose equivalent; $\text{AEDE}_{\text{outdoor}}$ – annual effective dose equivalent outdoor; $\text{AEDE}_{\text{indoor}}$ – annual effective dose equivalent indoor; 0.2 – outdoor occupancy factor; 0.7 Sv/Gy – dose conversion factor; 8760 – time conversion factor and 0.8 is the indoor occupancy factor.

4.2.5. Excess lifetime cancer risk

The value of excess lifetime cancer risk can be calculated by [23]

$$\text{ELCR}=\text{AEDE}\cdot\text{DL}\cdot\text{RF}, \quad (10)$$

where ELCR – excess lifetime cancer risk; DL – average duration of human life; RF – risk factor, Sv^{-1}). DL – average duration of life (estimated to be 70 years); RF – risk factor; Sv i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

5. Results and Discussion

5.1. Alexandria electrical station

5.1.1. The specific activity

The results of the specific activity for ^{238}U, ^{232}Th and ^{40}K radionuclides in soil sample of Alexandria electrical station are presented in Table 1. From

Table 1, the range of specific activity for ^{238}U in this location was 13.3 to 17.2 Bq/kg with an average of 15.4 ± 0.5 Bq/kg. In ^{232}Th specific activity was ranged from 5.3 to 9.6 Bq/kg with an average 6.2 ± ± 0.4 Bq/kg, while the specific activity in ^{40}K was ranged from 244.3 to 330.5 Bq/kg with an average value of 293.0 ± 8.4 Bq/kg. The differences between activities of the same nuclide are significant in different samples for these values of specific activities at Alexandria electrical station due to geochemical composition and origin of soil kinds in these location, which is sandy, and clay soils. Also, we see from Table 1, the activity of uranium is higher than thorium in all samples. Which is clear from the fact the average uranium is 2.5 times higher than that of the average thorium in this location. It is also noticed that the activity of ^{40}K exceeds markedly the values of each ^{238}U and ^{232}Th, as it is that the most abundant radioactive element into account. Furthermore, the too much use of potassium containing fertilizers in the adjacent to the sampling sites might contribute to the upper values of ^{40}K activity. The results of specific activity in natural radioactivity for the collected soil samples under study were lower than the world average according to UNSCEAR 2000 [22] which are 35,30 and 400 Bq/kg for ^{238}U, ^{232}Th and ^{40}K respectively.

Table 1. **Results of natural radioactivity of Alexandria electrical station**

No.	Sample Code	Specific activity, Bq/kg		
		^{238}U	^{232}Th	^{40}K
1	A1	14.6 ± 0.6	5.1 ± 0.2	277.9 ± 3.2
2	A2	14.6 ± 0.7	5.0 ± 0.2	287.6 ± 3.3
3	A3	14.2 ± 0.6	6.4 ± 0.3	244.3 ± 3.0
4	A4	13.3 ± 0.6	5.4 ± 0.2	266.5 ± 3.1
5	A5	17.0 ± 0.8	5.7 ± 0.2	295.1 ± 3.4
6	A6	17.2 ± 0.8	6.3 ± 0.3	303.9 ± 3.5
7	A7	17.0 ± 0.7	6.6 ± 0.3	301.4 ± 3.4
8	A8	13.5 ± 0.7	6.3 ± 0.3	317.3 ± 3.5
9	A9	15.6 ± 0.7	9.6 ± 0.4	330.5 ± 3.6
10	A10	16.5 ± 0.7	5.9 ± 0.3	305.9 ± 3.5
Average ± S.D		15.4 ± 0.5	6.2 ± 0.4	293.0 ± 8.4
Worldwide average		32	30	400

5.1.2. Radiological effects

Table 2 shows the radiological effects (Ra_{eq}, D_r, H_{ex}, H_{in}, I_γ, AEDE and ELCR) of the soil samples collected from Alexandria electrical station. Using above equation, the radium equivalent activity found in the soil samples are shown in Table 2. The radium equivalent activity calculated for the same soil sample varies from 41.51 to 54.68 Bq/kg with an average value of 46.82 ± 2.10 Bq/kg. It is concluded that for all the soil samples analyzed the radium equivalent activity value is well and less the permissible limits of 370 Bq/kg [24]. The calculated absorbed dose rate varied from 20.70 to 27.18 nGy·h^{-1} with an average value of 23.27 ± 0.673 nGy/h, represents ≈ 45 % of the world average outdoor exposure due to terrestrial gamma-ray (55 nG/h), depending on the UNSCEAR 2000) [22]. The recorded value in study area for most samples, are important for health, which indicates no hazard effects to the people living there. The ultimate use of the specific activity measured in the soil samples is to detect the radiation dose delivered externally in the form of gamma dose. The external hazard index were calculated from 0.112 to 0.147 with an average value of the 0.126 ± 0.005, the calculated average values were less than unity according to the radiation protection report [25]. These radionuclides are few sources of radon and its radioactive progeny. The internal exposure by radon ranged between 0.147 to 0.189 with an average value of the 0.167 ± 0.004, therefore the calculated average values were less than unity according to the radiation protection report [25]. The calculated I_γ values for the samples of this location are presented in Table 2. The values range from 0.320 to 0.419 with an average of 0.359 ± 0.01. These calculated values are less than the international values $I_\gamma < 1$ [25]. The calculated indoor, outdoor and total of AEDE values are listed in Table 3. These average values were 0.114 ± 0.004, 0.028 ± 0.0006 and 0.142 ± 0.005 mSv/y respectively that we notice that these values are less than the corresponding worldwide values of 0.42, 0.08 and 0.50 mSv/y respectively [26]. The calculated Excess lifetime cancer risk of this location are shown in Table 3. These values vary from 0.444 · 10^{-3} to 0.583 · 10^{-3} with an average 0.499 ± 0.018 · 10^{-3}. According to these results, the risk of cancer is negligible.

Table 2. **The radium equivalent (Ra_{eq}), the absorbed dose rate (D_r), external (H_{ex}), internal (H_{in}) hazard index and radioactivity level index (I_γ) of the soil samples of Alexandria electrical station**

No.	Sample Code	Ra_{eq}, Bq/kg	D_r, nGy/h	H_{ex}	H_{in}	I_γ
1	A1	43.35	21.58	0.117	0.156	0.334
2	A2	44.02	21.96	0.118	0.158	0.339
3	A3	42.19	20.82	0.113	0.152	0.321
4	A4	41.51	20.70	0.112	0.147	0.320
5	A5	47.88	23.72	0.129	0.175	0.367
6	A6	49.55	24.55	0.133	0.180	0.379
7	A7	49.63	24.58	0.134	0.180	0.380
8	A8	46.90	23.56	0.126	0.163	0.364
9	A9	54.68	27.18	0.147	0.189	0.419
10	A10	48.47	24.09	0.130	0.175	0.372
Average ± S.D		46.82 ± 2.10	23.27 ± 0.673	0.126 ± 0.005	0.167 ± 0.004	0.359 ± 0.01
Worldwide average		<370	55	<1	<1	<1

Table 3. **The outdoors, the indoors and the total annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) of the soil samples of Alexandria electrical station**

No.	Sample Code	$AEDE_{indoor}$, mSv/y	$AEDE_{outdoor}$, mSv/y	AEDE, mSv/y	$ELCR \cdot 10^{-3}$
1	A1	0.105	0.026	0.132	0.463
2	A2	0.107	0.026	0.135	0.471
3	A3	0.102	0.025	0.127	0.447
4	A4	0.101	0.025	0.127	0.444
5	A5	0.116	0.029	0.145	0.509
6	A6	0.120	0.030	0.150	0.527
7	A7	0.121	0.030	0.151	0.527
8	A8	0.115	0.028	0.144	0.506
9	A9	0.133	0.033	0.166	0.583
10	A10	0.118	0.029	0.147	0.517
Average ± S.D		0.114 ± 0.004	0.028 ± 0.0006	0.142 ± 0.005	0.499 ± 0.018
Worldwide average		0.42	0.08	0.50	–

5.2. Musayyib electricity station

5.2.1. The specific activity

Table 4 show the results of specific activity for ^{238}U, ^{232}Th and ^{40}K in soil samples of Musayyib electricity station. The measured specific activity of ^{238}U, ^{232}Th and ^{40}K in this location were ranged from 10.0 to 18.7 Bq/kg with an average 13.9 ± 0.9 Bq/kg, from 4.8 to7.4 Bq/kg with an average 6.0 ± 0.3 Bq/kg and from 207.5 to 294.2 Bq/kg with an average 269.5 ± 8.6 Bq/kg respectively. These differences are attributable due to soil type in this location, which is sandy, and clay soils. Also, we see from Table 4 that, the specific activity of uranium is higher than thorium in all samples. Also as the soil samples of Alexandria electrical station, it is noted that the values of specific activity of ^{40}K exceeds markedly the values of both ^{238}U and ^{238}Th. Finally, we found that the values of specific activity were lower than world average according to UNSCEAR 2000 [22].

Table 4. **Results of natural radioactivity of Musayyib electrical station**

No.	Sample Code	Specific activity, Bq/kg		
		^{238}U	^{232}Th	^{40}K
1	M1	13.0 ± 0.6	7.1 ± 0.3	261.9 ± 3.1
2	M2	18.7 ± 0.8	6.4 ± 0.3	263.8 ± 3.1
3	M3	10.0 ± 0.6	4.8 ± 0.2	207.5 ± 2.7
4	M4	14.9 ± 0.7	5.7 ± 0.3	258.3 ± 3.1
5	M5	16.8 ± 0.8	4.8 ± 0.3	261.4 ± 3.2
6	M6	10.5 ± 0.7	6.6 ± 0.3	283.5 ± 3.2
7	M7	10.7 ± 0.6	5.2 ± 0.3	289.7 ± 3.3
8	M8	15.1 ± 0.7	5.6 ± 0.3	293.9 ± 3.3
9	M9	15.8 ± 0.7	7.4 ± 0.3	294.2 ± 3.3
10	M10	13.6 ± 0.6	6.7 ± 0.3	280.8 ± 3.2
Average ± S.D		13.9 ± 0.9	6.0 ± 0.3	269.5 ± 8.6
Worldwide average		32	30	400

5.2.2. Radiological effects

The radiological effects (Ra_{eq}, D_r, H_{ex}, H_{in}, I_γ, AEDE and ELCR) of the soil samples collected from Musayyib electrical station are presented in Table 5. From Table 5, we found that the average values of Ra_{eq}, D_r, H_{ex}, H_{in}, I_γ, AEDE and ELCR due to natural radioactivity in soil samples were 72.40 ± 2.51 Bq/kg, 21.52 ± 0.719 nGy/h, 0.116 ± 0.004, 0.154 ± 0.006, 0.332 ± 0.011, 0.169 ± 0.005 mSv/y and 0.591 ± ± 0.019 · 10^{-3} respectively. We compared the average values of the radiological effects in Tables 5 and 6 with the value of world average, it is found that Ra_{eq}, is less the permissible limits of 370 Bq/kg [24], the absorbed dose rate is lower than average value according to UNSCEAR 2000 [22], H_{ex}, H_{in}, remains less than unity according to the radiation protection report [25], also I_γ was less than the international values $I_\gamma < 1$, while the AEDE indoor, outdoor and total values were less than the corresponding worldwide values of 0.42, 0.08 and 0.50 mSv/y respectively [26] and at last the values of ELCR are very little, therefore, it may be decided that the risk of cancer is negligible.

Table 5. **The radium equivalent (Ra_{eq}), the absorbed dose rate (D_r), external (H_{ex}), internal (H_{in}) hazard index and radioactivity level index (I_γ) of the soil samples of Musayyib electrical station**

No.	Sample Code	Ra_{eq}, Bq/kg	D_r, nGy/h	H_{ex}	H_{in}	I_γ
1	M1	43.28	21.49	0.116	0.152	0.332
2	M2	48.05	23.51	0.129	0.180	0.363
3	M3	32.88	16.38	0.088	0.115	0.253
4	M4	43.02	21.27	0.116	0.156	0.329
5	M5	43.84	21.61	0.118	0.163	0.334
6	M6	41.70	21.01	0.112	0.140	0.324
7	M7	40.41	20.45	0.109	0.138	0.316
8	M8	45.75	22.79	0.123	0.164	0.352
9	M9	49.09	24.32	0.132	0.175	0.375
10	M10	44.85	22.34	0.121	0.157	0.345
Average ± S.D		43.29 ± 2.51	21.52 ± 0.719	0.116 ± 0.004	0.154 ± 0.006	0.332 ± 0.011
Worldwide average		<370	55	<1	<1	<1

Table 6. **The outdoors, the indoors and the total annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) of the soil samples of Musayyib electrical station**

No.	Sample Code	$AEDE_{indoor}$, mSv/y	$AEDE_{outdoor}$, mSv/y	AEDE, mSv/y	ELCR · 10^{-3}
1	M1	0.105	0.026	0.131	0.461
2	M2	0.115	0.028	0.144	0.505
3	M3	0.080	0.020	0.100	0.351
4	M4	0.104	0.026	0.130	0.457
5	M5	0.106	0.026	0.132	0.464
6	M6	0.103	0.025	0.128	0.451
7	M7	0.100	0.025	0.125	0.439
8	M8	0.111	0.027	0.139	0.489
9	M9	0.119	0.029	0.149	0.522
10	M10	0.109	0.027	0.137	0.479
Average ± S.D		0.105 ± 0.004	0.026 ± 0.0006	0.132 ± 0.005	0.462 ± 0.019
Worldwide average		0.42	0.08	0.50	–

6. Conclusions

The specific activity for ^{238}U, ^{232}Th and ^{40}K of Alexandria and Musayyib electrical stations are lower than the world average values according to UNSCEAR 2000. In addition, it is found that most of the radiological effects such as Ra_{eq}, D_r, H_{ex}, H_{in}, I_γ and AEDE are less than the world average according to the radiation protection report UNSCEAR (2000), UNSCEAR (2008), OECD (1979) and ICRP (1993). Hence, it can be concluded that no harmful radiation effects are posed to the population who live in the study area.

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ПРИРОДНА РАДІОАКТИВНІСТЬ ТА РАДІОЛОГІЧНІ ЕФЕКТИ У ЗРАЗКАХ ҐРУНТУ ОСНОВНИХ ЕЛЕКТРИЧНИХ СТАНЦІЙ У ПРОВІНЦІЇ ВАВИЛОН

Виміряно природні радіонукліди ^{238}U, ^{232}Th і ^{40}K для зразків ґрунту, відібраних з місцевості електричних станцій «Олександрія» та «Аль-Мусаїб». Також для всіх зразків, відібраних для даного дослідження, були розраховані радіологічні ефекти. Для оцінки природної радіоактивності 20 зразків, відібраних із згаданих вище електричних станцій, було використано метод гамма-спектрометрії. При порівнянні результатів даного дослідження зі світовими даними, наведеними Науковим комітетом ООН з дії атомної радіації (НКДАР), Організацією економічного співробітництва та розвитку (ОЕСР) і Міжнародною комісією з радіологічного захисту (МКРЗ), можна зробити висновок про те, що немає ніякого ризику для здоров'я працівників зазначених електричних станцій у зв’язку із знаходженням цих радіонуклідів у ґрунті.

Ключові слова: природна радіоактивність, електричні станції, провінція Вавилон, гамма-спектрометр.

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ЕСТЕСТВЕННАЯ РАДИОАКТИВНОСТЬ И РАДИОЛОГИЧЕСКИЕ ЭФФЕКТЫ В ОБРАЗЦАХ ПОЧВЫ ОСНОВНЫХ ЭЛЕКТРИЧЕСКИХ СТАНЦИЙ В ПРОВИНЦИИ ВАВИЛОН

Измерены природные радионуклиды ^{238}U, ^{232}Th и ^{40}K для образцов почвы, отобранных из местности электрических станций «Александрия» и «Аль-Мусаиб». Также для всех образцов, отобранных для данного исследования, были рассчитаны радиологические эффекты. Для оценки естественной радиоактивности 20 образцов, отобранных с упомянутых выше электрических станций, был использован метод гамма-спектрометрии. При сравнении результатов данного исследования с мировыми данными, приведенными Научным комитетом ООН по действию атомной радиации (НКДАР), Организацией экономического сотрудничества и развития **(**ОЭСР) и Международной комиссией по радиологической защите (МКРЗ), можно сделать вывод о том, что нет никакого риска для здоровья работников указанных электрических станций в связи с нахождением этих радионуклидов в почве.

Ключевые слова: естественная радиоактивность, электрические станции, провинция Вавилон, гамма-спектрометр.

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