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Evaluation of natural radioactivity in Selected Soil Samples from the Archaeological of Ur City by using HPGe detector

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ABSTRACT

In this paper, the determination of specific activity concentrations in ten soil samples collected from the antiquity's area of the archaeological of Ur city, were carried out using HPGe scintillation detector. The results of measurements have shown that the specific activity, for ^{238}U varied from (16.520 Bq/kg) to (30.620 Bq/kg), with average value (24.730 ±4.05 Bq/kg), the specific activity of Th-232 was varied from (18.730 Bq/kg) to (31.670 Bq/kg), with average value of (25.098 ±3.41 Bq/kg), while the specific activity of K-40 was varied from (123.340 Bq/kg) to (261.480 Bq/kg), with average value of (189.767 ±39.47 Bq/kg). All soil samples of the archaeology of Ur city were found to be lower than the recommended values given by (UNSCEAR, 2000). In order to asses the radiological hazards of the radioactivity in soil samples of the archaeological of Babylon city, (Ra_{eq}, D_{γ}, AED_{in}, AED_{out}, EAD, I_{γ},I_{α}, H_{in} and H_{ex}) have been calculated, and all the obtained results were found lower than the allowed limits given by (UNSCEAR, 2000).

***Keyword*:** Natural radioactivity; Radiation hazard indices; HPGe detector; Ur city

1. INTRODUCTION

The radiation to which the human population is exposed comes from many diverse sources. Some of these sources are natural; others are the result of human activities. The radiation from natural sources include cosmic radiation, external radiation from radionuclides in earth's crust and internal radiation from radionuclides inhaled or ingested and retained in the body. The magnitude of these natural exposures depends on geographical location and on some human activities. Height above sea level affects the dose rate from cosmic radiation; radiation from the ground depends on the local geology; and the dose from radon, which seeps from the ground into houses [1]. Gamma radiation emitted from naturally occurring radioisotopes, such as K-40 and the radionuclides from the ^{232}Th and ^{238}U series and their decay products (also called terrestrial background radiation), which exist as trace levels in all ground formations, represents the main external source of irradiation to the human body. In the last decade, several studies were carried out to assess the average outdoor terrestrial gamma dose rate in air [2]. Ur Archaeological was an important Sumerian city-state in ancient Mesopotamia, located at the site of modern Tell el-Muqayyar in south Iraq's Thiqar Governorate. Although Ur was once a coastal city near the mouth of the Euphrates on the Arabic Gulf, the coastline has shifted and the city is now well inland, south of the Euphrates on its right bank, 16 kilometres from Nasiriyah city [3].

2. MATERIALS AND METHOD

Figure 1. The sampling locations in the antiquities area of Ur city.

Ten Soil samples were collected from locations in the antiquity's area of the archaeological of Ur city see Figure (1) in Thiqar governorate in south of Iraq. The samples were ground into a fine powder with a particle size less than 250 μm and then dried in a temperature-controlled furnace at 80 °C for one day to remove moisture. Each sample stored in a sealed polyethylene marinelli beaker for one month to achieve the secular equilibrium. Marinelli beaker was used as sampling and measuring container [4].

In the present work a (3×3) inch (HPGe) was used for gamma spectrometric measurements. Measurement with an empty Marinelli beaker under identical conditions was also performed to estimate the background radiation.

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 was performed by using a standard source of one litter capacity of Marinelli beaker of Europium (^{152}Eu), which has been prepared in this work with energies (121.8, 244.7, 344.3, 411.1, 444.6, 778.9, 964.0, 1085.8, 1112.0 and 1408.0 keV). The Energy calibration source should be counted long enough to produce well-defined photo peaks. The efficiency calibration of the (HPGe) detector was achieved using the same standard source of ^{152}Eu.

The specific activity concentrations of radionuclides in soil samples were obtained by using the equation [5]:

$$A = (Net \quad Area \quad under \quad the \quad peak) / M \times I_{\gamma}(E_{\gamma}) \times eff \times T \quad \ldots\ldots\ldots(1)$$

where:
A: the specific activity concentration of radionuclides measured in (Bq/kg).
M: mass of the soil sample (kg).
eff: the efficiency of the detectors at energy E_{γ}.
$I_{\gamma}(E_{\gamma})$: is the abundance at energy E_{γ}.
T: the time of measurement which was equal to (7200 s).

2. 1. Gamma Radiation Parameters (Radiation hazard indices)

A. 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 it is given by the expression [6]:

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

where:
A_U, A_{Th} and A_K are the specific activity concentrations of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K in (Bq/kg) units respectively.

B. Absorbed Gamma Dose Rate (D_γ)

Outdoor air absorbed gamma dose rate (D_γ) in (nGy/h) due to terrestrial gamma rays at (1 m) above the ground surface was determined from the specific activities of A_U, A_{Th} and A_K for ^{238}U, ^{232}Th and ^{40}K respectively in (Bq/kg) units using the following relation [7]:

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

C. Annual Effective Dose Equivalent

The estimated annual effective dose equivalent received by a member was determined using a conversion factor of (0.7 Sv/Gy), which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20 % and 80 % for indoors by using the following relations [8]:

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

$$(AED)_{out}\ (mSv/y) = D_\gamma\ (nGy/h)\times10^{-6}\times8760\ h/y\times0.20\times0.7Sv/Gy \quad \ldots\ldots\ldots(5)$$

D. Gamma Index (I_γ)

The gamma index (I_γ) for soil samples was determined by using the following relation [9]:

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

E. Alpha index (I_α)

The excess alpha radiation due to radon inhalation originating from building materials, such as soil, was estimated using the following relation [9]:

$$I_\alpha = \frac{A_{Ra}}{200\left(\frac{Bq}{kg}\right)} \leq 1 \quad \ldots\ldots(9)$$

where:

I_α : is the alpha index

A_{Ra}: is the specific activity concentrations of ^{226}Ra assumed in equilibrium with ^{238}U.

These concentrations reflected in the alpha index.The recommended upper limit of specific activity concentrations of ^{226}Ra is (200 Bq/kg) , for which alpha index ($I\alpha$) is equal to 1.

F. External (H_{ex}) and Internal (H_{in}) Hazard Indices

Beretka and Mathew [10] defined two other indices 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:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \qquad \text{.......... (7)}$$

Internal exposure to radon ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) and it is given by the relation [11]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad \text{.......... (8)}$$

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

3. RESULTS AND DISCUSSION

The results of the present work were summarized in Table (1), from which it can be noticed that, the highest value of specific activity of (^{238}U) in the soil samples of the archaeological of Ur city which was equal to (30.620 Bq/kg), while the lowest value of specific activity of (^{238}U) which was equal to (16.520 Bq/kg), with an average value of (24.730 ±4.05 Bq/kg). The present results have shown that values of specific activity for (^{238}U) in all studied samples were less than the recommended value of (35 Bq/kg) for the specific activity of (^{238}U) given by (UNSCEAR, 2000) [12], as in Fig. (2).

Table 1. Specific activities of radionuclides with some other parameters for all soil samples.

No. of sample	U-238 (Bq/K)	Th-232 (Bq/K)	K-40 (Bq/K)	Ra_{eq} (Bq/K)	D_γ (nGy/h)	Annual effective dose (mSv/y)		I_γ	($I\alpha$)	Hazard index	
						Indoor (AED_{in})	Outdoor (AED_{out})			H_{in}	H_{ex}
1	22.320	22.430	142.540	65.370	29.803	0.146	0.037	0.468	0.112	0.237	0.177
2	20.420	18.730	123.340	56.701	25.890	0.127	0.032	0.406	0.102	0.208	0.153
3	25.500	28.860	261.480	86.904	40.116	0.197	0.049	0.633	0.128	0.304	0.235

4	24.480	28.280	241.270	83.498	38.452	0.189	0.047	0.607	0.122	0.292	0.226
5	29.470	25.040	173.660	78.649	35.981	0.177	0.044	0.563	0.147	0.292	0.212
6	16.520	31.670	135.530	72.244	32.413	0.159	0.040	0.517	0.083	0.240	0.195
7	30.620	23.850	213.270	81.147	37.445	0.184	0.046	0.585	0.153	0.302	0.219
8	29.770	21.120	240.440	78.485	36.537	0.179	0.045	0.570	0.149	0.292	0.212
9	19.650	28.630	176.520	74.183	33.732	0.165	0.041	0.535	0.098	0.253	0.200
10	28.550	22.370	189.620	75.140	34.609	0.170	0.042	0.540	0.143	0.280	0.203
Ave.	24.730 ±4.05	25.098 ±3.41	189.767 ±39.47	75.232 ±5.51	34.498 ±3.23	0.169 ±0.016	0.042 ±0.004	0.542 ±0.049	0.124± 0.028	0.270± 0.18	0.203± 0.2
Min.	16.520	18.730	123.340	56.701	25.890	0.127	0.032	0.406	0.083	0.208	0.153
Max.	30.620	31.670	261.480	86.904	40.116	0.197	0.049	0.633	0.142	0.304	0.235
worldwide average [12]	35	30	400	370	55	1	1	1	1	1	1

The highest value of specific activity of (^{232}Th) in the studied samples which was equal to (31.670 Bq/kg), while the lowest value of specific activity of (^{232}Th) which was equal to (18.730 Bq/kg), with an average value of (25.098 ±3.41 Bq/kg). The present results have shown that values of specific activity for (^{232}Th) in all studied samples were less than the recommended value of (30 Bq/kg) for the specific activity of (^{232}Th) given by (UNSCEAR, 2000) [12], as in Fig. (2).

The highest value of specific activity of (^{40}K) in the studied samples which was equal to (261.480 Bq/kg), while the lowest value of specific activity of (^{40}K) which was equal to (123.340 Bq/kg), with an average value of (189.767 ±39.47 Bq/kg). The present results have shown that values of specific activity for (^{40}K) in all studied samples were less than the recommended value of (400 Bq/kg) for the specific activity of (^{40}K) given by (UNSCEAR, 2000) [12], as in Fig. (2).

The highest value of radium equivalent activity (Ra_{eq}) in the studied samples which was equal to (86.904 Bq/kg), while the lowest value of (Ra_{eq}) which was equal to (56.701 Bq/kg), with an average value of (75.232 ±5.51 Bq/kg). The present results have shown that values of (Ra_{eq}) in all studied samples were less than the recommended value of (370 Bq/kg) for the radium equivalent activity given by (UNSCEAR, 2000) [12], see Fig. (3).

The highest value of absorbed dose rate (D_{γ}) in the studied samples which was equal to (40.116 nGy/h), while the lowest value of absorbed gamma dose rate which was equal to

(25.890 nGy/h), with an average value of (34.498 ±3.23 nGy/h). The present results have shown that values of absorbed gamma dose rate in all studied samples were less than the recommended value of (55 nGy/h) for the absorbed gamma dose rate given by (UNSCEAR, 2000) [12], see Fig. (3).

The highest value of indoor annual effective dose equivalent $(AED)_{in}$ in the studied samples which was equal to (0.197 mSv/y), while the lowest value of indoor annual effective dose equivalent which was equal to (0.127 mSv/y) ,with an average value of (0.169 ±0.016 mSv/y). The present results have shown that values of indoor annual effective dose equivalent in all studied samples were less than the recommended value of (1 mSv/y) for the indoor annual effective dose equivalent given by (UNSCEAR, 2000) [12], mentioned in Fig. (4).

The highest value of outdoor annual effective dose equivalent $(AED)_{out}$ in the studied samples which was equal to (0.049 mSv/y), while the lowest value of outdoor annual effective dose equivalent which was equal to (0.032 mSv/y), with an average value of (0.042 ±0.004 mSv/y). The present results have shown that values of outdoor annual effective dose equivalent in all studied samples were less than the recommended value of (1 mSv/y) for the outdoor annual effective dose equivalent given by (UNSCEAR, 2000) [12], mentioned in Fig. (4).

The highest value of gamma index (I_γ) in the studied samples which was equal to (0.633), while the lowest value of (I_γ) which was equal to (0.406) ,with an average value of (0.542 ±0.049). The present results have shown that values of activity gamma index in all studied samples were less than the recommended value of (1) for (I_γ) given by (UNSCEAR, 2000) [12], in Fig. (5).

The highest value of Alpha index (I_α) in the studied samples which was equal to (0.142), while the lowest value of Alpha index which was equal to (0.083), with an average value of (0.124 ±0.028).The present results have shown that values of Alpha index in all studied samples were less than the recommended value of (1) for the Alpha index given by (UNSCEAR, 2000) [12], in Fig. (5).

The highest value of internal hazard index (H_{in}) in the studied samples which was equal to (0.304), while the lowest value of internal hazard index which was equal to (0.208), with an average value of (0.270 ±0.18). The present results have shown that values of internal hazard index in all studied samples were less than the recommended value of (1) for the internal hazard index given by (UNSCEAR, 2000) [12], as shown in Fig. (6).

The highest value of external hazard index (H_{ex}) in the studied samples which was equal to (0.235), while the lowest value of external hazard index which was equal to (0.153), with an average value of (0.203 ±0.2). The present results have shown that values of external hazard index in all studied samples were less than the recommended value of (1) for the external hazard index given by (UNSCEAR, 2000) [12], as shown in Fig. (6).

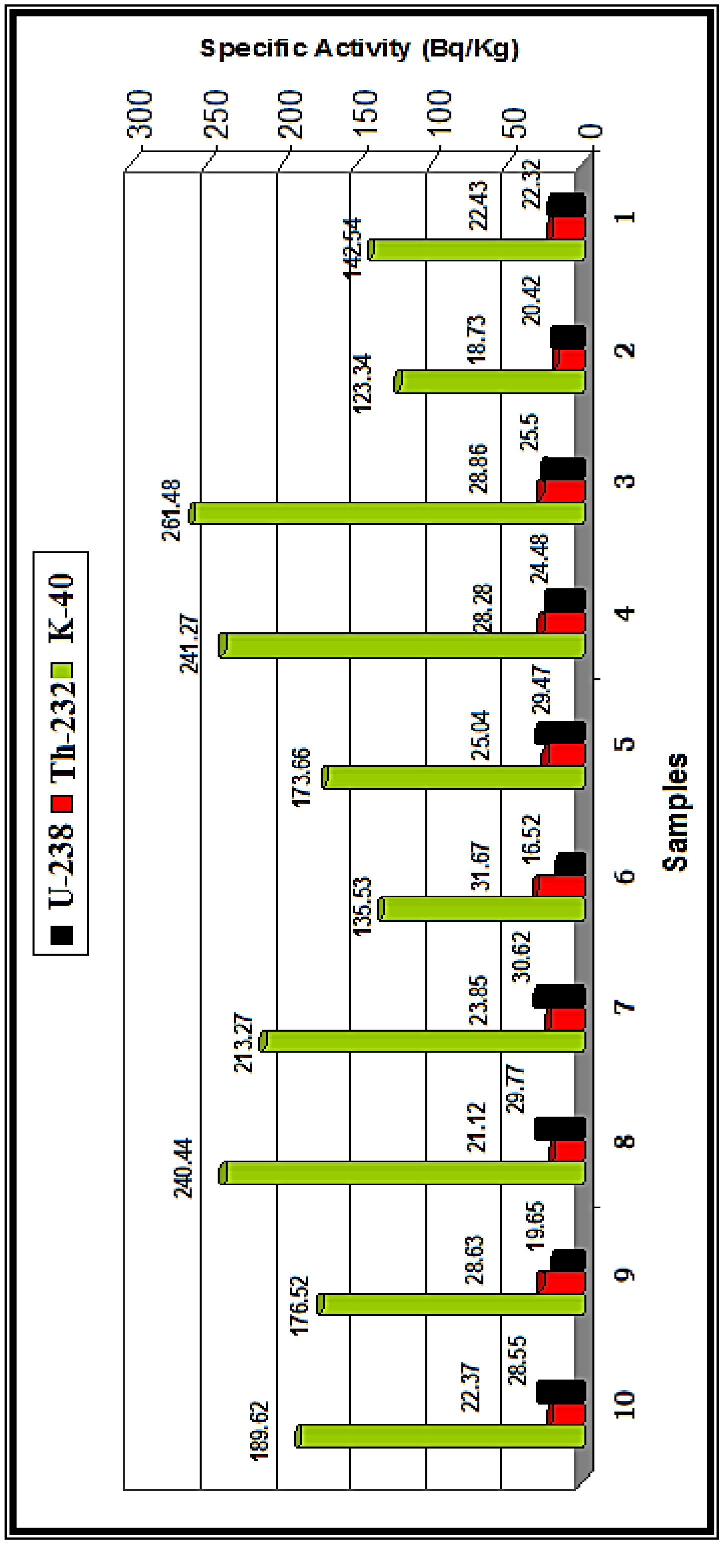

Figure 2. Specific activities of (^{238}U, ^{232}Th and ^{40}K) for all the soil samples.

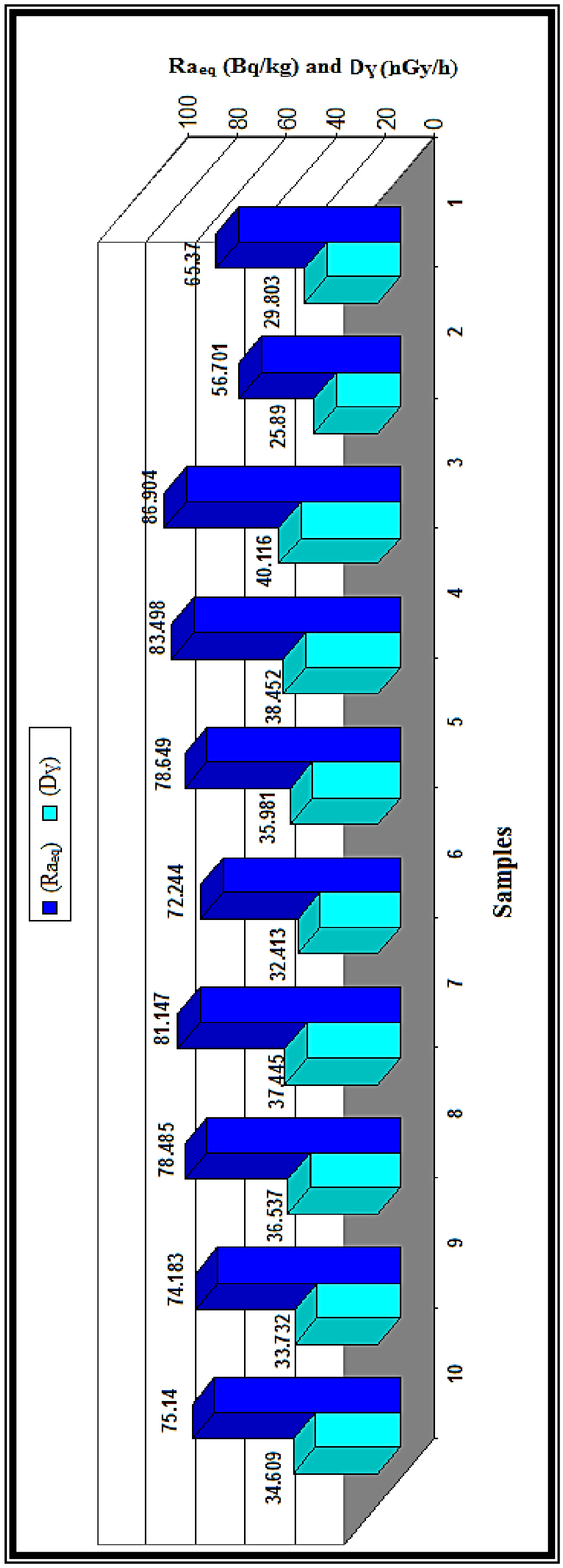

Figure 3. Radium equivalent activity and absorbed dose rate for all the soil samples.

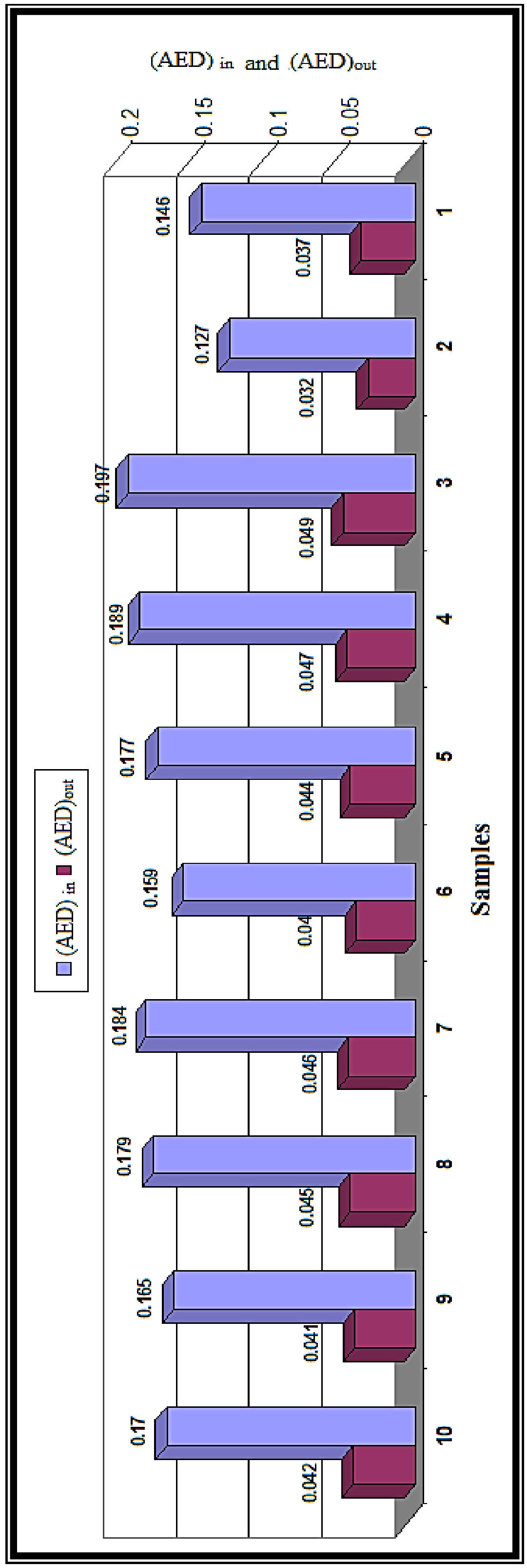

Figure 4. Indoor and outdoor annual effective dose equivalent and activity gamma for all the soil samples.

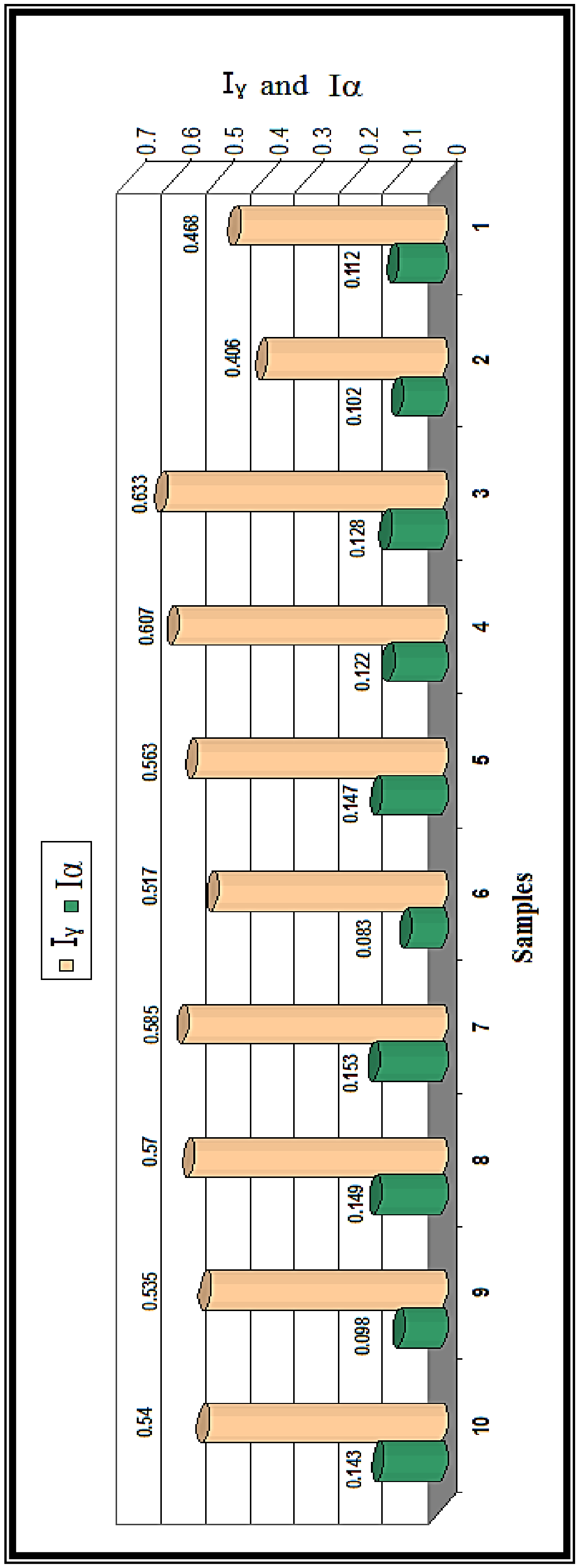

Figure 5. Gamma index and alpha index for all the soil samples.

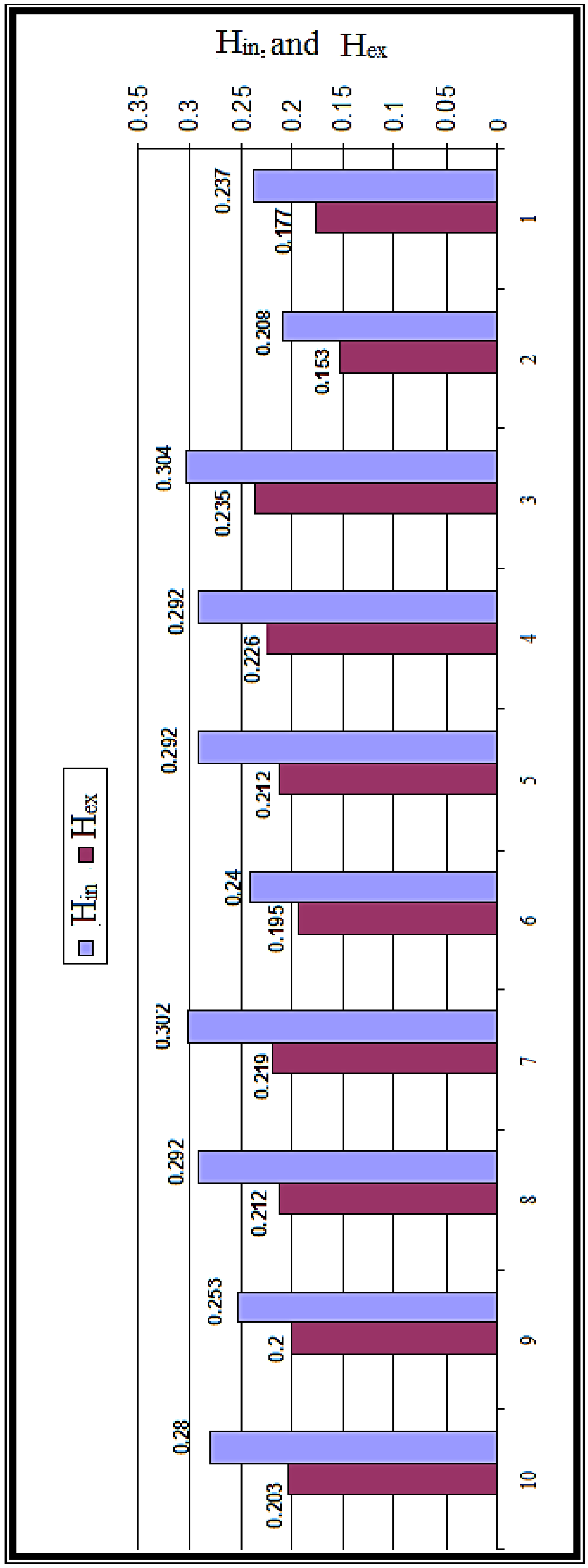

Figure 6. Internal and external hazard indices for all the soil samples.

4. CONCLUSIONS

All results of the present work concerning values of the specific activity for (^{238}U, ^{232}Th and ^{40}K) and radiation hazard indices [Ra_{eq}, D_{γ} , $(AED)_{in}$,$(AED)_{out}$, I_{γ} , Iα, H_{in} and H_{ex}], were found to be lower than their corresponding allowed limits, and hence will pose relatively none series health risk and the radioactive hazard is low for human beings (employees or tourists) in this area.

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