

## **CONCENTRATION OF U-238, U-235, RA-226, TH-232 AND K-40 FOR SOME GRANITE SAMPLES IN EASTERN DESERT OF EGYPT.**

**S. Harb\*, A. H. El-Kamel\*\*, A. I. Abd El-Mageed\*\*, A. Abbady\*, and Wafaa Rashed\*\***

*\* Physics department, Faculty of Science, Qena 83523, South Valley University.*

*\*\*Physics department, Faculty of Science Assiut University.*

### **Abstract**

The distribution of natural radionuclide  $\gamma$ -ray activities and their respective annual effective dose rates, produced by  $^{40}\text{K}$ ,  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{235}\text{U}$  and  $^{232}\text{Th}$ , were determined for granite samples collected along the road of Idfu - Marsa Alam in eastern desert of Egypt. This subject is important in environmental radiological protection, since granites are widely used as building material. The variation in concentration of radionuclides for thirty granite samples was determined. A HPGe spectrometer was used for quantification of gamma emitting radionuclides in the sediments. All sediments contained radionuclides from the uranium and thorium series as well as  $^{40}\text{K}$ .

$^{238}\text{U}$  concentrations in the samples ranged (from  $12.03 \pm 0.88$  to  $19.34 \pm 1.41$  Bq.kg<sup>-1</sup>),  $^{235}\text{U}$  (from  $1.16 \pm 0.11$  to  $4.83 \pm 0.44$ , Bq.kg<sup>-1</sup>),  $^{226}\text{Ra}$  (from  $9.69 \pm 0.82$  to  $18.97 \pm 1.33$  Bq.kg<sup>-1</sup>),  $^{228}\text{Ra}$  ranged (from  $10.24 \pm 0.70$  to  $17.35 \pm 1.29$ )  $^{232}\text{Th}$  range (from  $9.99 \pm 0.67$  to  $17.65 \pm 1.23$  Bq.kg<sup>-1</sup>) and  $^{40}\text{K}$  (from  $298.58 \pm 21.74$  to  $955.78 \pm 69.58$  Bq.kg<sup>-1</sup>).

Radium-equivalent activities ( $Ra_{eq}$ ) in addition to the internal hazard index ( $H_{in}$ ) have also been determined. Granite samples  $Ra_{eq}$  varies between 49.05 and 113.39 Bq.kg<sup>-1</sup>. The total absorbed dose rates in air calculated from the concentrations of the three radionuclides ranged from 24.24 to 58.05 nGy.h<sup>-1</sup> and the external annual effective dose rate of the areas were determined to be between 0.12 and 0.28 mSv.y<sup>-1</sup>. The results can be considered as base values for distribution of natural radionuclides in the region and will be used as reference information to assess any changes in the radioactive background level due to geological processes.

*Key words: natural radionuclides; HPGe spectrometer; absorbed dose rates*

### **Introduction**

Gamma radiation emitted from naturally occurring radioisotopes, such as  $^{40}\text{K}$  and the radionuclides from the  $^{232}\text{Th}$  and  $^{238}\text{U}$  series and their decay products (also called terrestrial background radiation), which exist at trace levels in all ground formations, represents the main external source of irradiation to the human body.

$^{238}\text{U}$ ,  $^{235}\text{U}$ , and  $^{232}\text{Th}$  are the parents of the three natural decay series, called the uranium (U) series, the actinium series and the thorium (Th) series, respectively. Each of these series consists of many daughter products generated through successive decay of parent

radionuclides. In the three long-lived series, decay cascades produce radioactive daughter nuclides, ultimately resulting in the stable isotopes of  $^{208}\text{Pb}$ ,  $^{207}\text{Pb}$  and  $^{206}\text{Pb}$ . Natural uranium is a composite of the isotopes  $^{238}\text{U}$  (99.28%),  $^{234}\text{U}$  (0.0057%), and  $^{235}\text{U}$  (0.72%) While on a mass basis there is far more  $^{238}\text{U}$  than  $^{235}\text{U}$  in a natural sample, the activity ratio is approximately 21:1 (Powell et al, 2007). The behavior and distribution of these decay series radionuclides in the environment are based on their biogeochemistry and half-life ( $t_{1/2}$ ), and the nature of their surroundings.

The naturally occurring radioisotopes are present in different concentrations in sedimentary rocks reflecting the origin of the sediments, the depositional environment and the evolution of the host basin. Furthermore, weathering, interaction with surface and ground waters, secondary mineral precipitation and ion adsorption by clay minerals are some of the many geological processes that can continuously change the radioisotope distribution in the sediments.

The activity concentrations of  $^{226}\text{Ra}$ ,  $^{214}\text{Bi}$ ,  $^{214}\text{Pb}$  (from  $^{238}\text{U}$  decay series),  $^{228}\text{Ac}$ ,  $^{212}\text{Bi}$ ,  $^{212}\text{Pb}$  (from  $^{232}\text{Th}$  decay series) and  $^{40}\text{K}$  were measured using a HPGe spectrometer. According to the rule that exposure should be "as low as reasonably achievable", the radium equivalent, the external hazard index, the absorbed dose and the annual effective dose were assessed and compared with results of other studies and with the worldwide average value in the United Nations Scientific Committee on the Effects of Atomic Radiation report (UNSCEAR, 1988).

## **Material and methods**

### ***Samples collection and preparation***

A total of 30 basalt samples were collected randomly along the road of Idfu and Marsa Alam in eastern desert o Egypt. The masses of the collected samples varied between 250 and 350 gm. The samples were ground and crushed to fine grain size of about 100 mesh to small pieces and sieved in order to homogenize it and remove big size. The samples were then drying at 100 °C for 48 h to ensure that moisture is completely removed. The powdered samples were packed in a standard plastic container (7.5 x 5.5 cm) and after property tightening the threatened lid, the containers were sealed with adhesive tape and left for at least 4 weeks before counting by gamma spectrometry in order to ensure that the daughter products of  $^{226}\text{Ra}$  up to  $^{210}\text{Pb}$  and of  $^{232}\text{Th}$  up to  $^{208}\text{Pb}$  in secular equilibrium with their respective parent radionuclides and then the gamma ray spectrum was accumulated to up to 900 min (5,6).

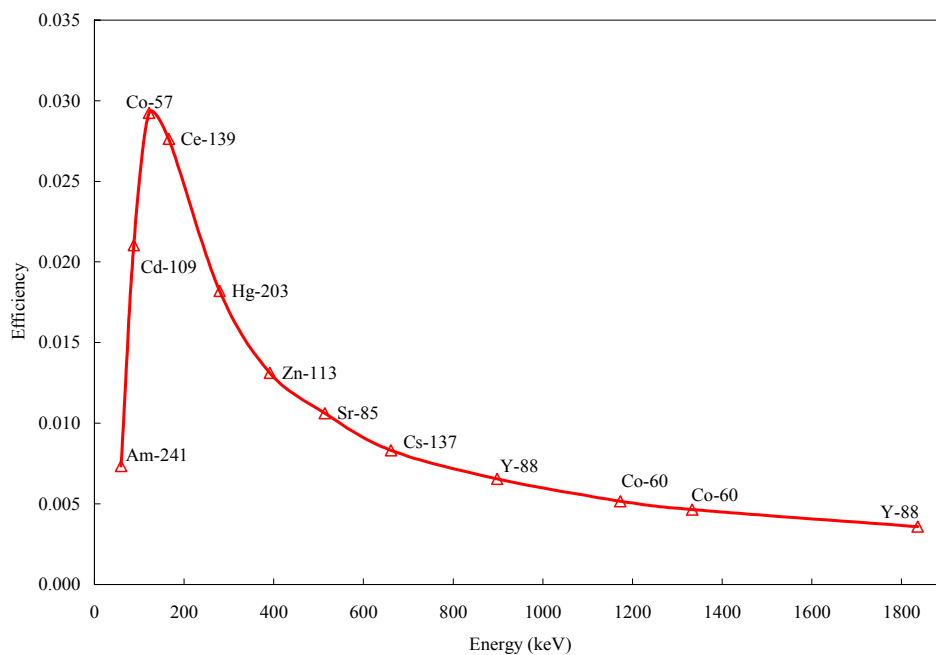
### ***Sample counting and detector efficiency calibration***

The samples containers were placed into the active volume of a shielded high purity germanium (HPGe) detector with its electronic circuits and the lead shield contained two inner concentric cylinders of copper and cadmium.. The detector has a potopeak relative efficiency of about 45% and an energy resolution of 1.91 keV FWHM for the 1332 keV gamma transition of  $^{60}\text{Co}$ . The detector was calibrated in absolute efficiency using a mixed twelve radionuclides gamma standard QCY48, Table I (obtained from Physikalisch Technische Bundesanstalt PTB, Germany). The standard was enclosed in the same plastic container used for the measuring of granite samples Figure 1.

The environmental  $\gamma$ -ray background at the laboratory site was determined using the same standard plastic container under identical measurement conditions from measurements prior, during and after the experiments, it was found that the background levels in the laboratory were maintained constant during the whole period of the measurements.

**Table I:** Radionuclides used for efficiency calibration QCY48 (Harb, 2004)

Nuclides	Energy (keV)	Gamma rays/s	Uncertainty (%)	Half- life time (d)
Am-241	59.54	1128	2.6	158047
Cd-109	88.03	647	6.2	462.6
Co-57	122.1	588	1.5	271.4
Ce-139	165.9	663	1.7	137.64
Hg-203	279.2	1942	1.4	46.6
Zn-113	391.7	2085	4.0	115.09
Sr-85	514	3863	2.5	64.84
Cs-137	661.6	2435	2.0	10958
Y-88	898	6231	1.8	106.6
Co-6	1173	3350	1.5	1924.9
Co-61	1333	3353	1.5	1924.9
Y-88	1836	6586	1.6	106.61



Full energy peak efficiency as a function of gamma ray energy for a typical HPGe

**Calculation of elemental concentration**

Count rates for each detected photopeak and activity for each of the detected nuclides are calculated. The specific activity (in Bq.kg<sup>-1</sup>),  $A_{Ei}$  of a nuclide  $i$ , and for a peak at energy  $E$ , is given by:

$$A_{Ei} = \frac{NP}{t_c \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times M} \dots\dots\dots (1)$$

Where  $NP$  is the number of count in a given peak area corrected for background peaks of a peak at energy  $E$ ,  $\varepsilon(E_\gamma)$  the detection efficiency at energy  $E$ ,  $t$  is the counting lifetime,  $I_\gamma(E_\gamma)$  the number of gammas per disintegration of this nuclide for a transition at energy  $E$ , and  $M$  the mass in kg of the measured sample.

Under the assumption that secular equilibrium was reached between <sup>232</sup>Th and <sup>238</sup>U and their decay products, the  $\gamma$ -ray transitions to measure the concentration of the assigned nuclides in the series (EML, 1990) are as follows:

- (a) <sup>234m</sup>Pa (1001.03 keV) for uranium-238.
- (b) <sup>214</sup>Bi (609.31, 1120.3 and 1764.49 keV), <sup>214</sup>Pb (295.22 and 351.93 keV) for radium-226.
- (c) <sup>208</sup>Tl (583.19 and 2614.53 keV), <sup>212</sup>Pb (238.63 and 300.09 keV) and <sup>212</sup>Bi (727.3 keV) for the thorium series, as well as <sup>228</sup>Ac (338.32, 463.1, 911.20 and 968.97 keV) for radium-228.
- (d) <sup>40</sup>K (1460.83 keV) for potassium.
- (e) <sup>235</sup>U activity concentration was calculated from equation 2.

<sup>235</sup>U and <sup>226</sup>Ra emit gamma-rays of energy 185.7 keV ( $I_\gamma$  57.2%) and 186.2 keV ( $I_\gamma$  3.6%), respectively. The detector energy resolution is not sufficient to easily separate these peaks. Therefore, the concentration of <sup>235</sup>U was calculated by subtracting the fraction of <sup>226</sup>Ra using the following equation:

$$^{235}U = \frac{\left( \frac{\left( \frac{C R_{187}}{\varepsilon_{Peak}} \right)}{M} - [^{226}Ra] I_\gamma ^{226}Ra \right)}{I_\gamma ^{235}U} \dots\dots\dots (2)$$

where  $CR_{187}$  is the count rate of the peak centered at 187 keV,  $\varepsilon_{Peak}$  is the detector efficiency at that energy,  $M$  is the mass of the sample (kg),  $I_\gamma ^{226}Ra$  is the gamma-ray emission fraction for <sup>226</sup>Ra,  $I_\gamma ^{235}U$  is the gamma-ray emission fraction for <sup>235</sup>U,  $[^{226}Ra]$  is the activity concentration of <sup>226</sup>Ra in the sediment (Bq.kg<sup>-1</sup>) based on the average of the <sup>214</sup>Bi and <sup>214</sup>Pb analyses, and  $[^{235}U]$  is the concentration of <sup>235</sup>U in the sediment (Bq.kg<sup>-1</sup>) (Powell et al, 2007).

The analysis of output spectrum was carried out with the help of commercial software programme Maestro 2.1 (EG&G ORTIC), and manually with the use of a spread sheet (Microsoft Excel).

**Calculation of radiological effects**

**Radium equivalent activity ( $Ra_{eq}$ )**

Distribution of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K in environment is not uniform, so that with respect to exposure to radiation, the radioactivity has been defined in terms of radium equivalent activity ( $Ra_{eq}$ ) in Bq.kg<sup>-1</sup> to compare the specific activity of materials containing different amounts of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K (Beretka and Mathew, 1985).

$$Ra_{eq} = C_{Ra} + 1.43 C_{Th} + 0.077 C_K ; \dots\dots\dots (3)$$

Where  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are specific activity concentration in Bq.kg<sup>-1</sup> of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K, respectively. The index is useful to compare the specific activity of materials containing different concentrations of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K.

**Estimation of gamma radiation doss (D):**

UNSCEAR (1988) has given the dose conversion factors for converting the activity concentrations of <sup>238</sup>U, <sup>232</sup>Th and <sup>40</sup>K into doses (nGy.h<sup>-1</sup> per Bq.kg<sup>-1</sup>) as 0.427, 0.662 and 0.043, respectively.

The gamma radiation population doses of those living in the area are given as:

$$D = 0.427C_U + 0.662 C_{Th} + 0.043 C_K; \dots\dots\dots (4)$$

Where D is the dose rate in nGy.h<sup>-1</sup> and C<sub>U</sub>, C<sub>Th</sub> and C<sub>K</sub> are the concentrations of uranium, thorium and potassium, respectively.

**Representative level index (I<sub>yr</sub>):**

In order to examine whether the samples meet these limits of dose criteria, Another radiation hazard index, the representative level index, I<sub>yr</sub>, used to estimate the level of γ-radiation hazard associated with the natural radionuclides in specific investigated samples, is defined as (NEA-OECD, 1979) from the following Equation (5):

$$I_{yr} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500}; \dots\dots\dots (5)$$

Where A<sub>Ra</sub>, A<sub>Th</sub> and A<sub>K</sub> are the concentrations of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K, respectively, in Bq.kg<sup>-1</sup>.

**External hazard index (H<sub>ex</sub>):**

The ultimate use of the measured activities in building materials is to estimate the radiation dose expected to be delivered externally if a building is constructed using these materials. To limit the annual external gamma-ray dose to 1.5 mSv.y<sup>-1</sup> (Saito et al., 1998; (UNSCEAR, 2000), the external hazard index (H<sub>ex</sub>) is given by the following equation:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}; \dots\dots\dots (6)$$

**Internal hazard index (H<sub>in</sub>):**

The internal exposure to <sup>222</sup>Rn and its radioactive progeny is controlled by the internal hazard index (H<sub>in</sub>) which is given by (Quindos et al., 1987; Cottens, 1990).

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}; \dots\dots\dots (7)$$

For the safe use of a material in the construction of dwellings, index (H<sub>in</sub>) should be less than unity and the maximum value of (H<sub>in</sub>) to be less than unity (Iqbal et al., 2000).

**Results and discussion**

As can be seen from Table 2 the activities of the <sup>235</sup>U, <sup>238</sup>U, <sup>226</sup>Ra, <sup>228</sup>Ra, <sup>232</sup>Th, and <sup>40</sup>K activities, calculated with the individual activity estimates and weighted by the reciprocal of their variances. The indicated <sup>226</sup>Ra value corresponds to the mean calculated with the two <sup>214</sup>Pb and the three <sup>214</sup>Bi full absorption peaks.

The concentration of <sup>235</sup>U, <sup>238</sup>U and <sup>226</sup>Ra varied from 1.16±0.11 to 4.83±0.44, from 12.03±0.88 to 19.34±1.41 and from 9.69±0.82 to 18.97±1.33 with average values 2.23±0.21, 15.64±1.14 and 13.72±1.01 Bq.kg<sup>-1</sup>, respectively.

Also Table 2 presents the activity concentration of <sup>228</sup>Ra, <sup>232</sup>Th, and <sup>40</sup>K ranged from 10.24±0.70 to 17.35±1.29, from 9.99±0.67 to 17.65±1.23 and from 298.58±21.74 to 955.78±69.58 with average values 14.12±1.06, 14.46±1.08 and 405.73±29.54 Bq.kg<sup>-1</sup>, respectively. All the measured samples have <sup>238</sup>U and <sup>232</sup>Th concentrations less than the average value of 35 Bq.kg<sup>-1</sup> from the UNSCEAR survey. The <sup>238</sup>U/<sup>226</sup>Ra and the <sup>232</sup>Th/<sup>228</sup>Ra activity ratio ranged from 0.83 to 1.60 with an average value of 1.17, and from 0.88 to 1.17 with an average value of 1.03, respectively, which closed to the unity.

**Table.2:** The activities concentrations of the <sup>235</sup>U, <sup>238</sup>U, <sup>226</sup>Ra, <sup>228</sup>Ra, <sup>232</sup>Th, and <sup>40</sup>K in Bq.kg<sup>-1</sup> for the measured samples.

Samples No.	<sup>235</sup> U	<sup>238</sup> U	<sup>226</sup> Ra	<sup>228</sup> Ra	<sup>232</sup> Th	<sup>40</sup> K	<sup>238</sup> U/ <sup>226</sup> Ra	<sup>232</sup> Th/ <sup>228</sup> Ra
1	1.90±0.18	14.09±1.03	13.21±0.95	15.09±1.11	14.92±1.14	345.05±25.12	1.07	0.99
2	2.03±0.19	13.08±0.95	13.09±1.03	14.17±0.98	13.13±0.94	378.24±27.54	1.00	0.93
3	1.92±0.18	12.70±0.92	12.97±0.87	13.38±0.98	13.25±0.94	373.70±27.21	0.98	0.99
4	1.87±0.17	17.89±1.30	12.39±0.97	12.51±0.84	13.63±1.00	351.57±25.59	1.44	1.09
5	2.41±0.22	17.66±1.29	15.45±1.22	16.56±1.54	15.00±1.08	402.53±29.30	1.14	0.91
6	1.37±0.13	16.34±1.19	12.51±0.87	16.08±1.10	16.97±1.47	402.58±29.31	1.31	1.06
7	2.16±0.20	12.91±0.94	13.72±1.14	15.35±1.15	17.65±1.23	360.01±26.21	0.94	1.15
8	2.14±0.20	13.42±0.98	14.05±0.99	14.52±1.09	14.83±1.07	351.77±25.61	0.95	1.02
9	1.16±0.11	12.58±0.92	12.07±0.89	10.61±0.93	10.12±0.74	356.50±25.95	1.04	0.95
10	2.18±0.20	17.60±1.28	11.72±0.88	12.02±1.18	13.33±1.12	362.29±26.38	1.50	1.11
11	2.31±0.21	14.31±1.04	14.70±1.05	13.72±0.99	14.77±1.08	365.30±26.59	0.97	1.08
12	2.23±0.21	17.66±1.29	15.05±1.09	17.35±1.29	16.78±1.33	360.98±26.28	1.17	0.97
13	1.23±0.11	13.14±0.96	11.64±0.92	11.88±0.83	13.35±0.94	327.09±23.81	1.13	1.12
14	2.43±0.22	19.34±1.41	14.01±1.01	14.24±1.03	16.22±1.33	392.71±28.59	1.38	1.14
15	2.13±0.20	14.11±1.03	17.08±1.24	16.68±1.21	16.45±1.19	392.01±28.54	0.83	0.99
16	2.10±0.19	14.77±1.08	11.92±0.95	16.48±1.17	16.11±1.12	373.29±27.18	1.24	0.98
17	1.28±0.12	15.47±1.13	10.64±0.86	10.24±0.70	10.02±0.68	354.67±25.82	1.45	0.98
18	1.96±0.18	16.15±1.18	11.12±0.86	14.52±1.04	15.63±1.24	387.44±28.21	1.45	1.08
19	1.94±0.18	12.03±0.88	9.69±0.82	12.00±0.92	12.14±0.88	348.54±25.37	1.24	1.01
20	2.41±0.22	13.80±1.00	13.97±1.05	14.89±1.15	13.71±0.99	375.98±27.37	0.99	0.92
21	2.29±0.21	15.33±1.12	12.74±0.97	13.73±1.06	15.19±1.12	395.43±28.79	1.20	1.11
22	2.70±0.25	19.34±1.41	17.62±1.19	16.28±1.41	16.21±1.19	442.29±32.20	1.10	1.00
23	2.20±0.20	18.06±1.31	13.90±0.96	13.18±0.99	13.62±1.01	382.80±27.87	1.30	1.03
24	2.08±0.19	15.65±1.14	14.98±1.04	15.34±1.11	13.48±0.98	304.43±22.16	1.04	0.88
25	2.40±0.22	17.57±1.28	14.21±1.08	14.81±1.07	15.69±1.08	398.34±29.00	1.24	1.06
26	2.40±0.22	13.36±0.97	11.77±0.90	10.30±0.84	9.99±0.67	298.58±21.74	1.13	0.97
27	4.21±0.39	18.78±1.37	11.72±0.81	15.27±0.67	15.70±1.31	488.10±35.53	1.60	1.03
28	4.83±0.44	19.33±1.41	17.00±1.37	14.61±1.28	15.94±1.14	955.78±69.58	1.14	1.09
29	2.48±0.23	13.95±1.02	13.59±1.32	11.29±1.29	13.25±0.92	298.07±21.70	1.03	1.17
30	2.27±0.21	18.84±1.37	18.97±1.33	16.47±0.85	16.86±1.36	845.74±61.57	0.99	1.02
Min.	1.16±0.11	12.03±0.88	9.69±0.82	10.24±0.70	9.99±0.67	298.58±21.74	0.83	0.88
Max.	4.83±0.44	19.34±1.41	18.97±1.33	17.35±1.29	17.65±1.23	955.78±69.58	1.60	1.17
Mean Value	2.23±0.21	15.64±1.14	13.72±1.01	14.12±1.06	14.46±1.08	405.73±29.54	1.17	1.03

**Table.3:** The calculated values of External hazard index ( $H_{ex}$ ), Internal hazard index ( $H_{in}$ ), level index  $I_{yr}$ , dose rate and radium equivalent  $Ra_{eq}$  of the samples under investigation.

Sample	$Ra_{eq}$	$D$	$I_{yr}$	$H_{in}$	$H_{ex}$
1	61.12	30.10	0.64	0.17	0.20
2	60.99	30.25	0.65	0.16	0.20
3	60.69	30.08	0.64	0.16	0.20
4	58.94	29.16	0.62	0.16	0.19
5	67.90	33.53	0.73	0.18	0.23
6	67.78	33.58	0.69	0.18	0.22
7	66.68	32.76	0.69	0.18	0.22
8	62.35	30.68	0.66	0.17	0.21
9	53.99	26.89	0.58	0.15	0.18
10	58.67	29.12	0.61	0.16	0.19
11	63.95	31.49	0.69	0.17	0.21
12	66.83	32.79	0.71	0.18	0.22
13	55.93	27.63	0.58	0.15	0.18
14	67.45	33.31	0.70	0.18	0.22
15	70.78	34.75	0.77	0.19	0.24
16	63.70	31.52	0.65	0.17	0.20
17	52.28	26.14	0.55	0.14	0.17
18	63.30	31.45	0.64	0.17	0.20
19	53.88	26.88	0.55	0.15	0.17
20	62.52	30.91	0.67	0.17	0.21
21	64.91	32.19	0.67	0.18	0.21
22	74.86	36.93	0.81	0.20	0.25
23	62.86	31.11	0.67	0.17	0.21
24	57.69	28.19	0.64	0.16	0.20
25	67.31	33.27	0.71	0.18	0.22
26	49.05	24.24	0.53	0.13	0.16
27	71.76	35.99	0.72	0.19	0.23
28	113.39	58.05	1.14	0.31	0.35
29	55.49	27.17	0.60	0.15	0.19
30	108.20	54.89	1.11	0.29	0.34
Min.	49.05	24.24	0.53	0.13	0.16
Max.	113.39	58.05	1.14	0.31	0.35
Mean Value	65.51	32.50	0.69	0.18	0.21

It is important to assess the gamma radiation hazards to human associated with the used these samples for buildings; these were done by calculating the different radiation hazard indices. The radium equivalent activities of samples under investigation were calculated on the basis of equation (3) and are shown in Table 2. The average  $Ra_{eq}$  value for the studied area 65.51 Bq.kg<sup>-1</sup> are below the internationally accepted value 370 Bq.kg<sup>-1</sup>.

Along the road of Idfu and Marsa Alam in eastern desert of Egypt, the absorbed dose rate fluctuated from 24.24 to 58.05 nGy.h<sup>-1</sup>, with a mean value of 32.50 nGy.h<sup>-1</sup>. These calculated values were lower than the estimate of average global terrestrial radiation of 55 nGy.h<sup>-1</sup> except sample No. 28 because of the uranium concentration in the sampling region is more dependent upon the climate, seasonal variability and the effects of evapotranspiration and the concentration of suitable complexing agents which can increase the solubility of uranium. The concentrations vary considerably spatially and temporally. The temporal variation may be seasonal, affecting changes in rainfall and run-off. Increased rainfall may result in more effective leaching and/or transport of uranium and lead to an increase in uranium concentration, consequently increasing of radiological effects.

The value of radiation hazard index called the representative level index  $I_{\gamma r}$  equation (5) must be less than unity for the radiation hazard to be negligible, i.e. the average value of level index for the studied samples in this work ranging from 0.53 to 1.14. The  $I_{\gamma r}$  values are below the internationally accepted value 1 except in one sample.

The calculated external gamma-ray dose have an average values less than the acceptable value  $1.5 \text{ mSv y}^{-1}$  (Saito et al., 1998; UNSCEAR, 2000), as shown in Table 3.

The external hazard index ( $H_{ex}$ ) and internal hazard index ( $H_{in}$ ), values for the studied areas are below the internationally accepted values. For the safe use of a material in the construction of dwellings, index ( $H_{in}$ ) should be less than unity (from 0.13 to 0.31). For the maximum value of ( $H_{in}$ ) to be less than unity (Iqbal et al., 2000). The average calculated values of ( $H_{in}$ ) for the samples studied in the investigated area ranging from 0.16 to 0.35 as shown in Table 3.

Therefore, the use of these materials in construction of dwellings is considered to be safe for inhabitants.

### **Conclusions**

The variation in concentration of radionuclides for thirty granite samples was determined. The activity concentrations of  $^{226}\text{Ra}$ ,  $^{214}\text{Bi}$ ,  $^{214}\text{Pb}$  (from  $^{238}\text{U}$  decay series),  $^{228}\text{Ac}$ ,  $^{212}\text{Bi}$ ,  $^{212}\text{Pb}$  (from  $^{232}\text{Th}$  decay series) and  $^{40}\text{K}$  were measured using a HPGe spectrometer. The mean value activity concentration of  $^{238}\text{U}$  in samples was  $(15.64 \pm 1.14 \text{ Bq.kg}^{-1})$ ,  $^{235}\text{U}$   $(2.23 \pm 0.21 \text{ Bq.kg}^{-1})$ ,  $^{226}\text{Ra}$   $(13.72 \pm 1.01 \text{ Bq.kg}^{-1})$ ,  $^{228}\text{Ra}$  ranged  $(14.12 \pm 1.06)$   $^{232}\text{Th}$   $(14.46 \pm 1.08 \text{ Bq.kg}^{-1})$  and  $^{40}\text{K}$   $(405.73 \pm 29.54 \text{ Bq.kg}^{-1})$ . The results can be considered as base values for distribution of natural radionuclides in the region and will be used as reference information to assess any changes in the radioactive background level due to geological processes.

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