УДК 539.16+616-006+631.438

E. S. Abd El-Halim[1], Nadia Walley El-Dine[1,*], Samia M. El-Bahi[1], Ibrahim E. El-Aassy[2], Enass M. El-Sheikh[2], Asma Mohammed Al-Abrdi[3]

[1] Faculty of Women for Arts, Science and Education, Physics Department, Ain Shams University, Cairo, Egypt
[2] Nuclear Materials Authority, Cairo, Egypt
[3] Physics Department, College of Science, Omar Al-Mukhtar University, Al-Bayda, Libya

*Corresponding author: nadia.walley@women.asu.edu.eg

EXCESSIVE LIFETIME CANCER RISK AND NATURAL RADIOACTIVITY MEASUREMENTS OF GRANITE AND SEDIMENTARY ROCK SAMPLES

Eighteen samples of sediments collected from Um Bogma, South Western Sinai, and twelve granite samples collected from Gabal Gattar, North Eastern Desert in Egypt have been investigated. Concentrations of radionuclides in sediment and granite samples were determined by γ-ray spectrometer using HPGe detector with a specially designed shield. The content of uranium is high in sediments and granite samples, and the content of ^{40}K in granite is higher than that in sediments. The absorbed dose rate ranged from 419 to 3908 nGy/h for sediment samples and from 1002 to 1307 nGy/h for granite samples. The representative external hazard indicies (H_{ex}) for sediment and granite samples were estimated. The state of radioactive disequilibrium in the U-series at Um Bogma and Gabal Gattar areas were also studied. The activity ratios between ^{226}Ra/^{238}U for sediment and granite were calculated. Thorium to Uranium concentration ratios (Clark value) was also estimated. The total excess lifetime cancer risk (ELCR) was measured.

Keywords: natural radioactivity, HPGe detector, sediment, granite, disequilibrium, excess lifetime cancer risk, activity ratio.

Introduction

Environmental natural radioactivity levels are depending on the geological and geographical structure [1]. Nevertheless, weathering, sedimentation, leaching, absorption processes, and the movement of groundwater may influence activity levels of natural radionuclides [2]. Assessment of radionuclides in solids and rocks in many parts of the world has been increasing in the past two decades because of their hazard on the health of the population [3].

The understanding and awareness about radiation in outdoor and indoor environment is important for determining the population exposure to radiation.

The outdoor exposure is from the geological formation, sand, soil, etc., to which human beings are exposed. The radioactivity of the soil environment is one of the main sources of exposure to humans, and the decay products of ^{238}U and ^{232}Th series and ^{40}K represent the main external source of radiation to human body. According to investigation, these radionuclide become part of the soil in the following ways: 1) as part of earth's original crust (i.e. primordial radionuclides), 2) produced and deposited by cosmic ray interactions (i.e. cosmogenic radionuclides) and 3) through man-made release (i.e. man-made radionuclides) [4].

The indoor exposure is due to the gamma-rays radiation from the building materials and alpha radiation from the decay of radon.

It has been observed that the natural radiation that appears at different horizons of the soils depends primarily on the geological formation in each region of the world. Similarly, trace quantities of radioactive elements have been reported in all rock types, however concentrations vary considerably based on rock types and also on the types of radioisotope. High radiation levels from ^{40}K, ^{238}U and ^{232}Th have been associated with granitic and silicic igneous rocks [5], while lower levels of radiations are associated with sedimentary rock with the exception of shale and phosphate [6].

In this study, the natural radioactivity concentration of ^{40}K, ^{238}U (^{226}Ra), and ^{232}Th in some sedimentary and granite rock samples collected in different regions in Egypt have been investigated.

The results were used to assess the radiological hazard associated with the absorbed gamma dose rate D, the annual effective dose rate, radium equivalent activities (Ra_{eq}) and external hazard index (H_{ex}) from gamma radiation. Also excessive lifetime cancer risk in the samples under investigation was calculated.

Geologic setting

The main exposed sedimentary rock units are belonging to seven formations of Paleozoic Era; four of them are belonging to early Carboniferous and the other to the Cambrian.

The Cambrian formations are Sarabit El Khadim, Abu Hamata and Adediya, while the Carboniferous formations are Um Bogma, El Hashash, Magharet El Miah, and Abu Zarab. We don't faced all of them in the area of the study (Fig. 1).

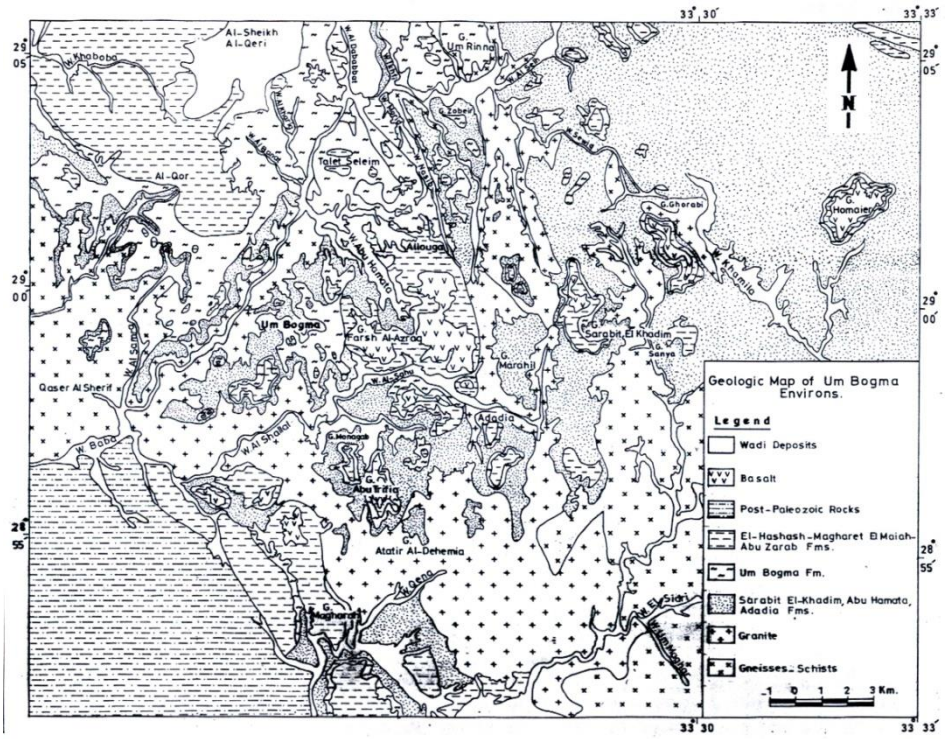

Fig. 1. Geologic map of Um Bogma area [10, 11].

This study is supported by the Um Bogma Formation, which is considered to be the most important formation as it hosts most of the radioactive anomalies. It is subdivided into three members as the following:

a) Lower Shaley-Ore member – is the oldest rock of the Carboniferous and it is consisted of black shale and thin sandy dolomite and manganese-iron ore [7]. Authors of [8] introduced the karstification process in this member and the formation of karstified dolostone rocks with intrakarstic product manganese ores and caliche nodules [9]. This rock unit is highly radioactive, where U/Th concentration reaches 1000 - 2000 ppm (parts per million);

b) Middle Marly Dolostone-Siltstone member – is also karstified and lateritized covering the soil, thickness is about 6 - 8 m and the radioactive content is 100 - 250 ppm. It is composed of marl with siltstone and gibbsite-bearing siltstone;

c) Upper Dolostone member – is unconformably overlying the karstified and lateritized soil and consists of bedded dolostone with thin shale interbeds. The dark grey claystone in different localities is enriched with sulphur products from oxidation of calchopyrite and pyrite, thickness is 3 – 4 m. The dolostone beds are present as step-like forms and in some parts are not deposited and variated to grey claystone. It is low radioactive (5 ppm) while the dark grey claystone contains 60 – 100 ppm. El Hashash formation is unconformably overlying Um Bogma formation. It is consisted of sandstone, and thin siltstone at the base. The thickness is about 10 – 20 m, and it is low radioactive except the alunite at the base.

The geological environments of the North Eastern Desert, with the uranium distribution drew attention to the importance of Gabal Gattar located 35 km to the west of Hurghada city, at the Red Sea coast (Fig. 2). Gabal Gattar granite is the host rock for uranium mineralization including seven uranium mineralized occurrences, namely GI-GVII [12]. GV is the site under investigation. This site is characterized by high radioactivity and the presence of uranium mineralization at the contact zone between altered granite of Gabal Gattar and the Hammat sedimentary rock [13]. The granite of G. Gattar in this contact zone is strongly altered. It is mainly consisted of quartz and potash feldspars with some biotites, in addition to some accessory minerals like hematites and calcite. It is noticed that sometimes the quartz in this granite at the contact zone is dissolved and designated as episyenitized granite. This new rock is very porous and filled with cavities, which occasionally include uranium mineralization. Many authors discussed the characteristics of Hammamat sediments [14]. The Hammamat sedimentary rocks in this site are mainly composed of slates and siltstone with angular to sub-angular quartz crystals embedded in a clay matrix. Feldspar minerals are noticed in relatively small amount. Sericite forms the majority of the remainder and is sometimes replaced by carbonates. These Hammamat sediments, especially near the contact zone, are partly bleached, altered and moderately

silicified. They have various colors as gray, greenish gray and black [15]. Altered granites form a remarkable exposure in the western sector of the study area and a narrow strip to the east of Gabal Gattar pluton. They are essentially consisted of biotite and muscovite granodiorites. Younger granites are predominantly formed of coarse to medium-grained pink granites. The rocks vary in color from pink to redish pink in fresh samples but they tend to turn into pale or reddish brown in color especially along the shear zones and the intersection of fractures due to alteration [16 - 18].

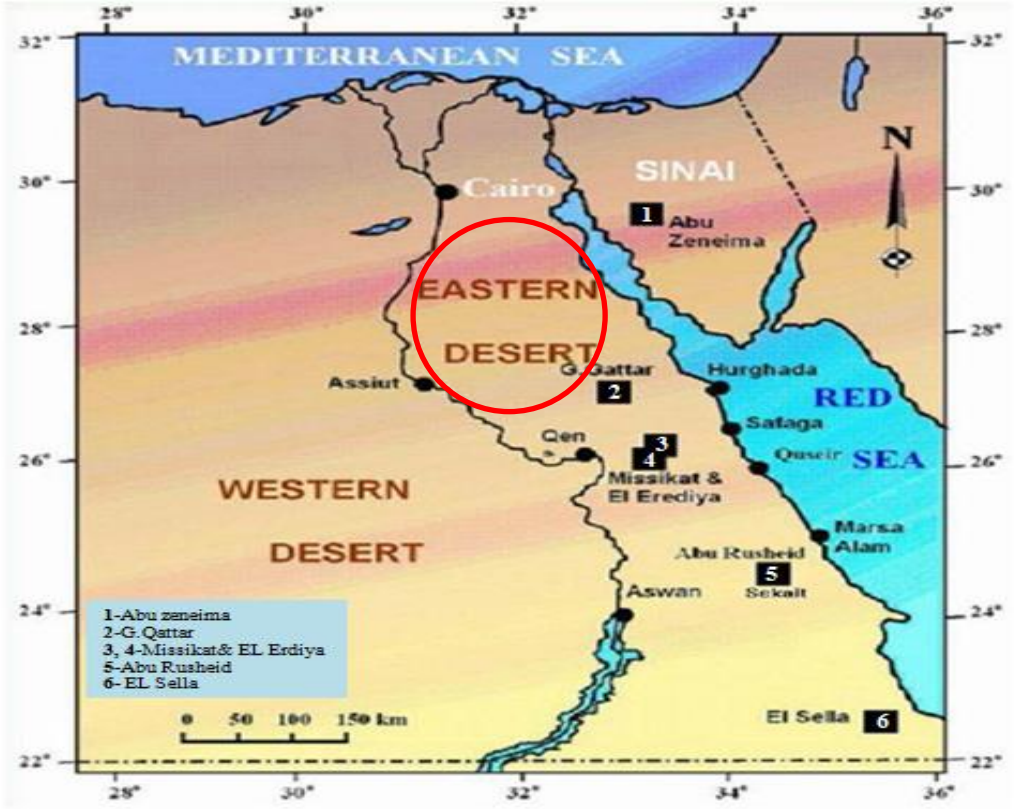

Fig. 2. Location map of G. Gattar (2) [13].

Materials and methods

Sampling and samples preparation

For radioactivity measurements, a total of thirty samples each of mass 1 kg, were collected from different locations in Egypt. Eighteen samples were from Um Bogma, southwest, Sinai. Twelve granite samples were collected from Gabal Gattar, North Eastern Desert. The samples were ground, homogenized and sieved to about 200 mesh.The samples were first weighted and placed in polyethylene bottles of 250 cm^3 volume. The bottles were completely sealed for more than one month to allow radioactive equilibrium to be reached. This step is necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample.

Experiment set up

High purity vertical germanium was coupled to a personal computer with a special electronic card to make it equivalent to a multichannel analyzer. The system also contains the usual electronic components of preamplifier, amplifier and power supply. The detector has resolution (FWHM) of 1.85 keV for the 1332.5 keV γ-ray line of ^{60}Co. The γ-ray spectrometer energy calibration was performed using ^{60}Co, ^{226}Ra and ^{241}Am point sources. The detector was surrounded by a special heavy lead shield of 10 cm thickness with inside dimensions of 28 cm diameter and 40 cm height. The absolute detection efficiency of the HPGe detector was determined by using three well-known reference materials obtained from the International Atomic Energy Agency for U, Th and K activity measurements: RGU-1, RGTh-1 and RGK-1 [19, 20]. The sample containers were placed on top of the detector for counting. The same geometry and size were used for both the samples and the reference materials [21]. The uranium standard (RGU-1) is U-ore diluted with silica with 4940 $Bq \cdot kg^{-1}$ of ^{238}U, 228 $Bq \cdot kg^{-1}$ of ^{235}U, a negligible amount of ^{40}K (less than 0.63 $Bq \cdot kg^{-1}$) and some traces of ^{232}Th (less than 4 $Bq \cdot kg^{-1}$). The thorium standard (RGTh-1) is

Th-ore diluted with silica having 3250 Bq kg^{-1} of ^{232}Th, but containing some ^{238}U (78 Bq·kg^{-1}) and ^{40}K (6.3 Bq·kg^{-1}). The potassium calibration standard (RGK-1) is produced from high purity (99.8 %) potassium sulphate with 14000 Bq·kg^{-1} of potassium with uranium and thorium contents lower than 0.001 and 0.01 ppm, respectively [20].

The γ-ray transitions used to measure the concentration of the assigned nuclides in the series are the following. ^{238}U was determined from the gamma rays emitted by its daughter products [22] ^{234}Th and ^{234m}Pa activities determined from the 63.3 and 1001 keV photo peaks, respectively, ^{214}Bi (609.3, 1120.3, 1238.1, 1377.7 and 1764.5 keV), ^{214}Pb (295.1 and 352.0 keV). The specific activity of ^{226}Ra was measured using the 186.1 keV from its own gamma-ray (after the subtraction of the 185.7 keV of ^{235}U). The specific activity of ^{232}Th was measured using the 338.4, 911.2 and 968.9 keV lines from ^{228}Ac and 583 keV peak from ^{208}Tl, and ^{40}K was measured using 1460.8 keV peak.

In order to determine the background contribution due to naturally occurring radionuclides in the environment around the detector, an empty polyethylene beaker of the same 250 cm^3 volume was counted with the same geometrical conditions as the sample. The measurement time for both activity and background measurement was 70000 s. The background spectra were used to correct the net gamma- ray peak areas for the studied isotopes.

Results and discussion

The activity concentration of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K (in Bq/kg) in the samples under investigation are listed in Table 1.

Table 1. **The activity concentration of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq/kg with ^{226}Ra/ ^{238}U ratios of the sediment samples**

Samples	^{226}Ra	^{238}U	^{232}Th	^{40}K	^{226}Ra/^{238}U
2S	1154 ± 35	980 ± 30	57.2 ± 1.7	479 ± 14	1.18 ± 0.03
3S	4850 ± 150	6320 ± 190	58.4 ± 1.8	345 ± 10	0.76 ± 0.02
4S	2390 ± 70	2320 ± 70	68.2 ± 2.1	562 ± 17	1.03 ± 0.03
5S	4430 ± 130	3540 ± 110	49.7 ± 1.5	445 ± 13	1.25 ± 0.04
6S	1770 ± 60	914 ± 27	44.5 ± 1.3	376 ± 11	1.94 ± 0.05
7S	1920 ± 60	1850 ± 60	63.5 ± 1.9	489 ± 15	1.04 ± 0.03
8S	2450 ± 70	3130 ± 90	59.2 ± 1.8	353 ± 11	0.78 ± 0.02
9S	2710 ± 90	2220 ± 70	54.3 ± 1.6	337 ± 10	1.22 ± 0.04
11S	759 ± 23*	716 ± 22*	126 ± 4**	296 ± 9	1.06 ± 0.03
12S	1144 ± 34	1103 ± 33	75.5 ± 2.3	677 ± 20	1.04 ± 0.03
13S	2980 ± 90	2265 ± 70	42.2 ± 1.3	343 ± 10	1.31 ± 0.04
14S	4550 ± 140	3410 ± 100	51.4 ± 1.5	541 ± 16	1.33 ± 0.04
15S	1730 ± 50	1410 ± 40	30.9 ± 0.9*	459 ± 14	1.23 ± 0.04
16S	2320 ± 70	2180 ± 70	73.4 ± 2.2	362 ± 11	1.06 ± 0.03
17S	2080 ± 70	1950 ± 60	47.6 ± 1.4	275 ± 8*	1.06 ± 0.03
18S	7060 ± 210	7100 ± 210	74.7 ± 2.2	757 ± 23	0.99 ± 0.03
19S	4110 ± 130	4110 ± 130	65.7 ± 2.0	524 ± 16	1.00 ± 0.03
20S	8750 ± 260**	840 ± 250**	91.4 ± 2.7	902 ± 14**	1.04 ± 0.03

* The lower value.
** The higher value.

From Table 1 it is clear that the activity concentrations of the studied sediment samples are higher than the permissible levels for uranium and radium (33 and 32 Bq/kg, respectively). The activity concentrations are higher than the permissible level (45 Bq/kg) for thorium except of samples No. 6S, 13S and 15S, while eight samples have potassium activity lower than the permissible level of 412 Bq/kg in accordance with UNSCEAR 2010 [23] (Fig. 3).

The activity concentrations for different nuclides in Bq/kg for 12 granite samples are given in Table 2.

From Table 2 it is clear that the activity concentrations of the studied granite samples are higher than the permissible level for radium (32 Bq/kg), uranium (33 Bq/kg), thorium (45 Bq/kg) and potassium (412 Bq/kg) [23] (Fig. 4).

The activity ratios ^{226}Ra/^{238}U were calculated for sediment (see Table 1) and granite (see Table 2). Most of the sedimentary samples show equilibrium (0.9 - 1.1) between ^{226}Ra and ^{238}U, while 9 samples show disequilibrium (1.22 - 1.94). All the granite samples show state of equilibrium between ^{226}Ra and ^{238}U except of one sample.

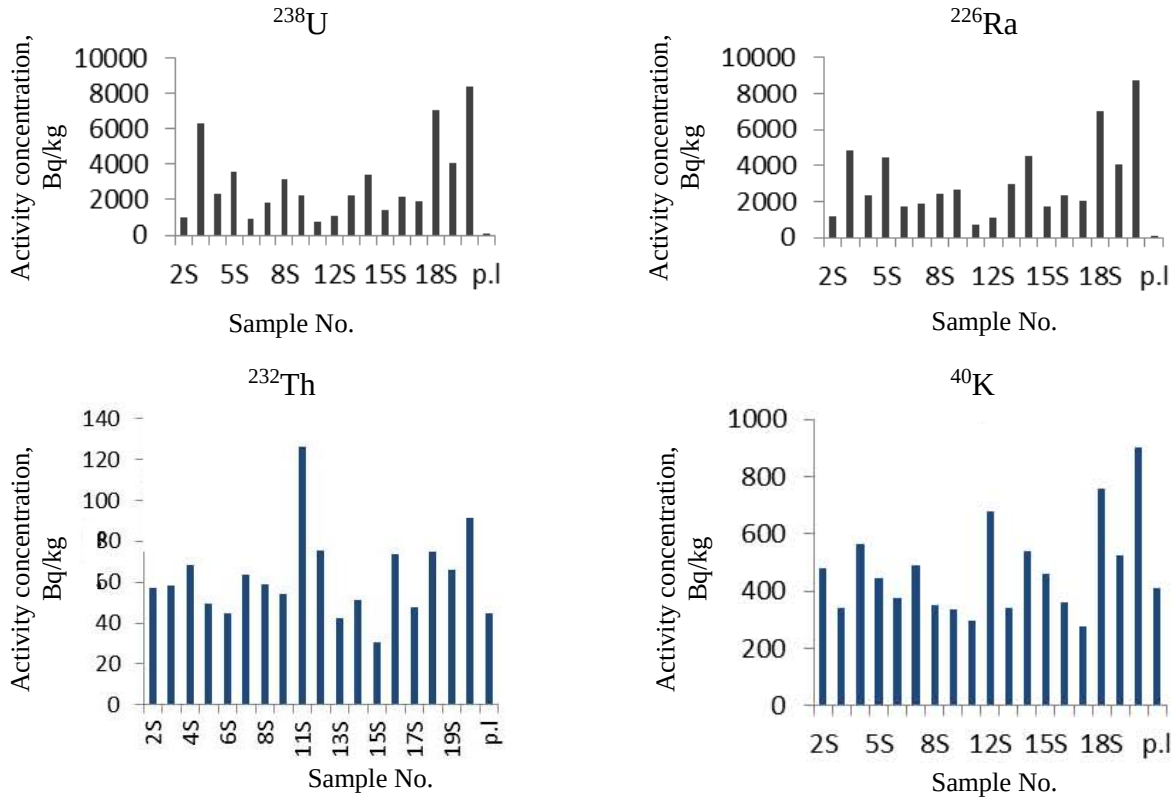

Fig. 3. The activity concentrations for ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K in the sediment samples in comparison with the permissible limits (p.l.).

Table 2. **The activity concentration of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq/kg with ^{226}Ra/^{238}U ratios in granite samples**

Samples	^{226}Ra	^{238}U	^{232}Th	^{40}K	^{226}Ra/^{238}U
1G	2560 ± 80	2510 ± 80	82.8 ± 2.5	1309 ± 40	1.02 ± 0.03
2G	2260 ± 70	2370 ± 70	81.7 ± 2.5	1195 ± 36	0.96 ± 0.03
3G	2740 ± 80	2430 ± 70	79.5 ± 2.4	1254 ± 38	1.13 ± 0.03
4G	2090 ± 60*	2310 ± 70*	71.9 ± 2.2*	1162 ± 35*	0.90 ± 0.03
5G	2320 ± 70	2680 ± 80	89.1 ± 2.7	1264 ± 38	0.86 ± 0.02
6G	2420 ± 70	2480 ± 80	88.4 ± 2.7	1282 ± 39	0.98 ± 0.03
7G	2410 ± 70	2410 ± 80	94.9 ± 2.9**	1299 ± 40	1.00 ± 0.03
8G	2560 ± 80	2580 ± 80	89.0 ± 2.7	1312 ± 39	0.99 ± 0.03
9G	2750 ± 80**	2750 ± 80**	81.8 ± 2.5	1373 ± 41	1.00 ± 0.03
10G	2570 ± 80	2530 ± 80	90.0 ± 2.7	1330 ± 40	1.02 ± 0.03
11G	2450 ± 70	2470 ± 80	93.2 ± 2.8	1379 ± 41**	0.99 ± 0.03
12G	2510 ± 80	2580 ± 80	91.8 ± 2.8	1361 ± 41	0.98 ± 0.03

* The lower value.
** The higher value.

The concentrations of ^{238}U (ppm) and ^{232}Th (ppm) and their ratios for sediments and granite samples are shown in Tables 3 and 4.

From Table 3, the concentrations of ^{238}U range between 57.7 and 676 ppm, and ^{232}Th between 7.6 and 31 ppm, while the ^{232}Th/^{238}U ratios range between 0.279 and 0.5377 which is lower than the Clark's value (3.5), which indicates that these locations are enriched in uranium.

Table 4 gives the radionuclides concentration of ^{238}U and ^{232}Th for the granite samples at G. Qattar, in which the concentrations are varying between 187 and 223 ppm, and 17.7 and 23.4 ppm, respectively. The ratios of ^{232}Th/^{238}U are less than the Clark's value (3.5) in all samples, which indicates that these locations are enriched in uranium.

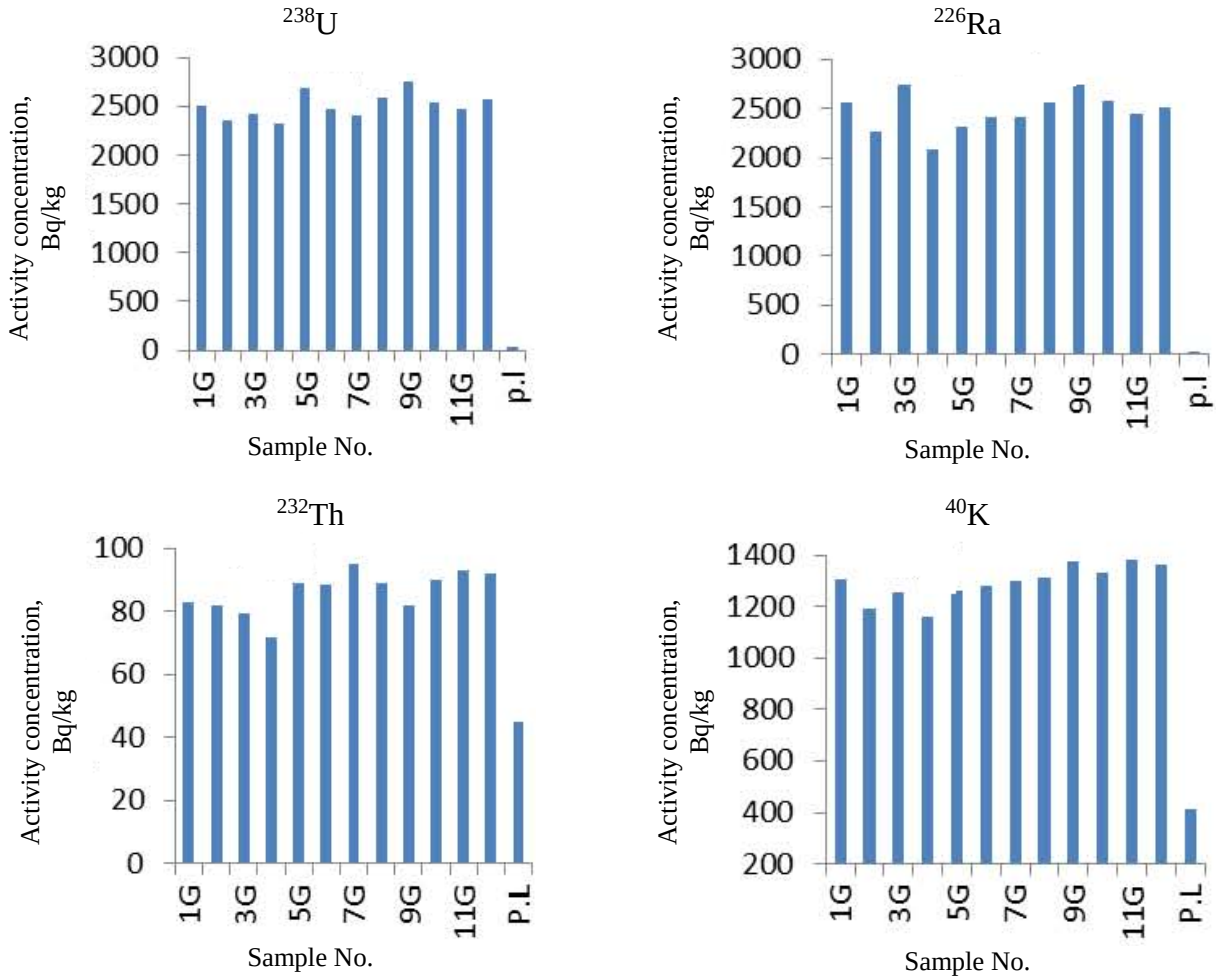

Fig. 4. The activity concentrations for ^{226}Ra, ^{238}U, ^{232}Th, ^{40}K in the granite samples in comparison with the permissible limits (p.l.).

Table 3. **Activity concentration of ^{238}U and ^{232}Th in sediment samples (in ppm) and ^{232}Th/^{238}U ratio**

Sample	^{238}U	^{232}Th	^{232}Th/^{238}U
2s	79.1 ± 2.4	14.1 ± 0.4	0.178 ± 0.007
3s	512 ± 15	14.3 ± 0.4	0.028 ± 0.001
4s	187 ± 6	16.7 ± 0.5	0.089 ± 0.004
5s	285 ± 9	12.2 ± 0.4	0.043 ± 0.002
6s	74.0 ± 2.2	11.0 ± 0.3	0.148 ± 0.006
7s	149± 5	15.6 ± 0.5	0.105 ± 0.005
8s	252 ± 8	14.6 ± 0.4	0.058 ± 0.002
9s	179 ± 5	13.4 ± 0.4	0.075 ± 0.003
11s	57.7 ± 1.7*	31.0 ± 0.9**	0.538 ± 0.022
12s	88.9 ± 2.7	18.6 ± 0.6	0.209 ± 0.009
13s	183 ± 5	10.4 ± 0.3	0.057 ± 0.002
14s	275 ± 8	12.6 ± 0.4	0.046 ± 0.002
15s	113 ± 3	7.6 ± 0.2*	0.067 ± 0.003
16s	176 ± 5	18.1 ± 0.5	0.103 ± 0.004
17s	157 ± 5	11.7 ± 0.4	0.074 ± 0.003
18s	572 ± 17	18.4 ± 0.6	0.032 ± 0.001
19s	331 ± 10	16.2 ± 0.5	0.049 ± 0.002
20s	676 ± 20**	22.5 ± 0.7	0.033 ± 0.001

* The lower value.
** The higher value.

Table 4. **Activity concentration of ^{238}U and ^{232}Th in the granite samples (in ppm) and ^{232}Th/^{238}U ratio**

Sample	^{238}U	^{232}Th	^{232}Th/^{238}U
1G	203 ± 6	20.4 ± 0.6	0.101 ± 0.004
2G	191 ± 6	20.1 ± 0.6	0.105 ± 0.005
3G	197 ± 6	19.6 ± 0.6	0.099 ± 0.004
4G	187 ± 6*	17.7 ± 0.5*	0.094 ± 0.004
5G	217 ± 7	22.0 ± 0.7	0.101 ± 0.005
6G	200 ± 6	21.8 ± 0.7	0.109 ± 0.005
7G	195 ± 6	23.4 ± 0.7**	0.120 ± 0.005
8G	209 ± 6	22.0 ± 0.7	0.105 ± 0.005
9G	223 ± 7**	20.2 ± 0.6	0.090 ± 0.004
10G	205 ± 6	22.2 ± 0.7	0.108 ± 0.005
11G	200 ± 6	23.0 ± 0.7	0.115 ± 0.005
12G	208 ± 6	22.6 ± 0.7	0.109 ± 0.005

* The lower value.
** The higher value.

Radiological hazard indices

Radium equivalent activity (Ra_{eq})

Since the distribution of the natural radionuclides are not uniform in the samples under analysis, a radiological index called radium equivalent (Ra_{eq}) activity has been defined to estimate the radiation risk associated with these radionuclides. This index is calculated by the equation [24]

$$Ra_{eq} = C_{Ra} + (C_{Th} \cdot 1.43) + (C_K \cdot 0.077),$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively. This common index is convenient for comparing the specific activities of materials containing different concentrations of these radionuclides.

External hazard index

The external hazard index due to the emitted γ-rays of the samples is calculated and examined according to the criterion

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \le 1,$$

where C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th, ^{40}K in Bq/kg, respectively.

Representative level index

This index can be used to estimate the level of γ-radiation hazard associated with the natural radionuclides in the samples; it is given by the equation

$$I_\gamma = C_{Ra}/150 + C_{Th}/100 + C_K/1500,$$

where C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th, ^{40}K in Bq/kg, respectively.

Estimation of γ-radiation dose

The absorbed gamma dose rates in air at 1 m above the ground surface for the uniform distribution of radionuclides (^{238}U, ^{232}Th and ^{40}K) were calculated by using equation

$$D = 0.427 \cdot C_U + 0.662 \cdot C_{Th} + 0.043 \cdot C_K \quad \text{(nGy/h)},$$

where C_U, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K in Bq/kg, respectively.

Annual effective dose

The annual outdoor effective dose (E_{out}) is estimated from the outdoor external dose rate (D_{out}), time of stay in the outdoor or occupancy factor (OF = 20 % of 8760 h in a year) and the conversion factor (CF = 0.7 Sv·Gy^{-1}) to convert the absorbed dose in air to effective dose. During the present study, the E_{out} was calculated using the following equations from UNSCEAR, 2010 [23]:

$$E_{out} = D_{out}\,(\text{nGy h}^{-1}) \cdot 0.2 \cdot 8760\ \text{h} \cdot 0.7\ (\text{Sv} \cdot \text{Gy}^{-1}) = \\ = D_{out} \cdot 1.226\ \mu\text{Sv}.$$

The calculated values of the radium equivalent Ra_{eq}, the external hazard index, the representative level index and the dose rate are given in Table 5 for the sediment samples, and in Table 6 for the granite samples.

The values of radium equivalent of sediment samples at Um Bogma, south west Sinai, Egypt, are higher than the permissible level of 370 Bq/kg (UNSCEAR, 2010 [23]), the value of radioactivity level index (I_γ) is found more than 1, and the average external hazard is found to be more than 1. The values of the Dose rate calculated during present study are higher than the permissible level of 59 nGy/h (UNSCEAR, 2010 [23]).

Table 5. **The radium equivalent, the external hazard index, the representative level index and dose rate for the sediment samples. P.L. is permissible level**

Sample	Ra_{eq}, Bq/kg	H_{ex}, Bq/kg	I_γ, Bq/kg	D, nGy/h
2S	1273 ± 39*	3.4 ± 0.1	8.6 ± 0.3	558 ± 17**
3S	4950 ± 150	13.4 ± 0.4	33.1 ± 1.0	2160 ± 60
4S	2530 ± 80	6.8 ± 0.2	17.0 ± 0.5	1105 ± 35
5S	4540 ± 140	12.3 ± 0.4	30.3 ± 0.9	1980 ± 60
6S	1860 ± 60	5.0 ± 0.2	12.5 ± 0.4	813 ± 24
7S	2050 ± 60	5.5 ± 0.2	13.8 ± 0.4	895 ± 27
8S	2560 ± 80	6.9 ± 0.2	17.2 ± 0.5	1118 ± 34
9S	2810 ± 90	7.6 ± 0.2	18.8 ± 0.6	1225 ± 37
11S	960 ± 30	2.6 ± 0.1*	6.5 ± 0.2*	419 ± 13
12S	1310 ± 40	3.5 ± 0.1	8.8 ± 0.3	575 ± 18
13S	3060 ± 90	8.3 ± 0.3	20.5 ± 0.6	1340 ± 40
14S	4660 ± 140	12.6 ± 0.4	31.2 ± 0.9	2040 ± 60
15S	1810 ± 60	4.9 ± 0.2	12.1 ± 0.4	790 ± 24
16S	2450 ± 70	6.6 ± 0.2	16.4 ± 0.5	1075 ± 35
17S	2160 ± 60	5.8 ± 0.2	14.5 ± 0.4	945 ± 30
18S	7220 ± 220	19.5 ± 0.6	48.3 ± 1.5	3150 ± 90
19S	4240 ± 130	11.5 ± 0.3	28.4 ± 0.9	1850 ± 60
20S	8950 ± 270 0	24.2 ± 0.7**	59.9 ± 1.8**	3910 ± 120**
P.L.	370	1	1	59

* The lower value.
** The higher value.

Table 6. **The radium equivalent, the external hazard index, the representative level index and dose rate for the granite samples. P.L. is permissible level**

Sample	Ra_{eq} (Bq/kg)	H_{ex} (Bq/kg)	I_γ (Bq/kg)	D (nGy/h)
1G	2780 ± 80	7.5 ± 0.2	18.8 ± 0.6	1223 ± 37
2G	2470 ± 80	6.7 ± 0.2	16.7 ± 0.5	1084 ± 33
3G	2950 ± 90	8.0 ± 0.2	19.9 ± 0.6	1293 ± 39
4G	2280 ± 70*	6.2 ± 0.2*	15.4 ± 0.5*	1005 ± 35*
5G	2550 ± 80	6.9 ± 0.2	17.2 ± 0.5	1116 ± 34
6G	2650 ± 80	7.2 ± 0.2	17.9 ± 0.5	1162 ± 35
7G	2650 ± 80	7.2 ± 0.2	17.9 ± 0.5	1160 ± 35
8G	2790 ± 80	7.6 ± 0.2	18.9 ± 0.6	1226 ± 37
9G	2980 ± 90**	8.1 ± 0.2**	20.1 ± 0.6**	1310 ± 40**
10G	2810 ± 90	7.6 ± 0.2	19.0 ± 0.6	1232 ± 37
11G	2690 ± 80	7.3 ± 0.2	18.2 ± 0.6	1181 ± 35
12G	2750 ± 80	7.4 ± 0.2	18.6 ± 0.6	1206 ± 36
P.L.	370	1	1	59

* The lower value.
** The higher value.

For the sediment samples (Table 7), the outdoor effective dose rate E_{out} range from 0.51 to 4.79 mSv/y with an average value of 1.76 mSv/y; for the granite samples (Table 8), the outdoor effective dose rate E_{out} range from 1.23 to 1.60 mSv/y with an average value of 1.45 mSv/y; these averages are higher than the world's average of 0.07 mSv/y (UNSCEAR, 2010 [23]).

Table 7. **The values of outdoor effective dose rate in the sediment samples**

Sample	E_{out}, mSv/y
2S	0.68 ± 0.02
3S	2.65 ± 0.08
4S	1.35 ± 0.04
5S	2.43 ± 0.07
6S	1.00 ± 0.03

Continuation of the Table 7

Sample	E_{out}, mSv/y
7S	1.10 ± 0.03
8S	1.37 ± 0.04
9S	1.50 ± 0.05
11S	0.51 ± 0.02*
12S	0.70 ± 0.02
13S	1.64 ± 0.05
14S	2.50 ± 0.07
15S	0.97 ± 0.03
16S	1.31 ± 0.04
17S	1.16 ± 0.03
18S	3.87 ± 0.12
19S	2.27 ± 0.07
20S	4.79 ± 0.14**

* The lower value.
** The higher value.

Table 8. **The values of outdoor effective dose rate in the granite samples**

Sample	E_{out}, mSv/y
1G	1.50 ± 0.04
2G	1.33 ± 0.04
3G	1.59 ± 0.05
4G	1.23 ± 0.04*
5G	1.37 ± 0.04
6G	1.43 ± 0.04
7G	1.43 ± 0.04
8G	1.50 ± 0.05
9G	1.60 ± 0.05**
10G	1.51 ± 0.05
11G	1.45 ± 0.04
12G	1.48 ± 0.04

* The lower value.
** The higher value.

Excess lifetime cancer risk (ELCR)

The value of annual effective dose excess lifetime cancer risk (ELCR) was calculated by using the equation

$$ELCR_{out} = E_{out} \cdot LE \cdot RF,$$

where E_{out} is the annual effective dose, LE life expectancy (66 years) and RF (Sv^{-1}) is risk factor per Sievert, which is 0.05 [25].

The values of outdoor $ELCR_{out}$ range between $1.69 \cdot 10^{-3}$ and $15.8 \cdot 10^{-3}$ in the sedimentary samples (Table 9); all values are higher than the permissible level $0.29 \cdot 10^{-3}$ (UNSCEAR, 2008 [26].

The values of outdoor $ELCR_{out}$ excess lifetime cancer risk for all the granite samples are shown in Table10. They range between $4.06 \cdot 10^{-3}$ and $5.29 \cdot 10^{-3}$; all the values are higher than the permissible level of $0.29 \cdot 10^{-3}$ [26].

Table 9. **The value of outdoor $ELCR_{out}$ for the sedimentary samples. P.L. is permissible level**

Sample	$ELCR_{out} \cdot 10^{-3}$
2S	2.26 ± 0.07
3S	8.74 ± 0.26
4S	4.47 ±0.13
5S	8.01 ± 0.24
6S	3.29 ± 0.10
7S	3.62 ± 0.11
8S	4.52 ± 0.14
9S	4.96 ± 0.15
11S	1.69 ± 0.05*
12S	2.31 ± 0.07
13S	5.4 ± 0.16
14S	8.24 ± 0.25
15S	3.2 ± 0.10
16S	4.33 ± 0.13
17S	3.81 ± 0.11
18S	12.76 ± 0.38
19S	7.49 ± 0.22
20S	15.81 ± 0.47**
P.L.	0.29

* The lower value.
** The higher value.

Table 10. **The value of outdoor $ELCR_{out}$ for granite samples. P.L. is permissible level**

Sample	$ELCR_{out} \cdot 10^{-3}$
1G	4.95 ± 0.15
2G	4.38 ± 0.13
3G	5.23 ± 0.16
4G	4.06 ± 0.12*
5G	4.52 ± 0.14
6G	4.70 ± 0.14
7G	4.70 ± 0.14
8G	4.96 ± 0.15
9G	5.29 ± 0.16**
10G	4.98 ± 0.15
11G	4.78 ± 0.14
12G	4.88 ± 0.15
P.L.	0.29

* The lower value.
** The higher value.

Conclusion

The areas under investigation, Um Bogma in Sinai and Gattar in the eastern Desert contain sediments and granites with high uranium contents and low thorium relatively to uranium. This case pays attention for radionuclides distribution and its hazard effects. Some sediment samples showed disequilibrium state, while the majority of the sediment samples and all granite samples showed a

state of equilibrium. All the samples for sediment and granite have the $^{232}Th/^{238}U$ ratio less than the Clark's value (3.5) which indicates that these areas are enriched in uranium. The values of potassium in the granite rocks are greater than in the sediment rocks. The dose rate, radium equivalent and external hazard index have high values. The ELCR factor assessed during present study on the basis of outdoor effective dose (E_{out}) was found to be higher than the world's average of $0.29 \cdot 10^{-3}$ in sediment and granite.

Due to the obtained results, precautions must be taken for people who work in these areas to protect against high radioactivity. The data obtained in this study are reference values to be used as a data base line for drawing a radiological map of these regions, that is very important.

REFERENCES

1. M.S. Al-Masri et al. External gamma-radiation dose to Syrian population based on the measurement of gamma- emitters in soils. Journal of Radioanalylical and Nuclear Chemistry 267(2) (2006) 337.
2. R. Fujiyoshi, S. Sawamura. Mesoscale variability of vertical profiles of environmental radionuclides (^{40}K, ^{226}Ra, ^{210}Pb and ^{137}Cs) in temperate forest soils in Germany. Science of the Total Environment 320 (2004) 177.
3. A.M. Gbadebo, A.J. Amos. Assessment of radionuclide pollutants in bedrock and soils from Ewekoro cement factory, South Nigeria. Asian J. Applied Sci. 3 (2010) 135.
4. Radionuclides in Ecosystems (Washington, USEPA, 2007).
5. M. Harenyama et al. Two-dimensional measurement of natural radioactivity of granitic rocks by photosimulated luminescence technique. Geochemical Journal 34(1) (2000) 1.
6. J.H. Doveton, D.F. Merriam. Borehole petrophysical chemostratigraphy of Pennsylvanian black shales in the Kansas subsurface. Chem. Geol. 206 (2004) 249.
7. T. Weissbrod. The Paleozoic of Israel and adjacent countries. Part 2: The Paleozoic outcrops in southwestern Sinai and their correlation with those of southern Israel. Geological Survey of Israel Bulletin 48 (1969) 32 p.
8. M.A. El Sharkawi, M.M. El Aref, A.A. Mottelib. Manganese deposits in Carboniferous paleokarst profile, Um Bogma Region, west-central Sinai, Egypt. Mineralium Deposita 25 (1990) 34.
9. I.E. Aassy et al. Uranium in laterites, Southwestern Sinai, Egypt. In: First seminar on nuclear raw materials and their technology (Cairo, Egypt, 1 - 3 Nov., 1999) 1.
10. I.E. El Aassy et al. Report on the prospection and proving of some radioactive occurrences in west central Sinai, Egypt. Internal Report. (Cairo, Nuclear Materials Authority, 1986).
11. A.E. Omar. Geoenvironmental and radioactivity assessment of east Abu Zenima area, southwestern Sinai, Egypt using remote sensing and JIS. PhD Thesis (Egypt, Suez Canal University, 2016) 236 p.
12. M.Y. Attawiya. Petrochemical and geochemical studies of granite rocks from Gable Gattar area, Eastren Desert, Egypt. Arab. J. Nucl. Sci. Appl. 23(2) (1990) 13.
13. M.H. Shalaby, A.F. Moharem. Geochemistry and radioelement distribution in the fresh and altered hammamat sedimentary rocks along Wadi Baligh, North Eastern Desert, Egypt. Sedimentology of Egypt: journal of the Sedimentological Society of Egypt 9 (2001) 145.
14. M.L. EL Rakaiby, M.H. Shalaby. Geology of Gebel Qattar batholith, central Eastern Desert, Egypt. Int. J. Remote Sens. 13(12) (1992) 2337.
15. A.B. Salman, M.H. Shalaby, L.M. Noseir. Uranium province, Northern Red Sea Hills, Egypt. In: Proc. of the Intern. Earth Sciences Congress on Aegean Regions (Izmir, Turkey, 1 - 6 Oct., 1990) Vol. 1, p. 89.
16. H.M. EL Shatoury, M.E. Mostafa, E.F. Nasr. Granites and granitoid rocks in Egypt, a statistical approach of classification. Chemie der Erde 43 (1984) 83.
17. J.K. Greenberg. Characteristics and origin of Egyptian younger granites. Geological Society of America Bulletin 92 (1981) 749.
18. M.E. Roz. Geology and uranium mineralization of Gebel Qattar area, North Eastern Desert, Egypt. M.Sc. thesis. (Egypt, Cairo, Al-Azhar University, 1994).
19. Preparation and certification of IAEA gamma-ray spectrometry reference materials. RGU-1, RGTh-1 and RGK-1. IAEA/RL/148. International Atomic Energy Agency, 1987. 54 p.
20. R.M. Anjos et al. Natural radionuclide distribution in Brazilian commercial granites. Radiat. Meas. 39 (2005) 245.
21. S. Turhan, L. Gündüz. Determination of specific activity of ^{226}Ra, ^{232}Th and ^{40}K for assessment of radiation hazards from Turkish pumice samples. J. Environ. Radioact. 99 (2008) 332.
22. R.A. Sutherland, E. de Jong. Statistical analysis of gamma-emitting radionuclide concentrations for three fields in southern Saskatchewan, Canada. Health Phys 58 (1990) 417.
23. Sources and Effects of Ionizing Radiation. Report to General Assembly with Scientific Annexes (New York, United Nations Scientific Committee on the Effect of Atomic Radiation, 2010).
24. M. Tufail et al. Natural radioactivity from the building materials used in Islamabad and Rawalpindi, Pakistan. Science of the Total Environmental 121 (1992) 283.
25. A.A. Qureshi et al. Evaluation of excessive lifetime cancer risk due to natural radioactivity in the rivers sediments of Northern Pakistan. Journal of Radiation Research and Applied Science 7 (2014) 438.
26. H. Taskin et al. Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Kiklareli, Turkey. J. Environ. Radioact. 100 (2009) 49.

Е. С. Абд Ель-Халім[1], Надія Уоллі Ель-Дін[1,*], Самія М. Ель-Бахі[1], Ібрагім Е. Ель-Аассі[2], Енас М. Ель-Шейх[2], Асма Мухаммед Аль-Абрді[3]

[1] Жіночий факультет мистецтв, науки та освіти, кафедра фізики, університет Айн Шамс, Каїр, Єгипет
[2] Регулюючий орган з ядерних матеріалів, Каїр, Єгипет
[3] Фізичний факультет, коледж наук, Омар Аль-Мухтар університет, Аль-Байда, Лівія

*Відповідальний автор: nadia.walley@women.asu.edu.eg

ОЦІНКИ ВИНИКНЕННЯ ОНКОЛОГІЇ ТА ВИМІРЮВАННЯ ПРИРОДНОЇ РАДІОАКТИВНОСТІ ГРАНІТНИХ ТА ОСАДОВИХ ЗРАЗКІВ ПОРОДИ

Досліджено 18 зразків осадових відкладень, зібраних в Ум-Богмі, південно-західний Синай, та 12 гранітних зразків, зібраних у Габал Гаттар, північно-східна пустеля, в Єгипті. Концентрації радіонуклідів у зразках осадових відкладень та граніту визначали гамма-спектрометром із детектором HPGe із спеціально розробленим захистом. Вміст урану є високим у осадових породах і гранітних зразках, а вміст ^{40}K у граніті є вищим, ніж в осадових породах. Інтенсивність поглинутої дози коливалася від 419 до 3908 нГр/год для зразків осаду та від 1002 до 1307 нГр/год для зразків граніту. Було оцінено індекси зовнішньої небезпеки (H_{ex}) для зразків осадових порід та граніту. Також вивчалася ступінь порушення радіоактивної рівноваги в ряду урану для районів Ум-Богма і Габал Гаттар. Розраховано відношення активності ^{226}Ra/^{238}U для осадових порід та граніту. Також було оцінено співвідношення концентрації торію та урану (індекс Кларка). Визначено загальний ризик виникнення онкології (ELCR).

Ключові слова: природна радіоактивність, детектор HPGe, осадові породи, граніт, порушення радіоактивної рівноваги, ризик виникнення раку, відношення активностей.

Е. С. Абд Эль-Халим[1], Надия Уолли Эль-Дин[1,*], Самия М. Эль-Бахи[1], Ибрагим Е. Эль-Аасси[2], Енас М. Эль-Шейх[2], Асма Мухаммед Аль-Абрди[3]

[1] Женский факультет искусств, науки и образования, кафедра физики, университет Айн Шамс, Каир, Египет
[2] Регулирующий орган по ядерным материалам, Каир, Египет
[3] Физический факультет, колледж наук, Омар Аль-Мухтар университет, Аль-Байда, Ливия

* Ответственный автор: nadia.walley@women.asu.edu.eg

ОЦЕНКИ ВОЗНИКНОВЕНИЯ ОНКОЛОГИИ И ИЗМЕРЕНИЯ ПРИРОДНОЙ РАДИОАКТИВНОСТИ ГРАНИТНЫХ И ОСАДОЧНЫХ ОБРАЗЦОВ ПОРОДЫ

Исследовано 18 образцов осадочных отложений, собранных в Ум-Богме, южно-западный Синай, и 12 гранитных образцов, собранных в Габал Гаттар, северо-восточная пустыня, в Египте. Концентрации радионуклидов в образцах осадочных отложений и гранита определялись гамма-спектрометром с детектором HPGe со специально разработанной защитой. Содержание урана является высоким в осадочных породах и гранитных образцах, а содержание ^{40}K в граните выше, чем в осадочных породах. Интенсивность поглощенной дозы находится в диапазоне от 419 до 3908 нГр/ч для образцов осадочных пород и от 1002 до 1307 нГр/ч для гранита. Были оценены индексы внешней опасности (H_{ex}) для образцов осадочных отложений и гранита. Также изучалась степень нарушения радиоактивного равновесия в ряду урана для районов Ум-Богма и Габал Гаттар. Рассчитано отношение активности ^{226}Ra/^{238}U для осадочных пород и гранита. Также было оценено отношение концентрации тория и урана (индекс Кларка). Определен общий риск возникновения онкологии (ELCR).

Ключевые слова: природная радиоактивность, детектор HPGe, осадочные породы, гранит, нарушение радиоактивного равновесия, риск возникновения рака, отношение активностей.

Надійшла 09.08.2017
Received 09.08.2017