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ТЕХНІКА ТА МЕТОДИ ЕКСПЕРИМЕНТУ

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GAMMA ACTIVITY AS A GUIDE FOR THE BUILDING RAW MATERIALS SELECTION AND CONTROLLING THE ENVIRONMENTAL HAZARDS

The spectrometric measurements can provide an alarm for the radiation activity and radioelement concentrations. The activity increase over the ambient background can be achieved by well calibrated gamma-spectrometers. In comparison between Wadi El-Dahl and Abu Zawal quarries for building raw materials (feldspar), the activity concentration of El-Dahl stream sediments are 54.5 and 44.5 Bq/kg for uranium and thorium respectively. While the activity concentration of Abu Zawal rock quarry are 167.03 and 79.77 Bq/kg for uranium and thorium respectively. These activities yielding effective dose rates of 0.63 mSv/y for Wadi El-Dahl stream sediments and 1.48 mSv/y for Abu Zawal rock quarry. In summary, the spectrometric measurements are excellent selective tool to monitoring the environment against the radiation risk. In this aspect, Wadi El-Dahl stream sediment quarry considered as the more suitable for producing feldspar as a raw materials to building industry. In comparison, Abu Zawal rock quarry has a higher effective dose rate exceeds the international permissible limits which is 1 mSv/y. A total of 19 feldspar samples were completely described regarding their general chemical features by using x-ray fluorescence. From the study all the samples contain high concentration of barium and rubidium which can separate using different methods in order to use in different important industry.

Keywords: ground spectrometric survey, x-ray fluorescence, feldspar.

Introduction

Ground spectrometric survey

Ground multi-channel gamma-ray survey was carried out over the pegmatite body to the north of G. El-Urf granite and also over the stream sediments of Wadi El-Dahl as two big quarries for producing building raw materials in the Eastern Desert of Egypt (E. D.).

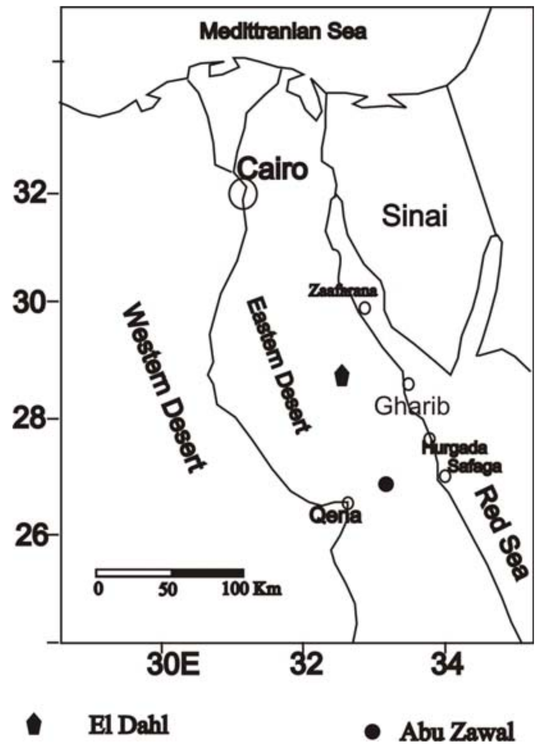

Fig. 1. Location map for El-Dahl and Abu Zawal quarries.

These areas are located in the northern E. D. of Egypt between latitudes 26°37′ N and 28°45′ N and longitudes 32°27′ E and 33°23′ E as shown in Fig. 1. The detailed spectrometric gamma-ray measurements have been done along 340 equally-spaced stations, directed N-S, with an average space of about 20 × 20 m in-between. Global Positioning System (GPS) instrument was used to set up the survey grid with Universal Transverse Mercator (UTM) coordinate system, using World Grid as datum.

Instrumentation

Spectral gamma-ray measurements have been conducted using a portable gamma-ray spectrometer model GS-256 Geofyzika Brno, Czeck Republic. This spectrometer has been calibrated using the locally-constructed Nuclear Materials Authority concrete calibration pads. Potassium is measured directly from the 1460 keV gamma-ray photons emitted by ^{40}K, where as uranium and thorium are measured indirectly from gamma-ray photons emitted by daughter products in their decay series. The channels have been selected in the field and the windows for uranium, thorium and potassium were seated at each respective peak for each channel. Uranium is monitored using gamma rays at approximately 1760 keV from ^{214}Bi, thorium at 2615 keV photons from ^{208}Tl. Measurements of uranium and thorium are normally referred to as equivalent uranium and equivalent thorium, i.e., eU and eTh. The corrected spectral gamma-ray measurements were estimated from the apparent surface concentrations of radioelements, potassium (K, in percent), equivalent uranium (eU, in ppm), and equivalent thorium (eTh, in ppm) in the investigated area in addition to their total gamma-ray response (Total Count (TC), in Ur). The measuring time was set up at 30 s to permit the accumulation of the gamma-ray emission. The data were directly stored in the field and dumped daily to the computer at the office.

Several methods and analytical techniques are used to identify and characterize mineral deposits and source rocks for the nuclear raw materials radiometric investigation comprise one of the most important techniques used for analysis of uranium and thorium in the ores and rock samples [1, 2, 3].

Qualitative interpretation of the data

The recorded ground radioactivity levels were found to vary widely from one place to another and to some extent within the same place. Naturally, the boundaries between these levels are not sharp, but merge into one another to various degrees. In some cases the ground radiometric gradients representing boundaries are steep and sharp enough to help delineate the zones and different rock types of heavy mineral concentrations which may hosting radioelements. The qualitative interpretation of the ground spectrometric survey data depends mainly upon the excellent correlation between the general pattern of the recorded measurements and the surface distribution of the various heavy mineral deposits. This has been achieved from the previous experience gained in the field of application of ground spectrometric survey data could be an aid in the interpretation of the surface geology.

Quantitative interpretation of the data

Detailed gamma-ray spectrometric survey was conducted on a grid pattern survey of 20 × 20 m spacing stations. The **c**oncentrations of natural radioelements, potassium, uranium, and thorium in the investigated areas were used for calculating the specific activity, exposure rate and equivalent dose rate. The conversion factor recommended in [4] is given in Table 1 assuming radioactive equilibrium.

Table 1. **Conversion of radioelement concentration to specific activity**

1 % k in rock	313 Bq/kg	^{40}k
1 ppm U in rock	12.35 Bq/kg	^{238}U or ^{226}Ra
1 ppm Th in rock	4.06 Bq/kg	^{232}Th

Theoretical gamma ray exposure rate and gamma ray dose rate 1m above a plane and infinite homogeneous soil medium per unit radioelement concentration assuming radioactive equilibrium in the U and Th decay series [4, 5], are represented in Table 2.

Table 2. **Exposure rate, dose rate and equivalent dose rate for K, U and Th per unit radioelement concentration assuming radioactive equilibrium in the U and Th decay series [4, 5]**

Radioelement concentration	Exposure rate, μR/h	Dose rates, nGy/h	Equivalent dose rate, mSv/y
1 % k in rock	1.505	13.078	0.080
1 ppm U in rock	0.653	5.675	0.035
1 ppm Th in rock	0.287	2.494	0.015

Results and discussion for ground spectrometer

Wadi El-Dahl measurements

Specific activity concentration

The calculated specific activity for the K, U and Th measurements of the present study is given in Table 3 where the lowest value of K specific activity is 970 Bq/kg while the highest value is 1299 Bq/kg, referring to the high content of potassium which can be neglected because its low effective energy. On the other hand, the average value of U specific activity is 54.5 Bq/kg while the average value of Th specific activity is 44.5 Bq/kg. The U and Th specific activities calculations lie close to the permissible limits.

Table 3. **The calculated specific activities for the K, U and Th measurements (Bq/kg) of Wadi El-Dahl, Eastern Desert, Egypt**

Location number	Concentration of K, %	Concentration of eU, ppm	Concentration of eTh, ppm	K specific activity	U specific activity	Th specific activity
1	4.15	4.55	10.95	1299	56.19	44.45
2	3.7	4.55	12	1158	56.19	48.72
3	3.5	4	11.5	970	49.4	46.69
4	3.35	4.3	10.75	1048	53.10	40.8
5	3.7	4.3	11.45	1158	51.25	46.48
6	3.5	4.9	12.7	1126	60.51	5.56
7	3.45	4.45	12	1079	54.95	48.72
8	3.8	4.5	13.3	1189	55.57	35.99

Continuation of Table 3

Location number	Concentration of K, %	Concentration of eU, ppm	Concentration of eTh, ppm	K specific activity	U specific activity	Th specific activity
9	3.95	4.1	12.1	1236	50.63	49.12
10	3.3	4.75	11.65	1032	58.66	50.75
11	3.65	4.3	13.25	1142	53.10	53.79
Average	3.64	4.42	11.97	1021	54.50	44.5

It is noticed that the permissible limits of specific activity per unit mass for all building materials studied are in the limit of world values (500; 50 and 50 Bq/kg) for C_k, C_{Ra} and C_{Th} respectively [6].

The comparison between the calculated specific activities of Wadi El-Dahl raw materials for U, Th and K with the international permissible limits and the locations are shown in Fig. 2.

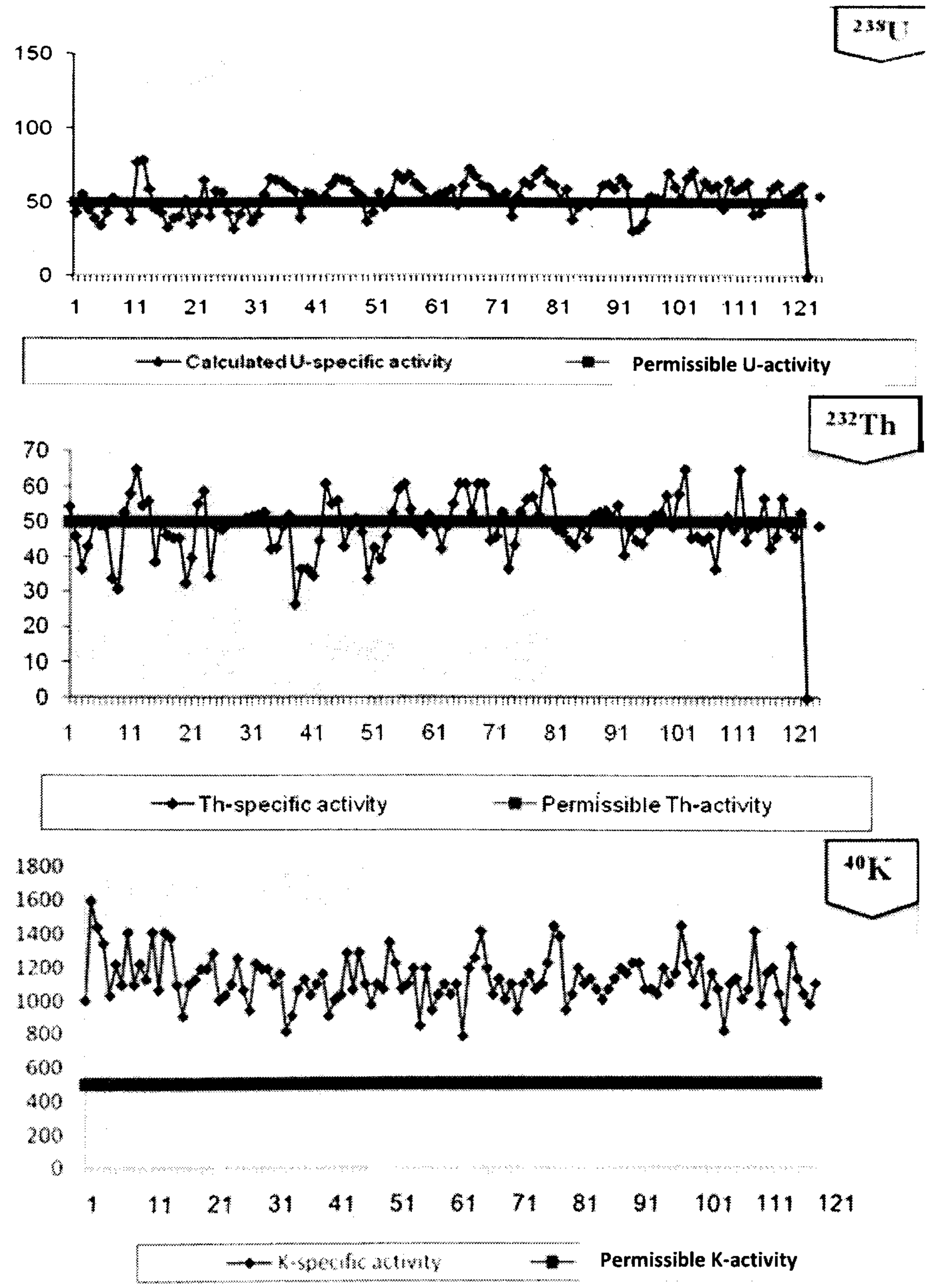

Fig. 2. Comparison between U, Th, K specific activities (Bq/kg) for Wadi El-Dahl Quarry, Eastern Desert Egypt and the International permissible limits.

Effective dose rate

Effective dose is a sum of multiples of equivalent doses affect in the human organs concerning weighting factors. Effective dose is expressed in mSv and usually reported annually (per year: y = 8760 h). For environmental gamma radiation the estimate is

$$E = D'_a \cdot t \cdot 0.7 \cdot 10^{-6},$$

where E is the effective dose (mSv/y); D'_a is the dose rate in air (nGy/h); t is the exposure time (h) and $0.7 \cdot 10^{-6}$ is the conversion coefficient (Sv/nGy) for human organs [7, 8].

$$D_a = \text{Exposure rate} \cdot 8.69 \text{ (nGy/h)},$$

$$E = \frac{\text{Dose rate (nGy/h)} \cdot 8760 \cdot 0.7}{1000000}$$

for each element and the sum of all elements.

The calculated exposure rate, dose rate and effective dose for the K, U and Th measurements of the present study are given in Table 4 and Fig. 3. Although the increase of the specific activity for K but the calculated value of effective dose rate in the present study is lower than the permissible limit "1.0 mSv/y" that recommended by the International Commission Radiological Protection [9] as the maximum annual dose to the public members.

Table 4. **Exposure rate, dose rate and calculated effective dose for the K, U and Th measurements of Wadi El-Dahl Quarry, Eastern Desert, Egypt**

Location number	Exposure rate, μR/h	Dose rate, nGy/h	Calculated effective dose, mSv/y
1	11.95	103.91	0.63
2	12.63	109.79	0.66
3	11.54	100.32	0.61
4	11.25	97.85	0.59
5	11.57	100.6	0.60
6	12.63	109.8	0.66
7	11.78	102.44	0.62
8	12.52	108.87	0.66
9	12.34	107.28	0.65
10	12.21	106.14	0.64
11	12.46	110.97	0.65
Averages	12.08	105.27	0.63

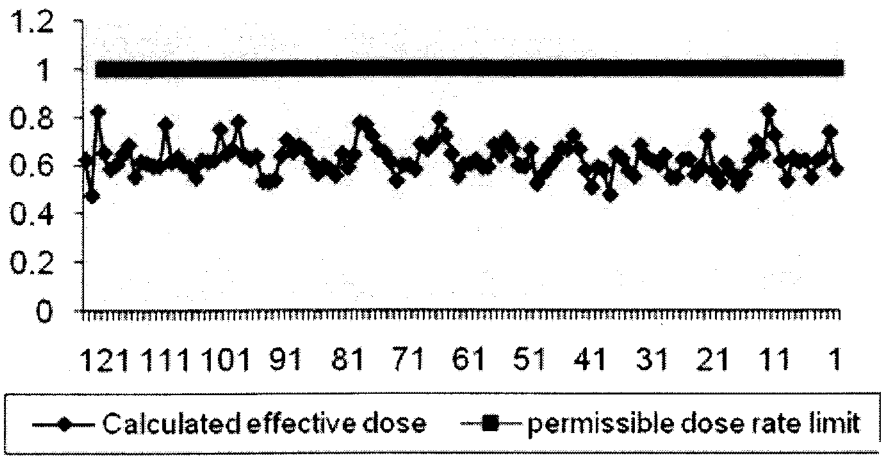

Fig. 3. Comparison between calculated effective dose rate for the data from Wadi El-Dahl, Eastern Desert, Egypt and the International permissible limits: x-axis – location of samples; y-axis – specific activities.

Wadi Abu Zawal measurements

Specific activity concentration

The calculated specific activities for the K, U and Th measurements of the present study are given in Table 5. The average value of K specific activity is 2541.56, it is too high referring to the high content of potassium. The average value of U specific activity is 167.03 Bq/kg while the average value of Th specific activity is 79.779 Bq/kg. The specific activities of the radioelements are higher than the permissible limit for each (500, 50, 50 Bq/kg respectively).

The comparison between the specific activities and the international permissible limits for U, Th and K respectively are shown in Fig. 4. This comparison ascertains the highest limits of the activities which may represent environmental hazards for using this locality to produce the geological raw materials for industry.

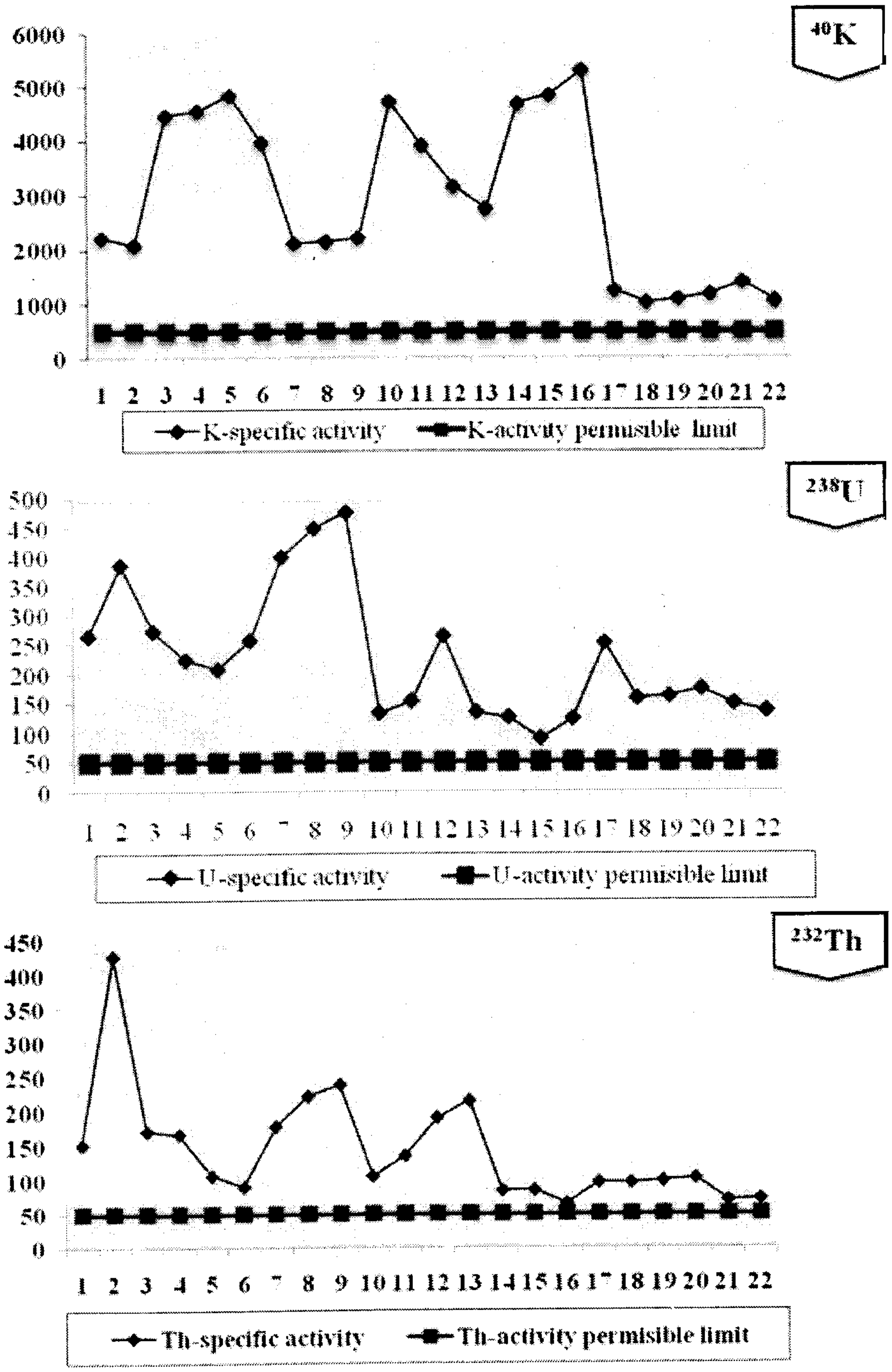

Fig. 4. Comparison between U, Th, K specific activities (Bq/kg) and the International permissible limits: x-axis – location of samples; y-axis – specific activities.

Table 5. **The calculated specific activities (Bq/kg) for the K, U and Th measurements from Abu Zawal quarry Eastern Desert, Egypt**

Number of profile	Total count	Concentration of K, %	Concentration of eU, ppm	Concentration of eTh, ppm	K specific activity	U specific activity	Th specific activity
1	54.5	5.5	17.4	25.2	1721	214.89	102.31
2	86.5	5.1	27.3	93	1596	337.15	377.58
3	37	12.7	18.1	30	3975	223.53	121.8
4	34.5	13	14.1	29	4069	174.13	117.74
5	75.8	13.9	12.8	14	4350	158.08	56.84
6	75.4	11.1	16.8	10.1	3474	207.48	41.01

Continuation of Table 5

Number of profile	Total count	Concentration of K, %	Concentration of eU, ppm	Concentration of eTh, ppm	K specific activity	U specific activity	Th specific activity
7	76.2	5.2	28.4	31.6	1627	350.74	128.29
8	83	5.3	32.3	42.3	1658	398.90	171.73
9	92	5.5	34.5	46.5	1721	426.07	188.79
10	69	13.5	6.7	13.9	4225	82.74	56.43
11	65.3	10.9	8.3	21	3411	102.50	85.26
12	77.9	8.5	17.4	34.6	2660	214.89	140.47
13	63.1	7.2	6.8	40.7	2253	83.98	165.24
14	72	13.4	6.1	8.5	4194	75.33	34.51
15	74	13.9	3.2	8.6	4350	39.52	34.91
16	71.8	15.4	5.9	3.8	4820	72.86	15.42
17	59.5	2.4	16.4	11.5	751	202.54	46.69
18	26	1.7	8.7	11.4	532	107.44	46.28
19	23	1.9	9	12	594	111.15	48.72
20	29	2.2	10	13	688	123.5	52.78
21	33	2.9	8	5	907	98.8	20.3
22	22	1.8	7	5.5	563	86.45	22.33
Averages					2541	167.03	79.77

Effective dose rate

The calculated exposure rate, dose rate and effective dose for the K, U and Th measurements of the present study are given in Table 6.

The average calculated value of the effective dose rate in the present study (1.48 mSv/y) is higher than the permissible limit "1.0 mSv/y" that recommended by the International Commission Radiological Protection [9] as the maximum annual dose to the public members.

The comparison between the calculated effective dose rate and the International permissible limit is shown in Fig. 5.

Table 6. **Exposure rate, dose rate and effective dose for the K, U and Th measurements**

Number of profile	Exposure rate, μR/h	Dose rate, nGy/h	Calculated effective dose, mSv/y
1	26.87	233.52	1.43
2	52.19	453.56	2.76
3	39.54	343.63	2.10
4	37.10	322.36	1.97
5	33.30	289.34	1.77
6	30.57	265.69	1.63
7	35.44	307.98	1.88
8	41.21	358.10	2.19
9	44.15	383.68	2.35
10	28.68	249.25	1.52
11	27.85	242.03	1.48
12	34.08	296.20	1.81
13	26.96	234.26	1.42
14	26.59	231.07	1.41
15	25.48	221.40	1.35
16	28.12	244.37	1.50
17	17.62	153.13	0.94
18	11.51	100.03	0.61
19	12.18	105.85	0.65
20	13.57	117.94	0.72
21	11.02	95.79	0.59
22	8.86	76.98	0.47
Averages	27.86	242.10	1.48

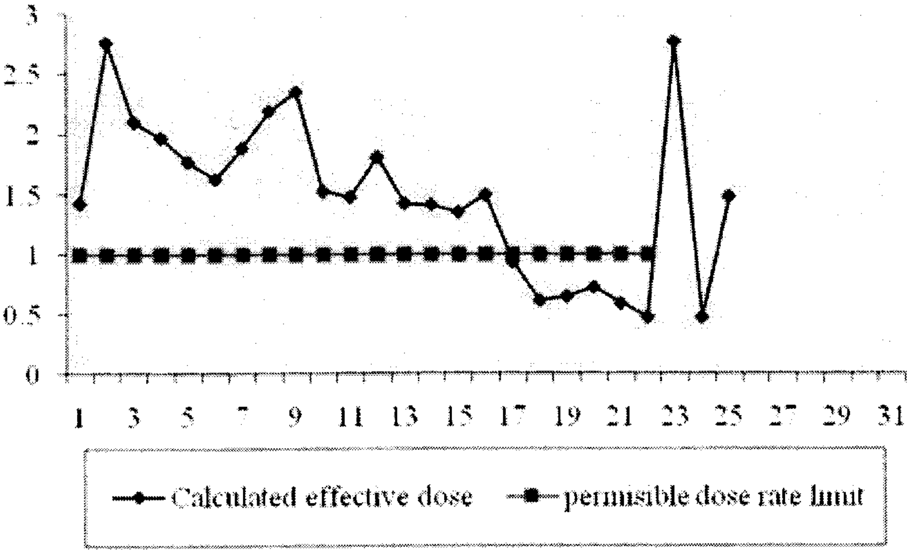

Fig. 5. The comparison between the calculated effective dose rate (mSv/y) and the International permissible limits: x-axis – location of samples; y-axis – effective dose rate.

Geochemical investigation

Generally, the stream sediment feldspar of Wadi El-Dahl and Abu Zawal rock feldspar considered as granitic rocks. The granitic rocks usually contain radioactive minerals of uranium or thorium and/or radioelement hosting minerals such as zircon, monazite niobium, yttrium and others as accessories [10]. In order to identify the source of the radioactivity in Wadi El-Dahl and Abu Zawal, some samples were collected to apply the geochemical analysis.

A total of 19 samples were completely described regarding their general chemical features. 12 stream sediment samples were collected from Wadi El-Dahl and 7 samples were collected from Abu Zawal quarry and prepared to achieve the accessory mineral paragenesis. The accessory minerals will measure by the x-ray fluorescence (XRF) technique at the x-ray laboratory Nuclear Materials Authority, Cairo Egypt.

Description of the System

XRF technology provides one of the simplest, most accurate and most economic analytical methods for the determination of the chemical composition of many types of materials. It is non-destructive and reliable, requires no, or very little, sample preparation and is suitable for solid, liquid and powdered samples [11].

In this study, the XRF technique was used to determine the trace element contents using PHILIPS X'Unique-II spectrometer with automatic sample changer PW 1510, (30 positions). This instrument is connected to a computer system using X-40 program for spectrometry.

The trace elements concentrations are calculated from the program's calibration curves which were set up according to international reference materials, (standards), as NIM-G, G-2, GSP-1, AGV-1, JB-1 and NIM-D.

The trace elements were measured by calibrating the system under the conditions of Rh-target tube, LiF-420 crystal, gas flow proportional counter, (GFPC), coarse collimators, vacuum, 30 kV and 40 mA for the determination of V, Cr, Co, Ni, Cu, Zn and Ga, 70 kV and 15 mA, for Rb, Sr, Y, Zr and Nb and 100 kV and 10 mA for the determination of Ba and Pb. The detection limit is the lowest concentration, and it is function of the level of background noise relative to an element signal [12]. The detection limit for the elements measured by XRF technique is estimated at 2 ppm for Rb, Nb, Ga, Co, Y and Sr and at 8 ppm for Pb and Cu and 5 ppm for other measured trace elements.

Sample preparation for x-ray fluorescence

A total of 19 samples were completely described regarding their general These samples were collected from Wadi El-Dahl as stream sediment (12 samples) and Wadi Abu Zawal (7 rock samples) in Eastern Desert of Egypt.

For trace elements analysis, pressed powder pellets were prepared by filling an alumina cup, (diameter 4 cm, height 1.2 cm and weight 3 gm), with 9 gm of crystalline boric acid covered by 1 gm of the grounded sample, (-200 mesh grain size), and then pressed under 12 t using semi-automatic hydraulic press model HERZOG HTP-40.

To avoid trace elements contaminations the powdered samples were subjected to complete chemical analysis in the laboratories of Nuclear Materials Authority using the wet chemical analyses for the major oxides and XRD to analyze the trace elements.

Analysis with the aim of knowing more chemical characters about these rocks samples, and consequently determines the environmental and health impact due to their using as building materials.

Results and discussion for x-ray fluorescence:

i. Wadi El-Dahl

The trace elements of Wadi El-Dahl steam sediment samples are presented in Table 7.

Table 7. **The concentration of the trace elements (ppm) for the selected samples from Wadi El-Dahl steam sediment and Gabal Abu Zawal rock samples**

Sample number	Cr	Co	Ni	Cu	Zn	Zr	Rb	Y	Ba	Pb	Sr	Ga	V	Nb
1	10	3	6	12	57	715	169	33	290	6	67	13	2	12
2	19	3	8	12	59	737	216	47	110	11	27	19	4	39
3	19	3	4	11	54	417	159	39	225	6	45	23	2	18
4	17	3	6	12	54	594	253	63	86	16	41	19	3	63
5	14	3	6	11	47	688	279	64	104	14	46	20	2	50
6	17	3	7	11	58	546	246	63	108	13	68	18	4	46
7	12	3	7	11	47	887	248	50	107	15	68	14	2	52
8	17	3	6	12	47	475	181	38	225	14	75	14	2	12
9	16	3	6	11	44	639	267	59	92	12	48	17	2	54
10	16	3	6	11	44	638	261	51	96	14	41	19	2	41
11	15	3	6	12	57	543	178	36	293	6	78	14	3	14
12	18	3	7	12	49	442	169	35	297	10	64	15	2	5

It clears that, samples from (1 to 12) have high concentration of zirconium and niobium which means a presence of uranium and thorium in this samples. Also strontium concentration varying between (27 - 78) ppm. Strontium has a great importance, where ^{90}Sr is a radioactive isotope with a half - life of 28.78 years. However the contribution of feldspar as raw material to the total specific radioactivity of building materials becomes relatively small because feldspar usually are used in relatively small portion in raw material of glass industry and ceramic industry. Therefore the use of feldspar from Wadi El-Dahl area as building material is safely for human life. From Table 7 all samples contain a high concentration of barium and rubidium.

ii. Wadi Abu Zawal

The trace elements of Wadi Abu Zawal rock samples are presented in Table 8.

Table 8. **The concentration of the trace elements (ppm) for the selected samples from Wadi Abu Zawal rock samples**

Sample number	Cr	Co	Ni	Cu	Zn	Zr	Rb	Y	Ba	Pb	Sr	Ga	V	Nb
13	30	3	8	12	31	25	176	34	237	11	86	14	3	u.d.
14	15	3	7	10	51	1072	287	56	126	70	24	26	21	297
15	14	2	5	11	14	u.d.	630	90	48	34	25	31	u.d.	3
16	12	2	6	11	13	u.d.	496	65	55	26	26	27	u.d.	u.d.
17	13	2	5	11	43	u.d.	629	84	57	21	21	25	u.d.	2
18	13	2	6	11	13	u.d.	549	77	132	29	29	24	u.d.	u.d.
19	12	2	5	12	14	u.d.	535	74	134	31	31	21	u.d.	u.d.

u.d. – under detection limit which is 2 ppm.

From the Table 8 it is clear that all samples contain a high concentration of barium and rubidium, which can separate using different methods in order to use in different important industry.

Barium

Barium sulfate is important to the petroleum industry, barium oxide is used in a coating for the electrodes of fluorescent lamps, barium carbonate is also used in glassmaking and barium fluoride is used for optics in infrared applications. Barium, commonly as barium nitrate, is used to give green colors in fireworks [13].

Rubidium

Rubidium has been considered for use in a thermoelectric generator. Other uses of rubidium include a working fluid in vapor turbines, a getter in photocell component. Rubidium is also used as an ingredient in special types of glass, in the study of potassium ion channels in biology. And as the vapor to make atomic magnetometers [14].

Conclusion

The ground spectrometric survey was carried out on the stream sediment of Wadi El-Dahl and Abu Zawal rock quarries as building materials to obtain the surface distribution of radioelements, K, U, Th and total radioactivity. The measured data were treated on the base of the specific activity for each radioelement to calculate the yielded terrestrial levels of radiation. The results clarify that the levels of the effective dose rate for the raw materials of Wadi El-Dahl (0.62 mSv/y) is lower than the permissible world limit of effective dose 1.0 mSv/y" that recommended by the International Commission on Radiological Protection (ICRP). Therefore, the use of the stream sediment feldspar from Wadi El-Dahl area as building materials is safely for human life. On the other hand, the calculated effective dose for the raw materials from Wadi Abu Zawal (1.48 mSv/y) is higher than the permissible limit, which may represent an environmental risk to use these materials in building industry. The geochemical analysis proved that the zirconium and niobium hosting minerals have an indication for the presence of uranium and thorium. It is clear that all the samples contain high concentration of barium and rubidium which can separate using different methods in order to use in different important industries.

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ВИМІРЮВАННЯ ГАММА-АКТИВНОСТІ ЯК ІНСТРУМЕНТ ВІДБОРУ СИРОВИНИ ДЛЯ БУДІВНИЦТВА ТА ДЛЯ КОНТРОЛЮ ЗА НАВКОЛИШНІМ СЕРЕДОВИЩЕМ

Спектрометричні вимірювання можуть надати інформацію щодо радіоактивності та концентрації радіоелементів. Підвищення активності зовнішнього фону може бути зафіксоване добре відкаліброваними гамма-спектрометрами. Проведено порівняння між кар'єрами Ваді-ель-Даль і Абу Завал, що використовуються для добування будівельної сировини (польового шпату). Установлено, що активність концентрації в покладах кар'єра Ваді-ель-Даль становить 54,5 і 44,5 Бк/кг для урану та торію відповідно. У той час як активність концентрації в покладах каменоломні Абу Завал становить 167,03 і 79,77 Бк/кг для урану та торію відповідно. Ця активність у покладах створює ефективні дози 0,63 мЗв/рік у кар'єрі Ваді-ель-Даль та 1,48 мЗв/рік у каменоломні Абу Завал. Таким чином, спектрометричні вимірювання є відмінним інструментом для моніторингу навколишнього середовища для захисту від радіаційного ризику. У цьому аспекті поклади в кар'єрі Ваді-ель-Даль вважаються більш придатними для добування польового шпату як сировини для будівельної індустрії. Для порівняння, каменоломня Абу Завал має вищу ефективну потужність дози та перевищує міжнародні допустимі норми, що становлять 1 мЗв/рік. Методом рентгенівської флуоресценції було описано 19 зразків польового шпату відповідно до їхніх загальних хімічних характеристик. Із досліджень видно, що всі зразки мають високу концентрацію барію і рубідію, що можуть бути використані окремо в різних важливих галузях промисловості.

Ключові слова: наземні спектрометричні дослідження, рентгенівська флуоресценція, польовий шпат.

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ИЗМЕРЕНИЕ ГАММА-АКТИВНОСТИ КАК ИНСТРУМЕНТ ОТБОРА СЫРЬЯ ДЛЯ СТРОИТЕЛЬСТВА И ДЛЯ КОНТРОЛЯ ЗА ОКРУЖАЮЩЕЙ СРЕДОЙ

Спектрометрические измерения могут предоставить информацию о радиоактивности и концентрации радиоэлементов. Повышение активности внешнего фона может быть зафиксировано хорошо откалиброванными гамма-спектрометрами. Проведено сравнение между карьерами Вади-эль-Даль и Абу Завал, используемых для добычи строительного сырья (полевого шпата). Установлено, что активность концентрации в залежах карьера Вади-эль-Даль составляет 54,5 и 44,5 Бк/кг для урана и тория соответственно. В то время как активность концентрации в залежах каменоломни Абу Завал составляет 167,03 и 79,77 Бк/кг для урана и тория соответственно. Эта активность в залежах создает эффективные дозы 0,63 мЗв/год в карьере Вади-эль-Даль и 1,48 мЗв/год в каменоломне Абу Завал. Таким образом, спектрометрические измерения являются отличным инструментом для мониторинга окружающей среды для защиты от радиационного риска. В этом аспекте залежи в карьере Вади-эль-Даль считаются более подходящими для добычи полевого шпата в качестве сырья для строительной индустрии. Для сравнения, каменоломня Абу Завал имеет более высокую эффективную мощность дозы и превышает международные допустимые нормы, составляющие 1 мЗв/год. Методом рентгеновской флуоресценции было описано 19 образцов полевого шпата в соответствии с их общими химическими характеристиками. Из исследований видно, что все образцы имеют высокую концентрацию бария и рубидия, которые могут быть использованы отдельно в разных важных отраслях промышленности.

Ключевые слова: наземные спектрометрические исследования, рентгеновская флуоресценция, полевой шпат.

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