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Evaluation of Natural Radioactivity forAbu Dabbab and NuwibiAlbite Granite, CentralEastern Desert, Egypt

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Abstract: *The present study aims to evaluation of the natural radioactivity of Abu Dabbaband Nuwibialbite granite, in theCentral Eastern Desert, Egyptusing GR-320 portable spectrometer and HPGe laboratory spectrometer. These two areas are enriched withrare metal Sn–Nb–Ta. The high technology and environmental applications of rare metals have grown dramatically.Tantalum is an important metal for the manufacture of tantalum capacitors utilized in mobile phones, laptop computers, digital cameras, as well as automotive and medical electronic equipment. Therefore, the environmental assessment of these two areas is very important. On the basis of ground spectrometric measurements of K, eU and eTh contents showmaxima (4.9%, 22 ppm and 40 ppm) respectively in Abu Dabab area, and (5.4%, 16 ppm and 39 ppm) respectively in Nuwibi area. The natural radioactivity levels have been determined by HPGe gamma ray spectroscopy for the collected albite granite samples. The activity concentrations are estimated for ^{238}U (range from 56 to 141Bq/kg),^{226}Ra(range from 87 to 147Bq/kg),^{232}Th (from 19to 98 Bq/kg) and ^{40}K (from 614 to 1153Bq/kg) for Abu Dabbab area, and ^{238}U (range from 37 to 80Bq/kg),^{226}Ra (range from 42 to 110Bq/kg),^{232}Th (from 62 to 119Bq/kg) and ^{40}K (from 713 to 1608Bq/kg) forNuwibi area. Absorbed dose rates in air outdoors are measured with average values of 112 nGy/hfor Abu Dabbab albite graniteand 132 nGy/hforNuwibi albite granite. The concentration of radioactive elements ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K at Abu Dabbaband Nuwibiexceeded the worldwide average which recommends the application of the radiation protection regulation. Whereas, the corresponding annual effective dose rates are calculated with average values of 0.14 and 0.16 mSv/y for Abu Dabbab and Nuwibi albite granite respectively which are less than the permissible level (1 mSv/y). Therefore, the two areas are saving for development projects concerning the use of the studied rocks.*

Key words*: Natural radioactivity, albite granite, HPGe detector,spectrometric, measurements.*

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I. Introduction

Natural radioactivity present in soil produces gamma radiations in the environment and changes the background radiations level. Everyone in the planet is exposed to these background levels of ionizing radiations. External exposure occurs as a result of irradiation and internal exposure because of inhalation and ingestion (Singh et al., 2009). The natural radioactivity in the environment arises due to the presence natural radionuclides namely ^{238}U, ^{232}Th and ^{40}K in various geological formations. The terrestrial radiation comprises of radiation emitted from these radionuclides and their progeny. ^{40}K is a singly occurring natural radionuclide, which also emits gamma radiation. Since, 98.5% of the gamma dose received from ^{238}U series are emitted from ^{226}Ra and its daughter products (UNSCEAR, 2000; Otwoma, 2013). The presence of the radioisotopes in materials causes external and internal exposure to the people who live in the building. All types of building materials such as concrete, cement, brick, sand, aggregate, marble, granite, limestone gypsum, etc. cause direct radiation exposure because of their radium, thorium and potassium content. Granitesare widely used as a building and ornamental material.

Granites are igneous rocks which were formed by slowly cooling of magma. Distinct types of granites have different geologic origins and mineralogic compositions. Granitic rocks contain different amounts of naturally occurring radionuclides of terrestrial origin, ^{238}U and ^{232}Th series and ^{40}K (Turhan S¸ 2012).Granites of Nuwibi and Abu Dabbab, central Eastern Desert of Egypt, have mineralogical and geochemical specialization. These granites are acidic, slightly per-aluminous to meta-aluminous, Li–F–Na-rich, and Sn–Nb–Ta-mineralized. Snowball textures, homogenous distributionof rock-forming accessory minerals, disseminated mineralization,and melt inclusions in quartz phenocrysts are typicalfeatures indicative of their petrographic specialization.Geochemical characterizations are consistent with low-P-raremetal granite derived from highly evolved I-type magma inthe late stage of crystallization. This stage is represented by the coexistence oftype-B melt and aqueous-CO_2 inclusions in association withtopaz, columbite–tantalite, as well ascassiterite mineral

inclusions. Thelate magmatic to early hydrothermal stage is represented by smallcrystallized silicic melt in greisen and the outer margins of themineralized veins. These inclusions are associated with beryl,topaz, and cassiterite mineralization. The last stage of immiscibility is fluid–fluid andrepresented by the coexisting H_2O-rich and CO_2-rich inclusions.Cassiterite, wolframite ± chalcopyrite, and fluorite arethe main mineral assemblage in this stage. The latestphase of fluid is low-saline, low-temperature (100–180 °C),and liquid-rich aqueous fluid(Mohamed, 2013). This work aims to determine radiation assessment of Nuwibi and Abu Dabbab rare-metal granites.

II. Geologic Setting

In the central Eastern Desert of Egypt, rare metal mineralization was examined during a joint Egyptian–Soviet exploration program in the early 1970s; Sn–Nb–Ta connected with albite granite have been discovered for the first time at Igla, Nuwibi, Abu Dabbab, and HumrWaggat by (Sabet et al. 1973). They have attributed the formation of rare-metal mineralization to the metasomatic alteration processes affecting the host granites (Abdalla et al. 2008) differentiated between cassiterite associated with magmatic and metasomatic albite granites based on chemical composition of cassiterite. He stated that "the cassiterite associated with the metasomatized albite granite is characterized by enhanced to moderate Nb, Ta, (with Nb/Ta ratios>1), Ti, and FeO (tot) and lower Ga_2O_3 (<0.01 %). On the other hand, the cassiterite in the magmatic albite granite is enriched in Ta, Nb, (with Nb/Ta<1 ratios), Ti, FeO (tot), and Ga_2O_3 (0.01–0.04 %).

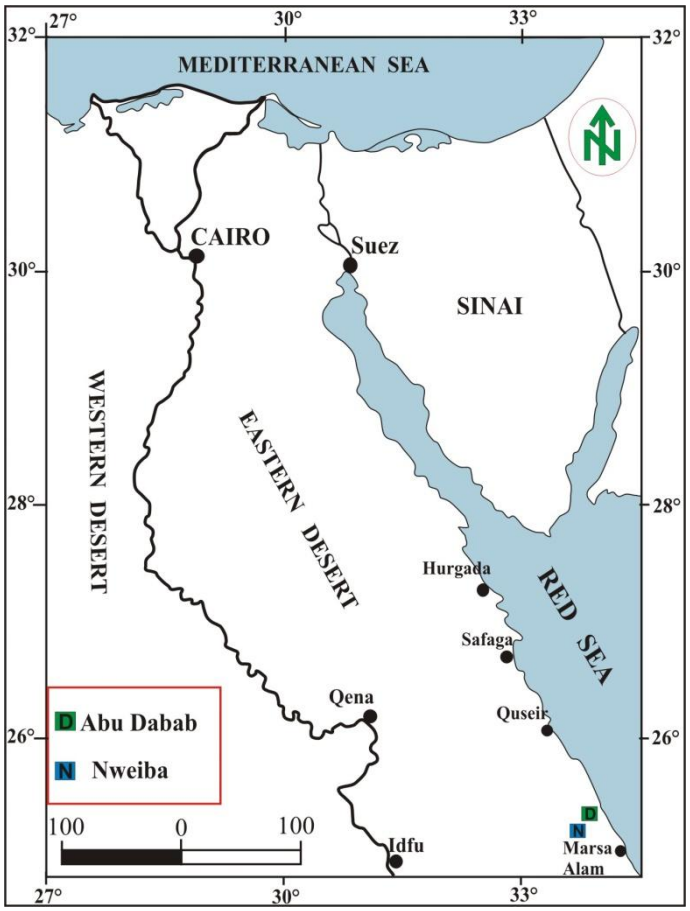

Fig. (1) Location map of Abu Dabab and Nuwibi areas, Central Eastern Desert, Egypt.

2.1. Abu Dabbab area

Abu Dabbab granites form sheet to stock-like intrusions. It has an ellipsoidal shape elongated in an E–W direction, located at 25° 20′ 37″ N and 34° 32′ 30″ E and covering an area of about 0.8 km^2 (Fig. 2). The maximum width in NE–SW direction is nearly 250 m. The stock is inclined towards the ESE and probably intruded into tension gashes created along a NW trending shear zone (Mohamed 1993). It is intruded into the Precambrian metasediments and associated metavolcanic and talc carbonates (Fig. 2).

2.2.Nuwibi area

Nuwibi albite granite lies between latitudes 25° 12′ to 25° 12′ 30″ N and longitudes 34° 29″ to 34° 29′ 35″ E. It covers an area 1.6 km^2. The granites of Nuwibi are divided into eastern and western parts by strike–slip fault along Wadi Nuwibi (Fig. 3). The granites in the eastern part have intruded the metasediments, metavolcanics, and serpentinite rocks. The granites in the western part are surrounded mostly by grey granites. Nuwibi is located 20 km SW of Abu Dabbab. The Nuwibi stock has a much larger surface area than the Abu Dabbab granite but shares similar petrography, contact relationships, age and alteration features. The contact between the Nuwibi granite and the country rock is locally marked by a stockscheider consisting of feldspar–quartz pegmatite and quartz cap (Jahn, 1996; Renno, 1997).Remarkably, and unlike the Abu Dabbab granite, the Nuwibi intrusion does not contain Sn mineralization.

Thealbite granites of both Abu Dabbab and Nuwibi possess chilled margins. Dark-coloured patches of rounded or dendritic shapes due to impregnations of manganese-iron are locally shown in the albite granites. Stockscheider marginal pegmatites, quartz segregations (quartz cap) are described by (Renno et al., 1993) and quartz-amazonite veins occur near the contact as well, and these are locally associated with minor greisenization of the metasediments (Helba et al. 1997, Mohamed 2013).

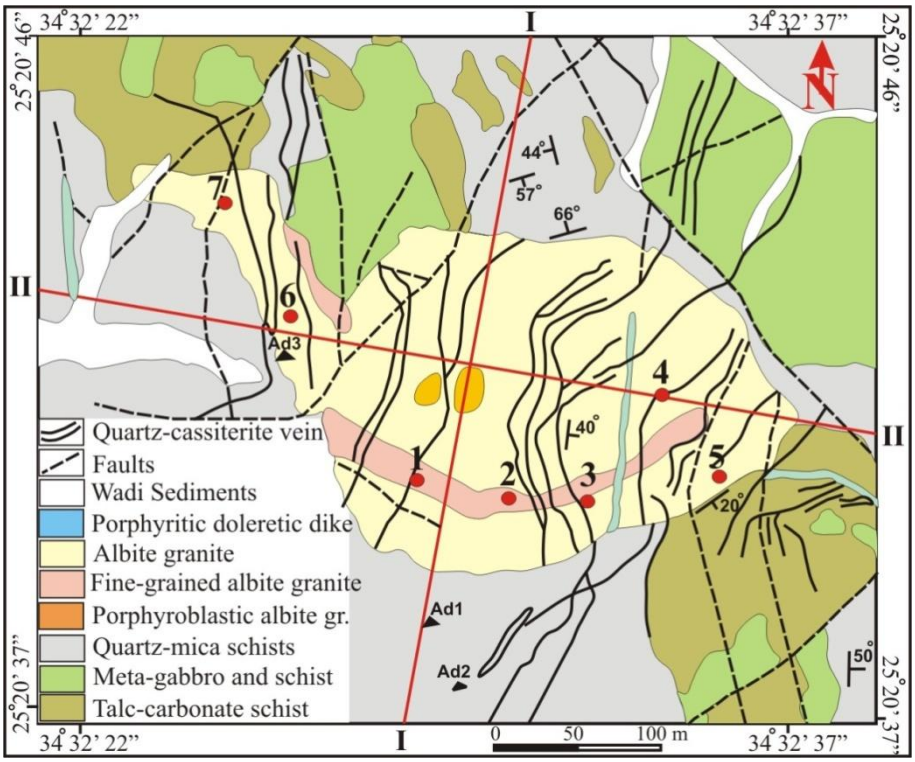

Fig. (2) Geologic map of Abu Dabab area, Central Eastern Desert, Egypt. (after Sabet et al. 1976 and Gaafar and Ali, 2015)

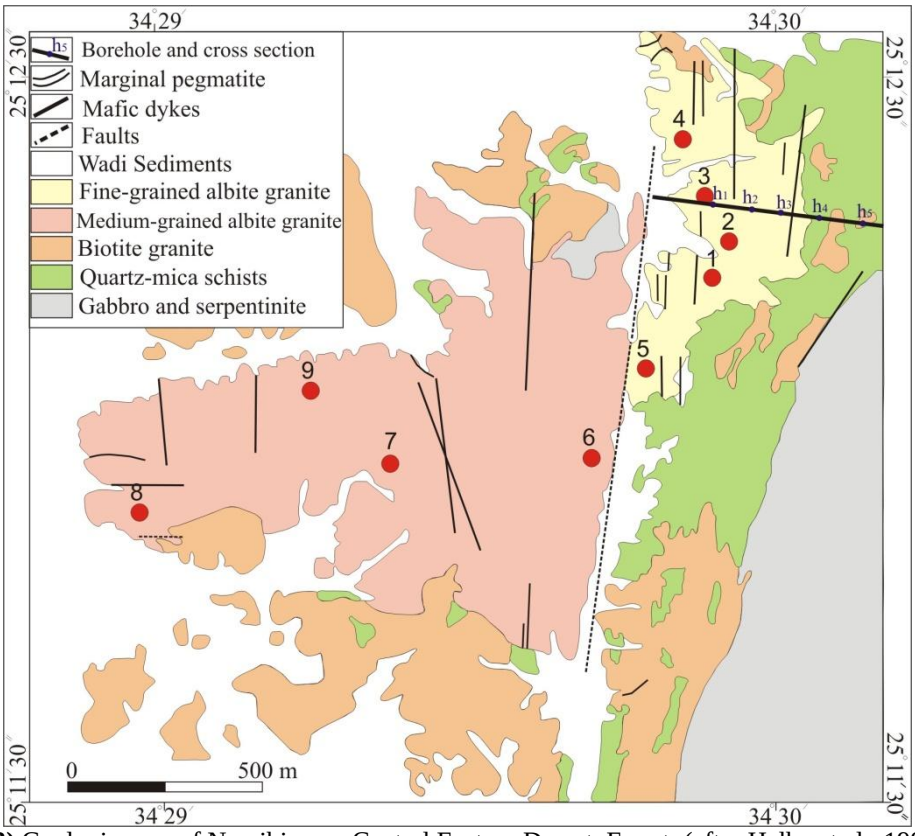

Fig. (3) Geologic map of Nuwibi area, Central Eastern Desert, Egypt. (after Helba et al., 1997 and Gaafar, 2014)

III. Measurements and Experimental Techniques

3.1. Ground Radiometric Survey

TheGR-320 Spectrometer is a portable handheld gamma-ray survey device for geophysical applications, readout TC (Ur), K (%), eU(ppm) andeTh (ppm). At each location three readings by GR-320 were recorded. The three readings were average and the three samples composed on representative sample for that location. Beneath each reading a rock sample was collected covering one square meter.

3.2. Laboratory Radiometric Measurements

Sixteen samples of granite were collected fromtwo areas at the central Eastern Desert of Egypt, Abu Dabbab and Nuwibi. The samples were dried, crushed and sieved through 2mm mesh size. Weighed samples were placed in polyethylene containers of 450 cm^3 volume. For γ-ray spectrometer each sample was carefully sealed for more than one month to reach secular equilibrium between ^{238}U and ^{232}Th and their corresponding daughters to be measured by gamma-ray spectrometry. This step was necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample. Each sample was then counted by using Hyper Pure Germanium Detector (HPGe), to estimate the activity levels of ^{238}U, ^{232}Th and ^{40}K in the 16samples. A high-resolution gamma-ray detection system in the Laboratories of the nuclear physical division, faculty of women, Ain shams University, was used for gamma-ray analysis. The detection system is basically a hyper pure germanium (HPGe), model No. GEM-15190, coaxial type detector with serial No. 27-p-1876A recommended operating bias, negative 3kV. The individual samples were placed on the detector manually during the work and each sample was analyzed for time of 70000s. The γ-ray emitting radionuclides, specifically recorded, were as follows: ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K.

IV. Results and Discussion

4.1 Results of ground radiometric

The mean concentrations ofeU, eTh and K were determined for the granite rocks of the two studied areas. Table (1) shows that granite rocks in Abu Dabbab area are characterized by radioelements content ranged from 6.4 to 22 ppm with an average value 11.8 ppm for eU, from 10.7 to 40 ppm with an average value 20.1 ppm for eTh and from 2.3% to 4.9% with an average value 3.5% for K. While, table (2) shows radioelements

concentrations of Nuwibi area that ranged from 6.3 to 16 ppm with an average value 11.2 ppm for eU, from 20 to 39 ppm with an average value 29.9 ppm for eTh and from 2.6% to 5.4% with an average value 4.1% for K.

Table (1) Ground Spectrometric data for albite granites of Abu Dabbab area, Central Eastern Desert, Egypt.

	Location	**T.C,** Ur	**K (**%)	**eU (**ppm)	**eTh (**ppm)
Dab1	25° 20.669' N 34° 32.555' E	30	3.2	7.6	26
		27	3	6.4	23
		26	2.3	10	22
Av.		**27.7**	**2.8**	**8**	**23.7**
Dab2	25° 20.667' N 34° 32.568' E	24.3	4.1	8.1	13.2
		26.2	4.3	8.8	12
		25.6	4.4	7.2	16
Av.		**25.4**	**4.3**	**8**	**13.7**
Dab3	25° 20.663' N 34° 32.586' E	29.7	4.5	9.7	12.1
		30.1	3.5	12.3	16.1
		27.2	4.3	11.6	13.3
Av.		**29**	**4.1**	**11.2**	**13.8**
Dab4	25° 20.680' N 34° 32.598' E	24.1	3.3	7.6	15.8
		22	2.6	9.7	11.6
		25	3.4	9.2	12.5
Av.		**23.7**	**3.1**	**8.8**	**13.3**
Dab5	25° 20.664' N 34° 32.615' E	21	2.6	8.9	14.3
		20.3	2.7	8.4	10.7
		20.8	2.3	8.3	11.7
Av.		**20.7**	**2.5**	**8.5**	**12.2**
Dab6	25° 20.709' N 34° 32.525' E	35.7	3.3	15.2	22.6
		40.5	3.5	20.8	25
		41.6	3.4	22	27.1
Av.		**39.3**	**3.4**	**19.3**	**24.9**
Dab7	25° 20.727' N 34° 32.509' E	49.7	4.4	18.5	40
		57.6	4.9	21.2	39
		46	4.1	17.2	37.7
Av.		**46**	**4.1**	**17.2**	**37.7**
Min.		**20.3**	**2.3**	**6.4**	**10.7**
Max.		**57.6**	**4.9**	**22**	**40**
Av.		**31**	**3.5**	**11.8**	**20.1**

Table (2) Ground Spectrometric data for albite granites of Nuwibi area, Central Eastern Desert, Egypt.

	Location	**T.C (**Ur)	**K (**%)	**eU (**ppm)	**eTh (**ppm)
Nwb1	25° 12.08'N 34° 29.92'E	41	3.4	11.2	26
		40	3.1	14	21
		39	3.5	11	24
Av.		**40**	**3.3**	**12.1**	**23.7**
Nwb2	25° 12.11'N 34° 29.93'E	37	2.7	16	22
		39	3	14	20
		36	2.6	13	23
Av.		**37.3**	**2.8**	**14.3**	**21.7**
Nwb3	25° 12.17'N 34° 29.89'E	42	4.2	15.4	22
		41	4.5	13	25
		40	4.1	12	24
Av.		**41**	**4.3**	**13.5**	**23.7**
Nwb4	25° 12.23'N 34° 29.89'E	40	4	13	31
		41	3.6	11	33
		39	4	12	27
Av.		**40**	**3.9**	**12**	**30.3**
Nwb5	25° 11.96'N 34° 29.84'E	36	4	7.2	26
		37	4.2	7.3	30
		38	4.4	7.4	25
Av.		**37**	**4.2**	**7.3**	**27**
Nwb6	25° 11.76'N 34° 29.75'E	40	4.4	7.1	37
		38	4.7	6.3	32
		39	4.3	6.7	33
Av.		**39**	**4.5**	**6.7**	**34**
Nwb7	25° 11.72'N 34° 29.42'E	44	4.1	12.3	38
		43	4.6	13	36
		47	4.5	14	39
Av.		**44.7**	**4.4**	**13.1**	**37.7**
Nwb8	25° 11.65'N	42	5.3	9.8	31

	34° 28.94'E	41	5.1	8	34
		44	5.4	10	35
Av.		**42.3**	**5.3**	**9.3**	**33.3**
Nwb9	25° 11.98'N 34° 29.14'E	43	4.6	13	37
		45	4	15	38
		44	5.3	8.5	39
Av.		**44**	**4.6**	**12.2**	**38**
Min.		**36**	**2.6**	**6.3**	**20**
Max.		**47**	**5.4**	**16**	**39**
Av.		**40.6**	**4.1**	**11.2**	**29.9**

4.2 Results of Laboratory Radiometric (HPGe)

The activity of a radioactive source is defined as the rate at which the isotope decays. Radioactivity may be thought of as the volume of radiation produced in a given amount of time. The radioactivity concentration of the different identified radionuclides was calculated by gamma ray spectrometry with the following simple regression (Tsoulfanidies, 1983):

$$\mathbf{A=Net\ area\ (cps)/\ I_{\gamma}.\ \zeta.\ M \quad Bq/Kg}$$

Where:

A=Activity concentration of the gamma spectral line in Bq/Kg

Net area (cps) = the net detected counts per second corresponding to the energy.

ζ = counting system efficiency of the energy.

M = Mass of sample in Kg.

$\mathbf{I}_{\gamma}$= Intensity of the gamma spectral.

4.2.1. Occupational Exposures during Exploration and Transportation Activities

The International Commission on Radiological Protection (ICRP, 1990)recommended that the effective dose resulting from any occupational activities dealing with radioactive materials should not exceed 20mSv/y. However, the International Atomic Energy Agency (IAEA, 2004) established a value of the activity concentration of radioactive material below which it is usually unnecessary to regulate this material. For the radioactive materials of natural origin, this value is 10kBq/kg for ^{40}K and 1kBq/kg for all other radionuclides of natural origin. Accordingly, for a material containing a mixture of the radionuclides; ^{238}U, ^{232}Th and ^{40}K, the total activity concentration (A_T) of this material is calculated as follows (Abdel-Razeket al., 2015):

$$\mathbf{A_T = A_U + A_{Th} + 0.1A_K\ (Bq/kg)}$$

Where:

A_U, $A_{Th}$and A_K are the mean activities of ^{238}U, ^{232}Th and ^{40}K in (Bq/kg), respectively.

4.2.2. Calculation of the Absorbed Dose Rate and Annual Effective Dose Rate

The assessment of the radiation doses in humans from natural sources is of special importance because the absorbed dose by γ-ray exposure is not only dependent on the γ-ray energy but also on the material owing to changes in physical properties (Knoll, 2000, El-Tahawy et al., 1992)**.**

There is concern that some of granite will cause excessive radiation doses to the total body due to γ-ray emitted by ^{232}Th decay chain, ^{214}Pb and ^{214}Bi progeny of ^{226}Ra and ^{40}K also contribute to the total body radiation dose. The absorbed dose rate in the soils calculated using the following equation:

$$\mathbf{D_R= K_K\ C_K + K_{Th}C_{Th} + K_{Ra}C_{Ra}(nGy/h)}$$

Where D_R is the absorbed dose rate (nGy/h) and C_K, $C_{Th}$and C_{Ra} are the concentration of the ^{40}K, ^{232}Th and ^{238}U (Bq/kg), whereas K_K, $K_{Th}$and $K_{Ra}$are the conversion factors (or dose rate coefficients) expressed in (nGy/h per Bq/Kg) for potassium (0.043), Thorium (0.662) and Radium (0.427) respectively (IBSSPAIR, 1996).

Finally, in order to make a rough estimate for the annual effective dose (E), one has to take into account the conversion coefficient from absorbed dose in air to effective dose and the outdoor occupancy factor. In the UNSCEAR (1993, 2000), the Committee used 0.7 Sv Gy^{-1} for the conversion coefficient from absorbed dose in air to annual effective dose received by adults, and 0.2 for the outdoor occupancy factor. Annual effective dose rate outdoors in units of mSv per year is calculated by the following formula (Michalis Tzortzis et al., 2002):

$$\mathbf{E}\ (\text{mSv y}^{-1}) = \mathbf{D_R \times 24\ h \times 365.25\ d \times 0.2\times 0.7 \times 10^{-6}}$$

Where, D_R is the Dose rate (nGy h^{-1}), 0.2 is the occupancy factor and 0.7 (Sv Gy^{-1}) is the conversion coefficient.

In table (3) the radioelements worldwide average values are 33 Bq/kg for ^{238}U, 32 Bq/kg for ^{226}Ra, 33 Bq/Kg for ^{235}U, 45 Bq/kg for ^{232}Th and 500 Bq/kg for ^{40}K. The worldwide average of outdoor dose rates value is 58nGy/h (UNSCEAR, 2010). Meanwhile, the concentrations of all samples are higher than the worldwide of ^{238}U, ^{226}Ra and ^{40}K, but is lower than the worldwide of ^{235}U, and the concentration is less than the worldwide of ^{232}Th except samples No. (Dab 4, Dab 5 and Dab 7), as shown in figure (4).

Figure (5) shows correlation curves of the activity concentrations between (^{238}U &^{226}Ra), (^{238}U &^{235}U), (^{238}U &^{232}Th), (^{238}U &^{40}K) and (^{40}K &^{232}Th) in Abu Dabbab area. The resultant correlations are weak in figures (5C &5D), strong in figures(5A&5B &5E). There is a high and positive correlation between ^{238}U &^{235}U (R^2=0.9972), also a high and positive correlation between ^{232}Th &^{40}K (R^2=0.7542) and a high positive correlation between ^{238}U &^{226}Ra (R^2=0.6923**)** because the two elements accompanied each other. Meanwhile, figure(5C) shows a negative correlation between ^{238}U &^{232}Th (R^2=0.2009**)** which could be explained due to the high U-enrichment. Figure (5D) shows a weak correlation between ^{238}U &^{40}K (R^2=0.2345)due to the lower activity concentration of ^{40}K compared to the high concentration of^{238}U.

Table (4) shows the radionuclides concentration of Abu Dabbab albite granite. The concentrations of ^{238}U, ^{235}U, ^{232}Th and ^{40}K are ranging between (4.55 – 11.4 ppm), (0.03 - 0.08 ppm), (4.68 - 24.2 ppm) and (1.96 – 3.7%) respectively. The ^{232}Th/^{238}U ratios for most samples are less than clark's value (3.5) which reflect U-enrichment for Abu Dabbab area. Whereas the sample No. (Dab 5) is slightly higher than clark's value which indicate slightly U-depletion.

Table (5) shows that the absorbed dose rate D_R (nGy/h) for Abu Dabbab samples is higher than the dose limit (58 nGy/h), as shown in figure (6). Meanwhile, the annual effective dose rate is lower than the worldwide limit (1mSv/y) for all Abu Dabbab samples.

Table (3) Activity concentration of ^{238}U, ^{235}U, ^{226}Ra, ^{40}K(Bq/Kg)for Abu Dabbab samples, Central Eastern Desert, Egypt.

samples	**^{238}U**	**^{226}Ra**	**^{235}U**	**^{232}Th**	**^{40}K**	**^{238}U/^{235}U**	**^{226}Ra/^{238}U**
Dab 1	56.	97.4	2.6	42.3	1003.9	21.3	1.7
Dab 2	75.5	86.6	3.5	24.5	1006	21.4	1.2
Dab 3	81.7	97.1	3.7	41.2	1153.8	21.9	1.2
Dab 4	140.7	122.2	6.7	63.2	750.6	21	0.9
Dab 5	78.3	102.9	3.7	97.9	614.4	21	1.3
Dab 6	66.4	88.1	3	18.9	1045.4	22	1.3
Dab 7	125.9	146.7	5.8	73.3	827.1	21.7	1.2
Min	56.4	86.6	2.6	18.9	614.4		
Max	140.7	146.6	6.7	97.9	1153.8		
Av.	89.3	105.8	4.2	51.6	914.5		
W.A.	**33**	**32**	**33**	**45**	**500**	**21.7**	**1**

Table (4) Concentration of ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra, ^{40}K and clark's value for Abu Dabbab albite granite, Eastern Desert, Egypt.

Samples	**^{238}U** (ppm)	**^{235}U** (ppm)	**^{232}Th (**ppm)	**^{40}K** (%)	**^{232}Th/^{238}U**
Dab 1	4.55	0.03	10.45	3.21	2.30
Dab 2	6.09	0.04	6.04	3.21	0.99
Dab 3	6.59	0.05	10.18	3.69	1.55
Dab 4	11.35	0.08	15.60	2.40	1.37
Dab 5	6.31	0.05	24.19	1.96	3.83
Dab 6	5.36	0.04	4.68	3.34	0.87
Dab 7	10.16	0.07	18.09	2.64	1.78

Table (5) Total activity concentration A_T, Dose rate D_R and the annual effective dose E for Abu Dabbab albite granite, Eastern Desert, Egypt.

Samples	**A_T**	**D_R (nGy/h)**	**E (mSv/y)**
Dab 1	199.08	95.26	0.12
Dab 2	200.60	91.71	0.11
Dab 3	238.27	111.78	0.14
Dab 4	278.97	134.19	0.17
Dab 5	237.69	124.70	0.15
Dab 6	189.90	85.85	0.11
Dab 7	281.96	137.87	0.17
average	232.35	111.62	0.14
D.L		**58**	**1**

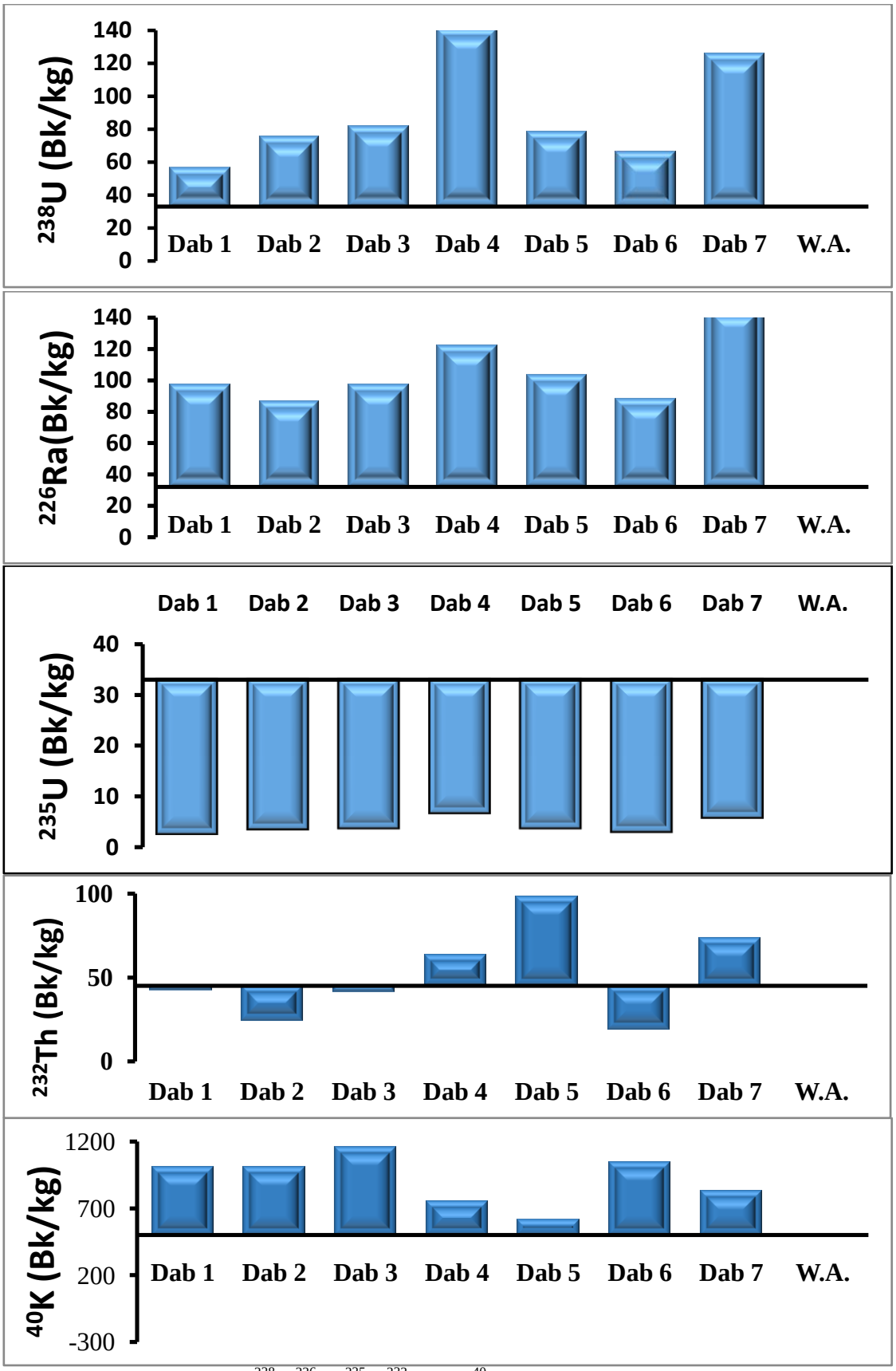

Fig. (4) Activity concentration of ^{238}U, ^{226}Ra, ^{235}U, ^{232}Th and ^{40}K for Abu Dabbab samples, Central Eastern Desert, Egypt.

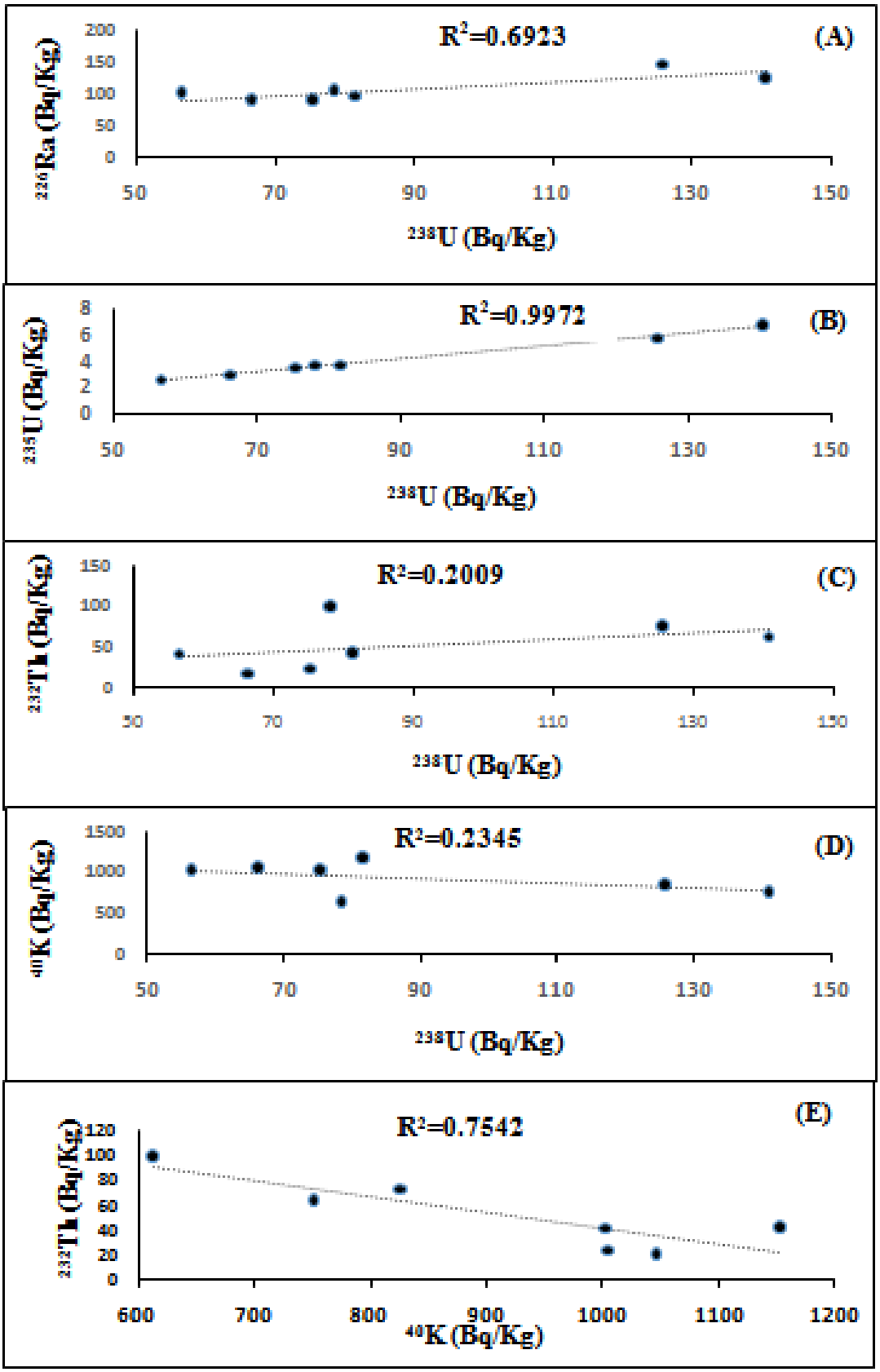

Fig. (5) Correlation curves of the activity concentrations between (^{238}U &^{226}Ra), (^{238}U &^{235}U), (^{238}U &^{232}Th), (^{238}U &^{40}K) and (^{40}K &^{232}Th) in Abu Dabbab area, Eastern Desert, Egypt.

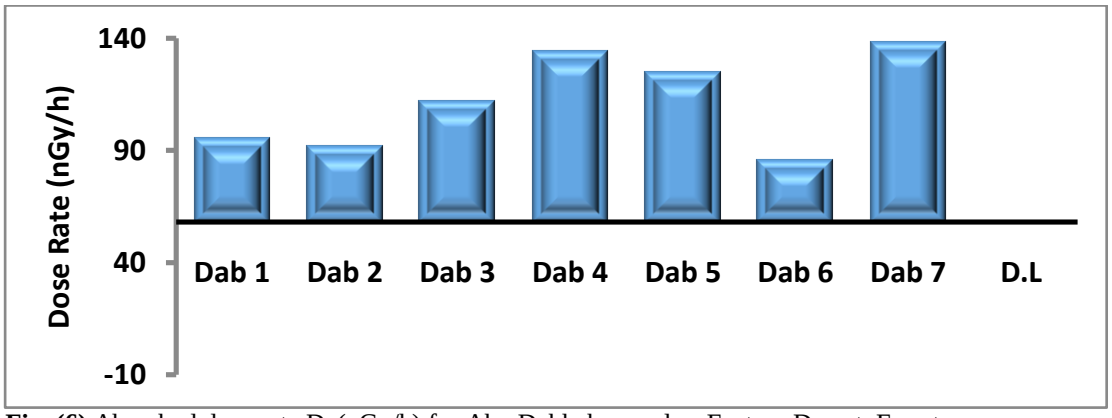

Fig. (6) Absorbed dose rate D_R(nGy/h) for Abu Dabbab samples, Eastern Desert, Egypt.

The concentrations of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K are higher than the world- wide average, while the concentration of ^{235}U is lower than the worldwidefor Nuwibi area, as shown intable (6) and figure (7)(UNSCEAR, 2010).

Table (6) Activity concentration of ^{238}U, ^{235}U, ^{226}Ra, and ^{40}K (Bq/Kg) for Nuwibisamples, Eastern Desert, Egypt

samples	^{238}U	^{226}Ra	^{235}U	^{232}Th	^{40}K	$^{238}U/^{235}U$	$^{226}Ra/^{238}U$
Nwb 1	62.3	96.5	2.8	78.8	1139	22.0	1.6
Nwb 2	78.5	83.9	3.7	78.2	1029	21.5	1.1
Nwb 3	76.4	110	3.6	78.2	1302	21.4	1.4
Nwb 4	80.1	81.1	3.8	80.1	1608	21.4	1.0
Nwb 5	56.0	75.9	2.7	61.8	945	21.1	1.4
Nwb 6	48.4	63.2	2.3	99.2	1233	21.1	1.3
Nwb 7	37.4	49.8	1.7	62.5	713	21.8	1.3
Nwb 8	40.0	41.5	1.9	102.5	1214	21.3	1.0
Nwb 9	66.6	71.0	3.1	119.2	1216	21.2	1.1
Min	37.4	41.5	1.7	61.8	712.7		
Max	80.1	110	3.8	119.2	1608		
Av.	60.6	74.8	2.8	84.5	1156		
W.A.	**33**	**32**	**33**	**45**	**500**	**21.7**	**1**

Figure (8) shows the correlation curves of the activity concentrations between (^{238}U&^{226}Ra), (^{238}U &^{235}U), (^{238}U &^{232}Th), (^{238}U &^{40}K) and (^{40}K &^{232}Th) inNuwibi area. The resultant correlations are strong in figures(8 A and B), but weak in figures(8 C, D and E). There is a high and positive correlation between ^{238}U and ^{235}U (R^2=0.9977), also a high positive correlation between ^{238}U and ^{226}Ra (R^2=0.6467) because the two elements accompanied each other. Meanwhile, figure(8C) shows a negative correlation between ^{238}U and ^{232}Th (R^2=0.0002) which could be explained due to the high U-enrichment. Figure(8 D) shows a weak correlation between ^{238}U and ^{40}K (R^2=0.3182) due to the lower activity concentration of ^{40}K than the higher-concentrated ^{238}U. Figure(8 E) shows a weak correlation between ^{232}Th and ^{40}K (R^2=0.1974), which indicates moderate level of ^{232}Th compared to very low ^{40}K concentrations.

Table (7) shows the radionuclides concentration for Nuwibi albite granite. The concentrations of ^{238}U, ^{235}U, ^{232}Th and ^{40}K are ranging between (3.02 – 6.46 ppm), (0.02 - 0.05 ppm), (15.27 - 29.44 ppm) and (2.28 – 5.14 %) respectively. The $^{232}Th/^{238}U$ ratio for (Nwb1, Nwb6, Nwb7, Nwb8, Nwb9) are higher than clark's value (3.5) which indicate slightly U-depletion. Whereas the sample No. (Nwb2, Nwb3, Nwb4, Nwb5) are less than clark's value which indicate slightly U-enrichment. Table (8) shows that the absorbed dose rate D_R (nGy/h) for Nuwibi samples is higher than the permissible dose limit (58 nGy/h), as shown in figure (9). Meanwhile, the annual effective dose (E) is lower than the worldwide level (1mSv/y) for Nuwibi albite granite.

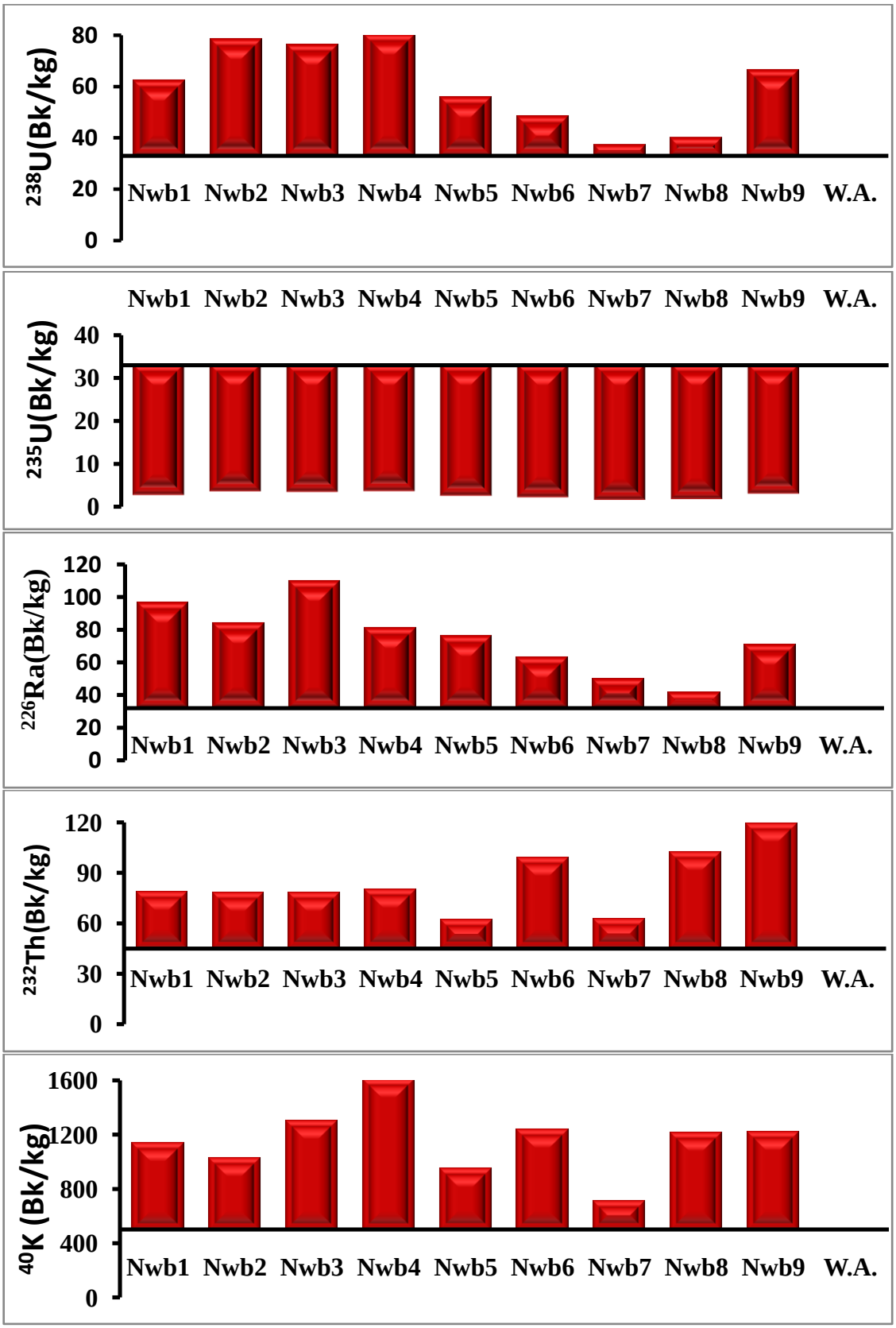

Fig. (7) Activity concentration of ^{238}U, ^{235}U,^{226}Ra,^{232}Th and ^{40}K for Nuwibi samples, Eastern Desert, Egypt.

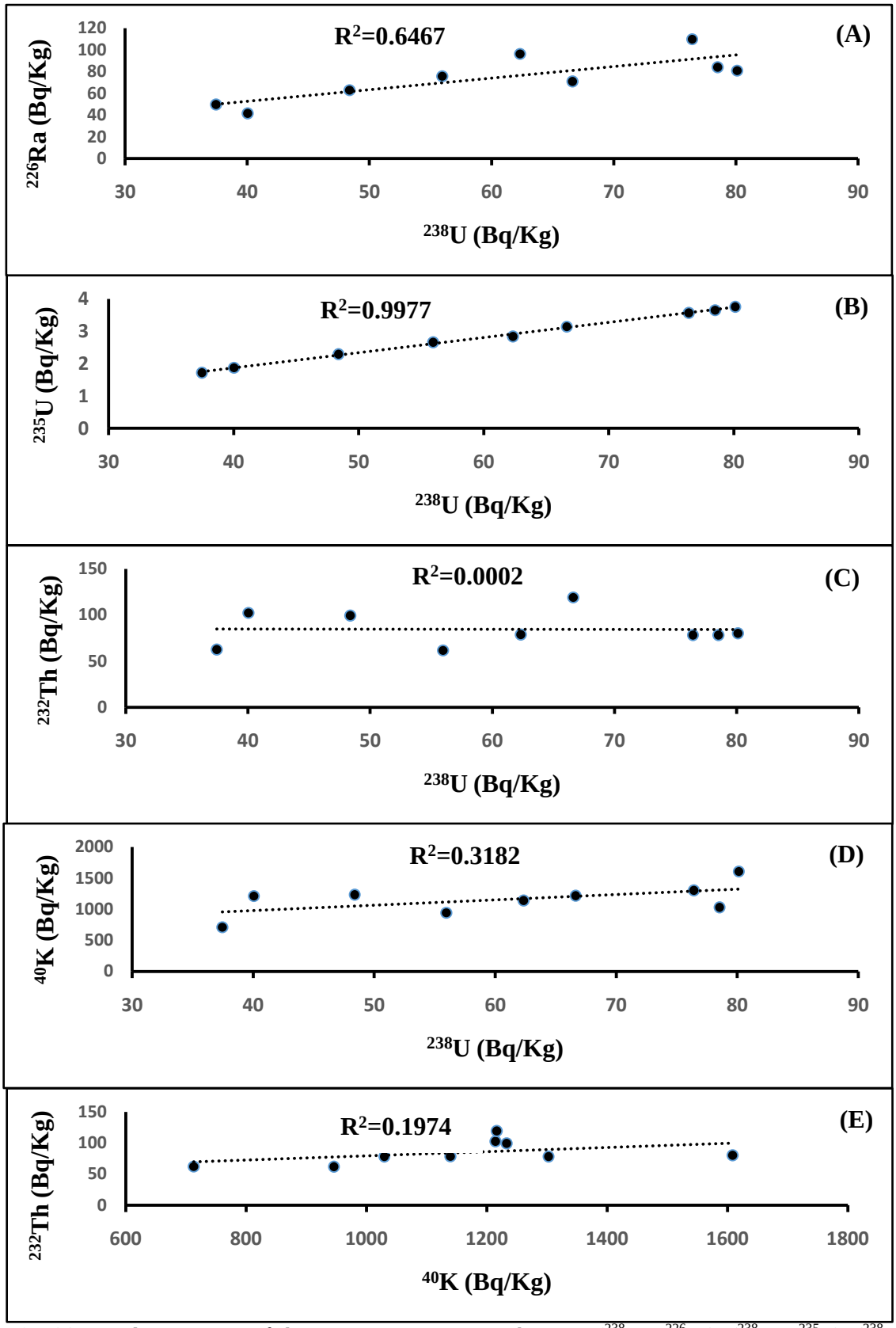

Fig. (8) Correlation curves of the activity concentrations between (^{238}U &^{226}Ra), (^{238}U &^{235}U), (^{238}U &^{232}Th), (^{238}U &^{40}K) and (^{40}K &^{232}Th)Nuwibi area, Eastern Desert, Egypt.

Table (7) activity concentration of ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra, ^{40}K and clark's value for Nuwibi, Eastern Desert, Egypt.

	^{238}U (ppm)	^{235}U (ppm)	^{232}Th (ppm)	^{40}K (%)	$^{232}Th/^{238}U$
Nwb1	5.03	0.04	19.45	3.64	3.87
Nwb2	6.33	0.05	19.30	3.29	3.05
Nwb3	6.16	0.04	19.30	4.16	3.13
Nwb4	6.46	0.05	19.77	5.14	3.06
Nwb5	4.51	0.03	15.27	3.02	3.38
Nwb6	3.90	0.03	24.50	3.94	6.28
Nwb7	3.02	0.02	15.42	2.28	5.11
Nwb8	3.23	0.02	25.31	3.88	7.84
Nwb9	5.37	0.04	29.44	3.89	5.48

Table (8) Total activity concentration A_T, Dose rate D_R and the annual effective dose E for Nuwibi albite granite, Eastern Desert, Egypt.

Samples	A_T	D_R(nGy/h)	E (mSv/y)
Nwb1	255.02	127.75	0.16
Nwb2	259.60	129.53	0.16
Nwb3	284.77	140.36	0.17
Nwb4	321.03	156.38	0.19
Nwb5	212.33	105.48	0.13
Nwb6	270.86	139.35	0.17
Nwb7	171.17	87.98	0.11
Nwb8	263.96	137.16	0.17
Nwb9	307.47	159.67	0.20
Av.	260.69	131.52	0.16
D.L.		**58**	**1**

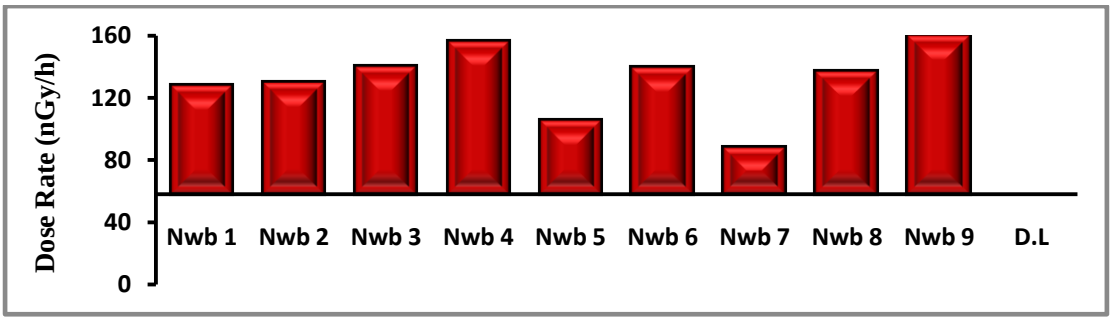

Fig. (9) Absorbed dose rate D_R (nGy/h) for Nuwibi samples, Eastern Desert, Egypt.

V. Conclusions

Since the albite granites of both Abu Dabbab and Nuwibi areas are used in the purpose of building materials and these granites enriched with rare metals that necessary for industry so, it was necessary to assessment their natural radioactivity of^{238}U, ^{226}Ra,^{232}Th, and ^{40}K.

Ground radiometric survey for Abu Dabbab albite granite revealed that the average concentration of eU, eTh and K are 11.8 ppm, 20.1 ppm and 3.5 % respectively. Meanwhile, the average contents of eU, eTh and K in Nuwibialbite granite are 11.2 ppm, 29.9 ppm and 4.1% respectively. Therefore, the two studied areas are higher than the recommended value for safety used as building materials (4.1 ppm, 12.3 ppm and 1.6% for eU, eTh and K% respectively)(UNSCEAR 1993).

The calculated$^{232}Th/^{238}U$ ratios are slightly less than clark's value (3.5) in Abu Dabbabalbite granite which indicate somewhat U-enrichment in this area. Whereas, four samplesof Nuwibiare equal clark's value meanwhile, other five samples are higher than clark's value which indicate that thereis slightly U-depletion in this area.

The activity ratio$^{226}Ra/^{238}U$ was calculated for all samples which show disequilibrium between ^{226}Ra and ^{238}U except samples Nos. (Dab 4, Nwb 2, Nwb 4, Nwb 8, Nwb 9) have equilibrium between^{226}Ra and ^{238}U. The $^{238}U/^{235}U$ activity ratio for all samples vary between 21 and 22 in Abu Dabbab albite granite and between 21 and 22 in Nuwibi albite granite, which include within the normal ratio (21.7).

Absorbed dose rate $D_R$for the two studied areas are higher than the permissible dose limit. This may indicate that the workers in the mines of granite receive higher total effective doses due to the high radioactivity of the two areas. Therefore, the workers must take the protections to reduce the risk.The calculated annual effective doses (E) for the two studied areas are lower than the worldwide value (1mSv/y).

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