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Distribution of Radioelements and Evaluation of Radiological Hazard effects on Stream Sediments and Cataclastic Rocks of Wadi Abu Rusheid, Southeastern Desert, Egypt

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ABSTRACT

In situ gamma and laboratory spectrometric measurements have been performed to characterise the natural radiation that emitted from the stream sediment and cataclastic rocks in Wadi Abu Rusheid, Southeastern Desert, Egypt. The results allowed us to delineate the origins and distributions of these natural radionuclides on the study area. Consequently, it can be possible to avoid any possible environmental impacts from these rocks and/or raw materials of high intensity of natural radiation sources. In situ gamma and laboratory spectrometric measurements illustrate that the natural radioactivity in Abu Rusheid area are very high, because this area contains a distinctive occurrence for uranium mineralization. Measured radioelement values for stream sediment and cataclastic rocks are higher than the recommended values for safety if used as building materials.

Keywords: Natural radioactivity; Annual gonadal dose equivalent Excess lifetime cancer risk

1. INTRODUCTION

The Eastern Desert of Egypt is bounded by the Nile Valley to the west and Red Sea to the east. It consists of a backbone of high and rugged mountains running parallel to the Red Sea coast. Wadi Abu Rusheid area is located in the south part of Eastern desert and it is considered as a distinctive occurrence of economically important rare-metal mineralization where the host rocks are represented by granitic gneisses (Raslan and Ali, 2011). Rare-metal mineralizations are particularly and genetically associated with post–orogenic granitoids (Tischendorf, 1977).

Several mineral deposits have been found in the study area, which can be grouped into two groups as follows: (1) Ore minerals group contains pyrite, brochanite, pyrolusite, Mn-franklinite, casseterite, kasolite, thorite, thorianite, columbite-tantalite and zircon, and (2) An associated gangue minerals group containing fluorite, mica, garnet, amazonite, tourmaline, goethite, hematite, magnetite, jarosite and thuringite (Mansour, 2005).

Materials originating from rocks which can use as building materials or even a raw material in the industry of building materials contain mainly natural radionuclides, including uranium (^{238}U) and thorium (^{232}Th) and their decay products and the radioactive isotope of potassium (^{40}K).

The present study aims to discuss the distribution of the radionuclides; U, Th and K in stream sediments and cataclysmic rocks at Abu Rusheid area which represents one of the highly radioactive locations in the southeastern desert of Egypt. Since rocks under study can be used in industries and building construction and because radiation exposure to the population can be increased appreciably by the use of building materials containing above normal levels of natural radioactivity. Therefore, it is important to assess the radiation hazards arising from naturally occurring radionuclides of these samples. The data provide basic information that may be used as reference to detect and determine the amount and extent of any possible future changes in the environmental radioactivity of the area.

2. GEOLOGICAL ASPECTS

Abu Rusheid area is located in the Southeastern Desert of Egypt (about 45 km southwest of Marsa Alam), (Fig.1) between latitudes 24° 37' 43" – 24° 38' 26" N and longitudes 34° 46' 00" – 34°46' 35" E (Fig. 1). The studied area is surrounded by a famous ancient mining area for emeralds. The area could be reached from the Red Sea coast through Wadi El Gemal and then Wadi Nugrus along a desert track about 40 km long. The area is also accessible from new asphaltic road which connects Idfu –Marsa Alam road with the area of Sheikh Shadli farther south.

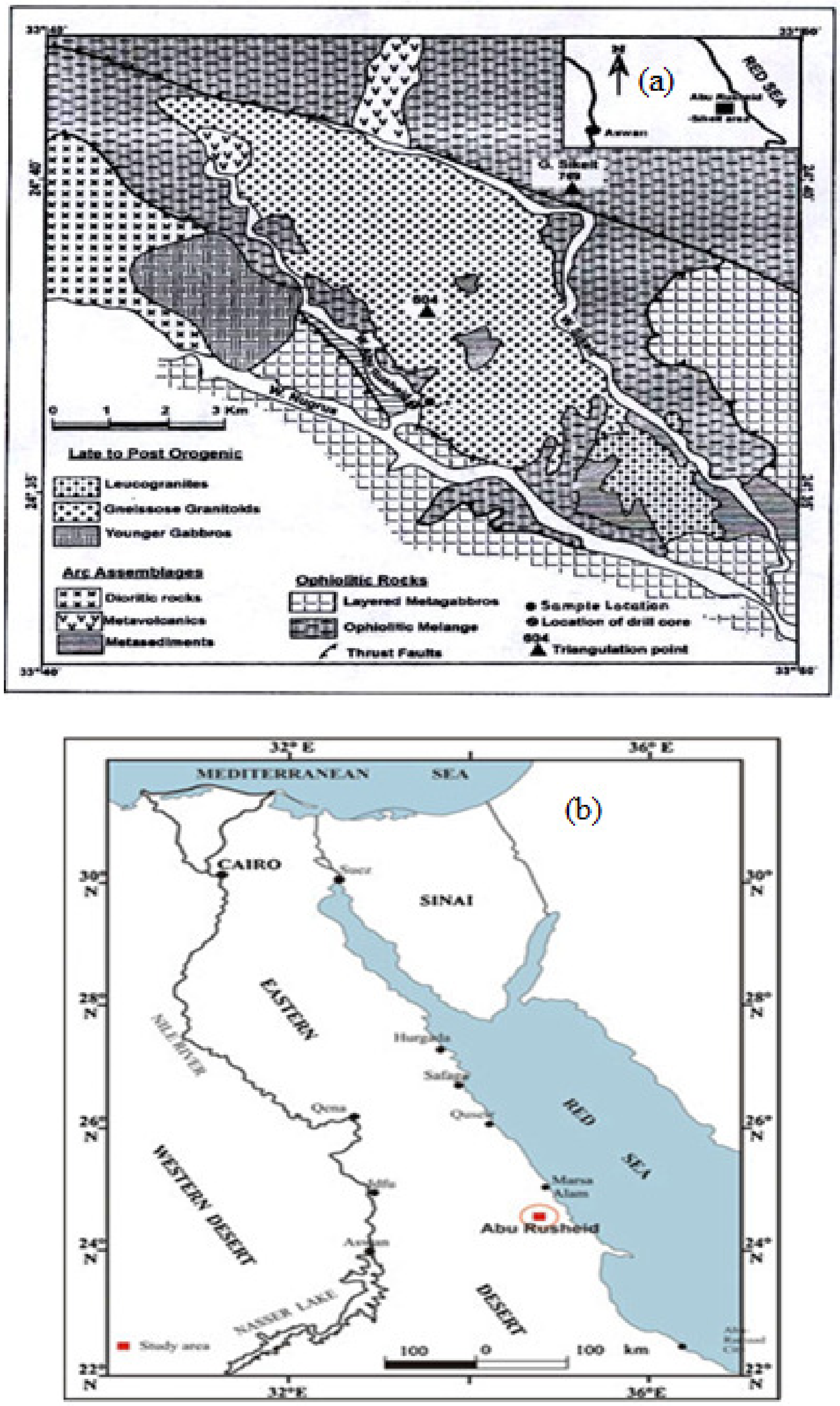

Figure (1):- a) Geologic map of Abu Rushied area, Southeastern Desert of Egypt (After, Ibrahim et al. 2000). b) Location map of the study area

The geologic setting of the area and the potentialities for mineralizations in Abu Rusheid area and its surrounding have been discussed by various workers (Sadek, 1952; El Shazly and Hassan, 1972; Krs, 1973; Sabet et al., 1976; Abdel Monem and Hurley, 1979; Ibrahim et al., 2002 & 2004). The study area is characterized by low to moderate topography. According to Higgins (1975), Ibrahim et al. (2002) and Kurtand Martin (2002), the tectono-stratigraphic sequence of Abu Rusheid Precambrian rock types are: (1) An ophiolitic melange, consisting of ultramafic rocks and layered metagabbros set in a metasediment matrix; (2) cataclastic rocks, including proto-mylonites, meso-mylonites, ultramylonites, silicified ultra-mylonites and augen mylonites; (3) Mylonitic two mica granites; and (4) Post-granite dykes and veins (lamprophyre, pegmatite and quartz).

3. MEASUREMENTS AND EXPERIMENTAL TECHNIQUES

3.1 Ground radiometric survey

In situ gamma–ray spectrometry measurements have been carried out using a GS-256 spectrometer (designed by Geofyzika Brno-Czech Republic) with a 3"×3" sodium iodide (Thalium) [NaI (Tl)] crystal detector. The device having an automatic dead-time correction and an internal ^{137}Cs source allows the spectrometer to automatically maintain system gain stability, is measured over a large body of water and in addition to a system work with the GPS units.

A total number of 227 sites (113 cataclastics, and 114 stream sediments) were considered to investigate their natural radioactivity due to ^{238}U (ppm), ^{232}Th (ppm) and ^{40}K (%).

Before field measurements, the spectrometer is calibrated on concrete pads containing known concentrations of U, Th and K. This calibration provides the stripping ratios and sensitivities required for correcting the measured eU, eTh and K.

The measurements are based on the detection of γ-radiation emitted in the decay of ^{214}Bi (^{238}U series) at 1.76 MeV, ^{208}Tl (^{232}Th series) at 2.41 MeV, and The primary decay of potassium ^{40}K (1.46 MeV) is measured directly.

The determinations of uranium and thorium are based on the assumption that the daughter nuclides are in equilibrium with the parent nuclides that is none of the intermediate steps in the decay series has been disrupted. Consequently, the deduced amounts of uranium and thorium are equivalent to what would be in equilibrium with the measured radioactivity of the bismuth or thallium isotopes (Killeen and Cameron, 1977). Therefore the term 'equivalent' or its abbreviation 'e' is used to indicate that equilibrium is assumed between the radioactive daughter isotopes monitored by the spectrometer, and their respective parent isotope. Based on replicate analyses, the precision of the determinations was ±10%.

3.2 Laboratory radiometric survey

A total number of forty seven samples from Abu Rusheid area (28 stream sediments and 19 cataclastic rocks) were subjected to radiometric analysis using NaI (Tl) gamma-ray spectrometers for determination of their radioelements concentration.

These samples were prepared for gamma-ray spectrometric analysis in order to determine their uranium, thorium, radium and potassium contents by using multi-channel analyzer of gamma-ray detector (Gamma-Spectrometer technique). The instrument used in determination of the four radioactive elements consists of a Bicron scintillation detector NaI (Tl) 76×76 mm, hermetically sealed with the photomultiplier tube in aluminum housing. The tube is protected by a copper cylinder protection of thickness 0.6 cm against induced X-ray and a chamber of lead bricks against environmental radiation. Uranium, thorium, radium and potassium are measured by using four energy regions representing Th-234, Pb-212, Pb-214 and K-40 at 93 keV, 239 keV, 352 keV, and 1460 keV for uranium, thorium, radium and potassium, respectively. The measurements were carried out in sample plastic containers, cylindrical in shape, 212.6 cm^3 volumes with 9.5 cm average diameter and 3 cm height. The rock sample is crushed to about 1 mm grain size, and then the container is filled with about 300-400 gm of the crushed sample sealed well and left for at least 28 days to accumulate free radon to attain radioactive equilibrium. The relation between the percentage of Rn-222 accumulation and time increase till reaching the steady stage after about 38 days (Matolin, 1991).

4. RESULTS AND DISCUSSION

The mean concentrations of eU, eTh and K were determined for the stream sediments which uses in the ceramic industry and cataclastic rocks which use as ornamental stone. Table (1) shows that ***Cataclastic rocks*** are characterized by radioelements content ranged from 22 to 1401 ppm with average value 110.6 ppm for eU, from 58 to 10050 ppm with average value 482.3 ppm for eTh and from 2.1% to 9.5% with average value 5.7% for K while ***Stream sediments*** radioelements concentrations ranged from 7 to 102 ppm with average value 33.4 ppm for eU, from 15 to 507 ppm with average value 109.1 ppm for eTh and from 1.7% to 6.6% with average value 4.9 % for K.

4.1 Geochemistry of U, Th and K in the studied rocks

From the elemental concentrations of eU, eTh and K the relationships between these elements were computed (table 1), and diagrammatically shown in figure (2).

eU- eTh/3.5

The remobilization parameter (eU- eTh/3.5) is very helpful in defining the trends of uranium migration (Abdel Meguid et al., 2003).The uranium migration value can be obtained by subtracting the original uranium content (eTh/3.5) from the present measured uranium content (eU). The original uranium content can be theoretically calculated by dividing eTh content by the eTh/eU which is ranging from 3 to 4 in acidic volcanics (Wenrich, 1985, Helmy S. O. Abouelnaga et al., 2014).

From table (1), eU- eTh/3.5 ranged from -1635 to 220.7 with average value -27.2 and from - 42.9 to 16.3 with average value 2.2 for cataclastic rocks and stream sediments respectively. The positive value (+ve) means that the uranium leaching in and the negative value (-ve) means leaching out (Ibrahim et al, 2010).

eTh/eU

eTh/eU ratio is indicative for the relative depletion or enrichment of radioisotopes (Orgün et al, 2007). Uranium enrichment can be indicated by the ratio decrease lower than 3, while uranium leaching out can be indicated by its increasing above 3. From table (1) we can observe that values of eTh/eU ratio for cataclastic rocks ranged from 0.5 to 20.6 with average value 3.8. This value is higher than clark value (3.5) which indicates that the radioelements in these rocks have not been significantly fractionated during weathering or involved in metasomatic activity (Clark et al, 1966). U-depletion is also clarified by the negative average value of remobilization parameter -27.2 (maybe by leaching).

With respect to stream sediments eTh/eU ratio rocks ranged from 1.9 to 5.8 with average value 3.2 whichis less than 3.5 (Clark's value), indicating enrichment of uranium in the study stream sediments.

eTh/ K

The potassium–thorium cross plot is widely used for the recognition of clay mineral associations and the discrimination of micas and feldspars (Macfarlane et al., 1989). As both thorium (by adsorption) and potassium (chemical composition) are associated with clay minerals, the ratio eTh/K expresses relative potassium enrichment as an indicator of clay-mineral species, and as might be diagnostic of other radioactive minerals (Doventon and Prensky, 1992; Anjos et al, 2005). So, If eTh/K ≥ 2×10^{-4}, the rock is thorium rich, and if eTh/K ≤ 1×10^{-4}, the rock is potassium rich (Ong and Shallehhuddin, 1988; Abu-Deif et al, 2007).

Table (1):- eU, eTh, eRa and K contents of the studied cataclastic and stream sediments rocks

Rock type	eU (ppm)		eTh (ppm)		K (%)		eTh/eU		eTh/eK		eU-eTh/3.5	
	Range	mean	range	mean	range	mean	range	mean	range	mean	range	mean
Cataclastic	22 – 1401	110.6	58 – 10050	482.3	2.1 – 95	5.7	0.5 – 20.6	3.8	18.6 – 230	60.6	-1635 – 220.7	- 27.2
Stream Sediments	7 – 102	33.4	15 – 507	109.1	1.7 – 6.6	4.9	1.9 – 5.8	3.2	8.8 – 81.8	21.7	-42.9 – 16.3	2.2

From table (1), eTh/ K ratio ranged from 18.6 to 230 with average value 60.6 and from 8.8 to 81.8 with average value 21.7 for cataclastic rocks and stream sediments, respectively. These values are much higher than 2×10^{-4} which means thorium enrichment.

Figure (2) illustrates the relationships between ^{238}U, ^{232}Th and^{40}K. Figure (1a) illustrate a very strong relationship between ^{238}U and ^{232}Th for cataclastic rocks (R= 0.8). This result indicates that the behavior of U and Th was controlled by magmatic processes.

Thorium displays poor increasing relation with potassium (R= 0.3) for stream sediments, while a strong relation (R= 0.9) for cataclastic rocks (Fig. 1b).With respect to eU- K relation, a moderate positive correlation was observed (R= 0.5) for stream sediments and strong (R= 0.9) for cataclastic rocks (Fig. 2c).

Variation diagrams of eU and eTh with their ratios display a positive correlation (Fig. 2d & e) confirming the previous results. eTh/eU and eTh/K variation diagram (Fig. 2f) exhibit that the samples under investigation lie in the leached- U sector.

The results obtained from laboratory measurements (Table 2) indicate that cataclastic rocks are characterized by radioactivity ranged from 37 to 81 with average value 61.7 ppm, from 25 to 43 with average value 35.4 ppm, from 159 to 242 with average value 212 ppm and from 2.7 to 3.7 with average value 3.1 % for ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K respectively. The corresponding values for stream sediments ranged from 3 to 27 with average value 15.3 ppm, from 3 to 26 with average value 13.3 ppm, from 14 to 74 with average value 41.3 ppm and from 1.3 to 2.4 with average value 1.9 %.

We can notice from the results in table (3) that the measured field values of eU, eTh, and K are about twice higher than the same samples measured in the laboratory, and this can be attributed to three reasons. The first is the high background radiation in the study area (Abu Rushied), which arising from primordial radionuclides (uranium, thorium, their decay products and potassium) as well as cosmic radiation. The second is related to the laboratory preparation for measuring the samples, where in the laboratory we take into account the background radiation created by cosmic radiation, contamination of natural or manmade radionuclides in the environment of the detector and subtract it from the obtained concentrations. The third reason may be attributed to that the measured samples in the laboratory represent a small part of the whole area which measured by in situ gamma ray and also the mass or bulk effect of the field measured samples.

Table (2):- eU, eTh, eRa and K contents which measured in the laboratory of the studied cataclastic and stream sediments rocks

Rock type	eU (ppm)		eRa (ppm)		eTh (ppm)		K (%)	
	range	mean	range	mean	range	mean	range	mean
Cataclastic	37-81	61.7	25-43	35.4	159-242	212	2.7-3.7	3.1
Stream Sediments	3-27	15.3	3-26	13.3	14-74	41.3	1.3-2.4	1.9
Safety for building	4		4		12.3		1.6	
Earth's crust	2.9				10.8		2.7	

Table (3):- Concentration of eU (ppm), eTh (ppm), and K (%) from laboratory and field measurements of stream sediments and cataclastic rocks of Abu Rusheid area. Precision is ±10%

Rock type	Laboratory			Field		
	eU	eTh	K	eU	eTh	K
Cataclastic	61.7	212.2	3.1	110.6	482.3	5.7
Stream Sediments	15.3	41.3	1.9	33.4	109.1	4.9

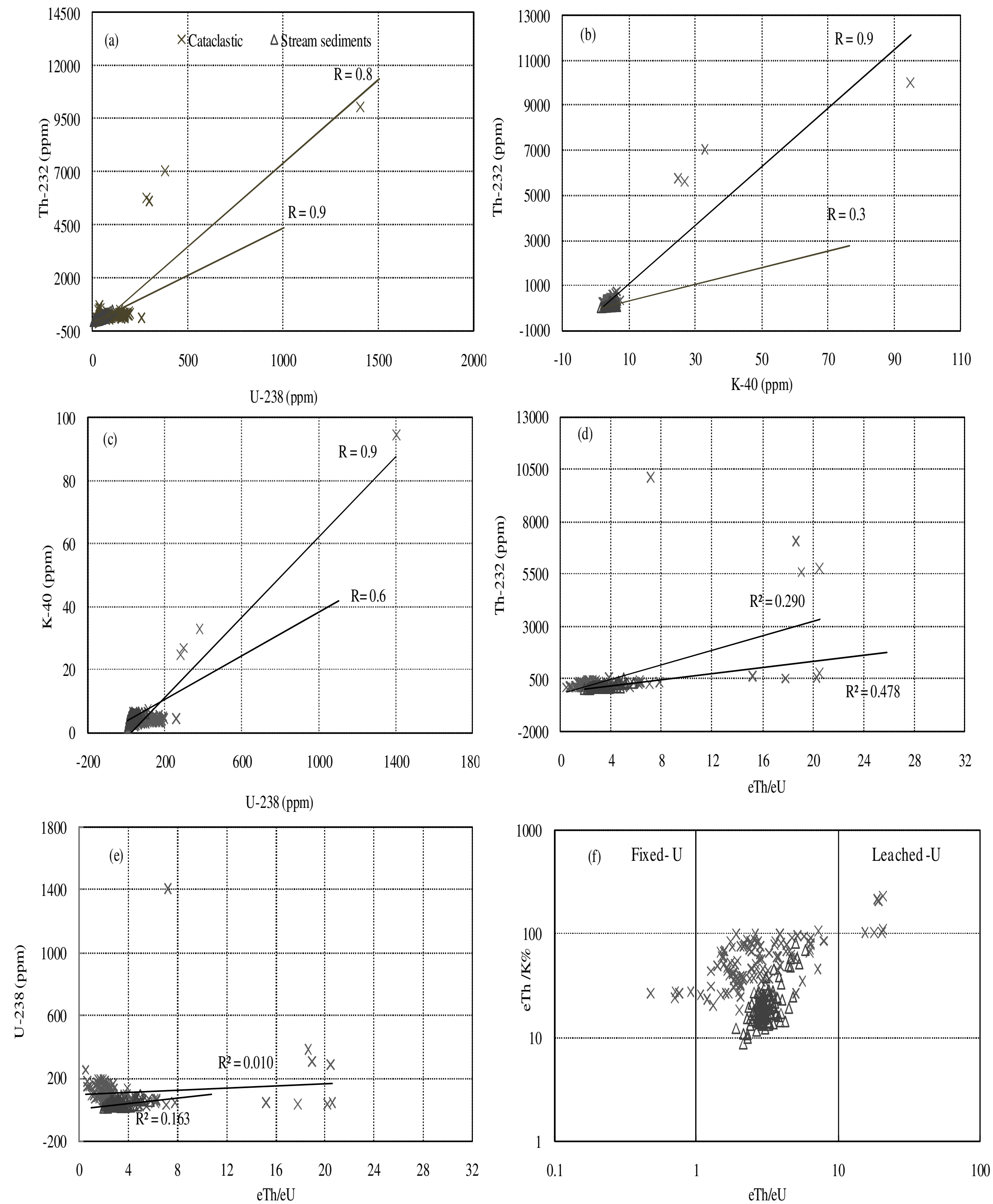

Figure (2):- Correlation between natural occurring radionuclides: (a) ^{232}Th vs. ^{238}U, (b) ^{238}U vs. ^{40}K and (c) ^{232}Th vs. ^{40}K (d) eTh vs. eTh/eU, (e) eU vs. eTh/eU and (f) eTh/K% vs.eTh/eU for cataclastic and stream sediment rocks

5. Evaluation of radiological hazard effects

Values of eU and eTh in ppm, as well as K, in %, were converted to activity concentration, Bq/kg, using the conversion factors given by International Atomic Energy Agency, (IAEA, 1989) and by Polish Central Laboratory for Radiological Protection (Malczewski et al., 2004; El Galy et al., 2008). The specific parent activity of a sample containing 1 ppm, by weight, of Uis 12.35 Bq/kg, 1 ppm of Ra is 11.1 Bq/kg, and 1 ppm of Th is 4.06 Bq/kg, and 1% of ^{40}K is 313 Bq/ kg. Therefore it can be easy to estimate the effects of this radiation through the calculation of the following parameters.

5.1 Radium equivalent activity, Ra_{eq}

The radium equivalent activity Ra_{eq} is a weighted sum of activities of the ^{238}U, ^{232}Th and ^{40}K radionuclides based on the assumption that 370 Bq/ kg of ^{238}U, 259 Bq/ kg of ^{32}Th and 4810 Bq/ kg of ^{40}K produce the same gamma ray dose rate (Beretka and Mathew, 1985).

$$Ra_{eq} = A_U + 1.43\ A_{Th} + 0.077\ A_K$$

where A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K in Bq/ kg. Ra_{eq} was estimated for the collected rocks and stream sediments samples and are given in Table 4. The values of Ra_{eq} varied from 758.1 to 77940.2 with average value 4303.4 Bq/kg for cataclastic rocks and from 214.5 to 4352.7 with average value 1164.3 Bq/kg for stream sediments. The obtained results are much higher than the acceptable world value (370 Bq/kg).

5.2 Gamma activity index, I_γ

The restriction on building materials for gamma radiation is based on a dose range of 0.3-1 mSv/y (Tzortzis *et al.*, 2003). In order to examine whether a building material meets these limits of dose criteria, the gamma activity concentration index I_γ was calculated from the following equation (Tzortzis *et al.*, 2003):

$$I_\gamma = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000}$$

A_U, A_{Th} and A_K are the concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively, in Bq/ kg. The above equation based on the fact that, radionuclides contribute to the external irradiation according to the ratios of their specific exposure rate constants, i.e., ^{40}K: ^{238}U: ^{232}Th = 1:10:15. This method uses the sum of three specific activity quotients as an index of gamma irradiation with denominators chosen to reflect the specific exposure rate and yield a sum equal to unity. For the activity concentration index, $I_\gamma \leq 2$ corresponds to a dose criterion of 0.3 mSv y^{-1}, while $I_\gamma \leq 6$ corresponds to 1 mSv y^{-1} in the report of the European Commission in 1999, as mentioned by Tzortzis *et al.*, (2003) and Anjos, (2005).

Thus, the activity concentration index should be used only as a screening tool for identifying materials which might be of concern to be used as construction or covering materials. According to this dose criterion, materials with $I_\gamma \geq 6$ should be avoided (Ravisankar et al., 2012), whereas these values correspond to dose rates higher than 1 mSv/y (EC, 1999), which is the highest value of dose rate in air recommended for population (UNSCEAR, 1993b, 2000).

Values of I_γ ranged from 2.7 to 271.6 with average value 14.9 for cataclastic rocks and from 0.8 to 15.1 with average value 4.1 for stream sediments. The average values of gamma activity index of the studied rock types are higher than the acceptable value (2). It is also observed from the results that the cataclastic rock samples have gamma index $I_\gamma > 6$ which correspond to dose rates higher than 1 mSv/y (EC, 1999), which is considered the highest value of dose rate in air recommended for population (UNSCEAR, 1993b, 2000). With respect to stream sediments it is observed that its value show $2 \leq I_\gamma \leq 6$ which indicates gamma dose contribution from these samples exceed 0.3 mSv/y but still lower than the highest value of dose rate in air 1 mSv/y recommend for population.

5.3 Alpha activity index, I_α

As radon progeny decay, they emit radioactive alpha particles and attach to aerosols, dust and other particles in the air. As we inhale, radon progeny are deposited on the cells lining the airways where the alpha particles can damage DNA and potentially cause lung cancer.

Several alpha indices have been proposed to assess the exposure level due to radon inhalation originating from building materials (European Commission (EC), 1999) (Krieger, 1981). Therefore the excess alpha radiation due to radon inhalation originating from building materials is estimated through the alpha index (I_α), which is defined as follows: (Elham Bavarnegin et al, 2013; Serena Righi and Luigi Bruzzi, 2006; Mohd Zubair et al, 2013).

$$I_\alpha = \frac{A_U}{200} \leq 1$$

A_U is the activity concentration of ^{238}U. The recommended exemption and upper level of ^{238}U activity concentrations in building materials are 100 and 200 Bq/kg, respectively, as suggested by ICRP, 1994. Thus, the recommended maximum concentration of ^{238}U is 200 Bq/kg, which gives I_α = 1. When the ^{226}Ra activity concentration of any building material exceeds this maximum value (200 Bq/kg), it is possible that radon exhalation from such material could cause the indoor radon concentration to exceed 200 Bq/kg.

Values of I_α ranged from 1.4 to 86.5 with average value 6.8 for cataclastic rocks and from 0.4 to 6.3 with average value 2.1 for stream sediments. We can notice that the values of alpha activity index are higher than the acceptable value. It can, therefore, be said that radon inhalation from buildings constructed with these materials is so large as to warrant restriction of their use in building construction.

5.4 Hazard indices (H_{ex} and H_{in})

External hazard index, H_{ex}

The external hazard index (H_{ex}) is used to measure the external hazard due to the emitted gamma radiation. It was calculated by the equation from (Beretka and Mathew, 1985; Orgun et al., 2007; S. Fares, et al., 2012):

$$H_{ex} = A_U/370 + A_{Th}/259 + A_K/4810 \leq 1$$

Where H_{ex} is the external hazard index and A_U, A_{Th} and A_K are the concentrations of ^{238}U, ^{232}Th and ^{40}K, in Bq/ kg, respectively. The external hazard index is obtained from Ra_{eq} expression through the supposition that its maximum value allowed (equal to unity) corresponds to the upper limit of Ra_{eq} (370 Bq/kg). The value of this index must be less than unity for the radiation risk from building material to be negligible (Hayumbu et al., 1995). For the maximum value of H_{ex} to be less than unity, the maximum value of Ra_{eq} must be less than 370 $Bqkg^{-1}$.

Values of H_{ex} ranged from 2 to 210.5 with average value 11.5 for cataclastic rocks and from 0.6 to 11.8 with average value 3.1 for stream sediments. The results of external hazard index reveal that its values for the studied rock type's samples are higher than the acceptable value. So the radiation risk from these rocks can't negligible, where these high values correspond to radium equivalent values higher than the upper limit (370 Bq kg^{-1}).

Internal hazard index, H_{in}

The internal hazard index (H_{in}) is used to control the internal exposure to ^{222}Rn and its radioactive progeny. It is given by the following equation (Beretka and Mathew, 1985; Orgun et al., 2007; S. Fares, et al., 2012):

$$H_{in}= A_U/185+A_{Th}/259A_K/4810 \leq 1$$

A_U, A_{Th} and A_K are the concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively, in Bq kg^{-1}. If the maximum concentration of uranium in samples under study is half that of the normal acceptable limit, then the value of H_{in} will be less than 1 (Beretka and Mathew, 1985). For the safe use of a material in the construction of dwelling, H_{in} should be less than unity (Beretka and Mathew, 1985). Values of H_{in} ranged from 2.8 to 257.2 with average value 15.3 for cataclastic rocks and from 0.8 to 15.2 with average value 4.3 for stream sediments. The results of internal hazard index reveal that the average values are higher than the acceptable value,so the radiation risk from these samples are hazard to the respiratory organs, therefore it can't used as a safety materials in the construction of dwelling.

5.5 External dose from naturally occurring radionuclides

External absorbed dose rate in outdoor air, D_{out}

The external absorbed dose rates D, in outdoor air at 1 m above the ground level, to the population can be calculated from activities of terrestrial radionuclides according to the following formula (Kohshi et al., 2001):

$$D= A_{Ei} \times C_F$$

Where A_{Ei} is the activity concentration (Bq kg^{-1}), and CF is the dose conversion factor (absorbed dose rate in air per unit activity per unit mass in units of nGy h^{-1} per Bq kg^{-1}). Dose conversion factors have been extensively calculated during the last 40 years by many researchers. In the present work, the considered dose rate conversion factors for ^{238}U, ^{232}Th and ^{40}K are those determined by Quindos et al., (2004) where C_U= 0.4551, C_{Th}= 0.5835 and C_K= 0.0429.

Values of D_{out} ranged from 335.9 to 32958.5 with average value 1840.8 for cataclastic rocks and from 97.7 to 1857.6 with average value 512.1 for stream sediments (table 2).

External absorbed dose rate in indoor air, D_{in}

Since samples under investigation are extensively used as construction material of dwelling, so it is important to estimate its contribution to indoor exposure. Considering the indoor contribution is 1.4 times higher than outdoor dose (UNSCEAR, 2000), the indoor dose rate was calculated as well:

$$D_{in} = D_{out} \times 1.4$$

Values of D_{in} ranged from 470.2 to 46141.9 with average value 2577.1 nGy/h for cataclastic rocks and from 136.8 to 2600.7 with average value 717 for stream sediments.

We can observe that the average values of outdoor dose rates (D_{out}) and indoor dose rates (D_{in}) for the rock samples under investigation are much higher than the acceptable world values at the same time higher than acceptable Egypt values reported in UNSCEAR (2000) report (table 2).

5.6 Annual effective dose, AEDE

Annual estimated average effective dose equivalent (AEDE) received by an individual was calculated using a conversion factor of 0.7 Sv/Gy, which was used to convert the absorbed rate to the human (adults) effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors (UNSCEAR, 1993b). The annual effective dose is determined using the following equations:

$$\text{AEDE (outdoor)} = D_{out}\ \text{nGy/ h} \times 8760\ \text{h} \times 0.7\ \text{Sv /Gy} \times 0.2$$

$$\text{AEDE (indoor)} = D_{in}\ \text{nGy/ h} \times 8760\ \text{h} \times 0.7\ \text{Sv /Gy} \times 0.8$$

Results which recorded in table (2) indicated that cataclastic rocks characterized by annual outdoor effective dose ranged from 0.4 to 40 with average value 2.3 mSv. and an annual indoor effective dose ranged from 2.3 to 226.4with average value 12.6 mSv. With respect to stream sediments, their values ranged from 0.1 to 2.3 with average value 0.6 mSv and from 0.7 to 12.8 with average value 3.5 mSv for annual outdoor effective dose and annual indoor effective dose, respectively.

Using the above equations, the annual effective doses for infants and children can also calculate taken into account the numerical values, 0.8 and, 0.9 of conversion factor for children and infants, respectively as reported in UNSCEAR (2000).

The results obtained from table (2) implied that the average values of the outdoor and the indoor annual effective dose equivalent for the studied rock types are higher than the world value. Consequently the total annual effective dose equivalent for cataclastic rocks (14.9mSv) and stream sediments (4.1) is much higher than the total world value (0.48 mSv).

5.7 Annual gonadal dose equivalent, AGDE

The gonads, the active bone marrow and the bone surface cells are considered as organs of interest by UNSCEAR (1988). Therefore, the annual gonadal dose equivalent (AGDE) due to the specific activities of ^{238}U, ^{232}Th, and ^{40}K was calculated using the following formula (Mamont-Ciesla et al., 1982; Zaidi *et al.*, 1999; Arafa, 2004; A. Chandrasekaran et al., 2014):

$$\text{AGDE} = (3.09 \times A_U + 4.18 \times A_{Th} + 0.314 \times A_K) \times 10^{-3}$$

A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K, receptively in Bq/kg.

Values of AGDE ranged from 2.4 to 233.4 with average value 13 mSv for cataclastic rocks and from 7.1 to 13.1 with average value 3.6mSv for stream sediments. The results imply that values of annual gonadal dose equivalent for the study rocks are higher than the world value (0.3 mSv) reported by Zaidi et al., (1999).

5.8 Excess lifetime cancer risk (ELCR)

This deals with the probability of developing over a lifetime at a given exposure level. It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose. Excess lifetime cancer risk (ELCR) is given as (Taskin et al., 2009; Shams A. M. Issa, 2013; Ajibode et al., 2013; Avwiri, et al. 2012)

$$ELCR = AEDE \times DL \times RF$$

Where, AEDE is the Annual Effective Dose Equivalent, DL is average Duration of Life (estimated to be 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP (1990) uses RF as 0.05 for the public (Taskin et al., 2009).

Values of excess lifetime cancer risk ranged from 9.5×10^{-3} to 933.7×10^{-3} with average value 52.1×10^{-3} and from 2.8×10^{-3} to 52.6×10^{-3} with average value 14.5×10^{-3} for cataclastic and stream sediments, respectively.

The average values of excess lifetime cancer risk are higher than the world value (0.29×10^{-3}) which reported in UNSCEAR (2000) report. This implies that the chances of having cancer by the workers who works in the study region are significant. In addition, these values are an important alert for the companies to avoid the use of these rocks as raw building materials.

A general review on the results illustrate that the natural radioactivity are very high, and this is because Abu Rusheid area represents a distinctive occurrence of uranyl mineralization in Egypt (Dawood, 2010).

The high radioactivity levels recorded for the investigated region Abu Rusheid may be also due to the fact that several mineral deposits have been found in the area, which can be grouped into two groups as follows: (1) Ore minerals group, which contains pyrite, brochanite, pyrolusite, Mn-franklinite, casseterite, kasolite, thorite, thorianite, columbite-tantalite and zircon, and (2) An associated gangue minerals group containing fluorite, mica, garnet, amazonite, tourmaline, goethite, hematite, magnetite, jarosite and thuringite. (Mansour, 2005, Assran et al., 2009).

The mineralization of Abu Rusheid area can be classified on the basis of mode of occurrence and lithological associations into secondary uranium minerals, thorium minerals and accessory minerals. The secondary uranium minerals represented by kasolite, curite, boltwoodite, autunite, coeffinite, carnotite, uranophane, torbernite and ishikawaite. While thorium minerals represented by uranothorite, cheralite and thorite. Finally, the common accessory minerals are cassiterite, zircon, columbite, fluorite, galena, zinc, monazite, xenotime and atacamite.

Table (4):- Range and average values of radium equivalent activity (Ra_{eq}), gamma activity index (I_γ), alpha activity index (I_α), external hazard index (H_{ex}), internal hazard index (H_{in}), outdoor external absorbed dose rates(D_{out}), indoor external absorbed dose rates(D_{in}), the total annual effective dose (AEDE), Annual gonadal dose equivalent (AGDE) and Excess lifetime cancer risk (ELCR) for regions under study

Rock type	Ra_{eq}(Bq/kg)	Activity indices		Hazard indices		External absorbed dose		AEDE		AGDE mSv	E LCR×10^{-3}
		I_γ	I_α	H_{ex}	H_{in}	D_{out}	D_{in}	outdoor	indoor		
Cataclastic	758.1-77940.2 (4303.4)	2.7-271.6 (14.9)	1.4-86.5 (6.8)	2-210.5 (11.5)	2.8-257.2 (15.3)	335.9-32958.5 (1840.8)	470.2-46141.9 (2577.1)	0.4- 40 (2.3)	2.3-226.4 (12.6)	2.4- 233.4 (13)	9.5- 933.7 (52.1)
Stream sediments	214.5-4352.7 (1164.3)	0.8-15.1 (4.1)	0.4-6.3 (2.1)	0.6-11.8 (3.1)	0.8-15.2 (4.3)	97.7- 1857.6 (512.1)	136.8-2600.7 (717)	0.1- 2.3 (0.6)	0.7- 12.8 (3.5)	7.1- 13.1 (3.5)	2.8- 52.6 (14.5)
World value	370	≤ 2	≤1	≤1	≤1	59	84	0.48		0.3	0.29
Egypt value						8 – 93 (32)	11.2 – 130.2 (44.8)				

5. CONCLUSIONS

Since cataclastic and stream sediments use in the purpose of building materials so it was necessary to study their natural radioactivity due to ^{238}U, ^{232}Th and ^{40}K. From the results we can conclude that:

1. The obtained mean values for the studied rock types are higher than that reported for Earth's crust, 2.9 ppm, 10.8 ppm and 2.7 % and also higher than the recommended values for safety used as building materials, 4.1 ppm, 12.3 ppm and 1.6 % for eU, eTh, and K, respectively, (Eisenbud and Gesell, 1997; UNSCEAR, 1993a).
2. The results indicating a very high radioactivity and this are because that Abu Rusheid area has distinctive radioactive minerals, (Dawood, 2010).
3. Cataclastic rocks and stream sediments of the region under investigation cannot uses as building materials but on the other hand the study region represents an important economic source of minerals and their metal values can use in several industrial applications.

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