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The assessment of natural radioactivity and its associated radiological hazards and dose parameters in granite samples from South Sinai, Egypt

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ABSTRACT

Gamma ray spectra of natural radioactivity from ^{238}U- and ^{232}Th series and from ^{40}K of eight (representing 40 collected samples) granite samples collected from Saint Katherine region, South Sinai, Egypt, had been measured using a gamma-ray spectrometer with an HPGe detector. The results reported in the present article include: Specific activities (A) of ^{226}Ra, ^{232}Th and ^{40}K radionuclides, Radium equivalent activities (Ra_{eq}), external and internal hazard indices (H_{ext}, H_{int}), external and internal level indices (I_γ, I_α), activity utilization index (I), exposure rate (ER) and other important parameters to the subject. The results have been presented in table graphs with the permissible maximum limits.

1. Introduction

Granite is widely used as a building material in the construction of homes. It contains the natural radionuclides ^{238}U, ^{232}Th and their progenies together with ^{40}K. This assures the importance of the assessment of radiation levels and the related radiological hazards to which the population might be exposed. Nearly in all nations, scientists probed since long time ago and are still probing the earth's crust and for a long time in the future to measure the radiation levels and quantify the hazards and doses affecting people, animals, plants and all kinds of life. In the present work, we are taking our share with other scientists in the world to arrive to a decision of building homes free of radiation.

2. Experimental steps

2.1. Sample collection and preparation

Total 40 granite samples were collected from eight locations of an area of ($2 \times 4 = 8$ km^2) south to Saint Katherine Monastery,

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South Sinai Governorate, Egypt. Five granite samples were taken from each location. The following steps were performed in the preparation: the samples were: mixed, pulverized, sieved to >1 mm grain size, stirred to become homogeneous, dried at 110 °C for 48 h to have dry mass samples. Finally, eight granite samples representing the eight locations are obtained. The 8 samples were weighed and sealed in polyethylene containers for 30 days for the short lived members of ^{222}Rn and ^{220}Rn series to reach a secular equilibrium.

2.2. Energy and efficiency calibrations

The calibration of the gamma ray detection system always includes two stages the energy and the efficiency calibrations. The energy calibration converts channel numbers to γ-ray energy in MeV and the efficiency calibration aimed to determine the gamma ray counting efficiencies over the full energy range of measurement.

The energy and efficiency calibrations of the detection system were performed using a set of high quality certified reference sources (IAEA, RG-set) with density similar to the densities of the measured samples. For calibrations, the reference source was placed in the same place as the samples when measuring their γ-ray spectra. For energy calibration, the amplifier gain has been adjusted to measure γ-rays in the energy range of 100 keV up to 2600 keV.

2.3. Gamma-ray spectra measurements

A high purity vertical HPGe detector (p-type with a relative efficiency of 25% and peak to Compton ratio of 54:1) was used for measuring the γ-ray spectra of the granite samples. The energy resolution (FWHM) of the detector was 1.9 keV at the 1332 keV γ-ray line of ^{60}Co source. The detector was coupled to a Canberra data acquisition system applying a Genie-2000 analysis software, version 3.0, with many functions including peak area determination, background subtraction together with both γ-ray energy and radionuclide identification. The HPGe detector was shielded with a lead cylinder of 10 cm thickness internally lined with 2 mm thick copper cylinder to absorb lead X-rays. The Sample containers were placed one at a time on the top of the detector (under the shield) for counting during an accumulation time of 80,000 s. All measurements were corrected for background radiation and backscattering.

The activity of ^{40}K has been calculated from its γ-ray line of energy 1460.8 keV. The activities of the decay products ^{214}Pb and ^{214}Bi were taken to represent ^{226}Ra using the γ-ray lines of energies 295.2 keV and 351.9 keV from ^{214}Pb and the 609.3 keV and the 1764.5 keV from ^{214}Bi while the specific activity of ^{232}Th has been calculated using γ-ray lines of energies 338.4 keV and the 911.2 from ^{228}Ac, the 727.3 keV from ^{212}Bi and the 583.2 keV from ^{208}Tl decay products (Debertin & Helmer, 1988).

The γ-ray spectra of the samples were measured twice at two different laboratories; the first one is our Lab at The Physics Department, Faculty of science, Suez Canal University, Ismailia, Egypt and the other lab at the Egyptian Atomic Energy Authority (EAEA), Cairo, Egypt. A good agreement between both measurements was obtained. The detection system specifications that mentioned in this section for our lab.

Table 1 – Annual effective dose equivalent (AEDE) in three types of dwellings (Hewamanna et al., 2001).

Type of dwellings	AEDE (mSv yr^{-1})
Block houses	0.44
Concrete houses	0.47
Stone houses	0.52

Table 2 – Average values of F for different organs or tissues (El-Gamal et al., 2007).

Organ or tissue	F
Lungs	0.64
Ovaries	0.58
Bone marrow	0.69
Testes	0.82
Whole body	0.68

3. Calculations of activities, hazard indices and dose parameters

In the calculations carried out in this section, we used the symbols: A_{Ra}, A_{Th} and A_K to represent the activity concentrations of ^{226}Ra for (^{238}U), ^{232}Th and ^{40}K radionuclides respectively.

3.1. Specific activity or activity concentration (A) in (Bq kg^{-1})

The activity concentration A_i of any γ-ray line taken to represent this parameter for the ^{226}Ra, ^{232}Th and ^{40}K radionuclides has been calculated using the relation (Amrani & Tahtat, 2001):

$$A_i\,(\mathrm{Bq\ kg^{-1}}) = \frac{C_i}{\varepsilon(E) \times t \times m}. \quad (1)$$

where C_i is the net peak area after subtraction of background of the γ-ray line at energy E, $\varepsilon(E)$ is the detector efficiency of such γ-ray line, t is the time of measurement in seconds and m

Table 3 – Gamma factors for the investigated radionuclides (Nemeth, 2000; Saito et al., 1998).

Radionuclide (A_i)	Gamma factor (F_i), nSv h^{-1}/Bq kg^{-1}
K-40	0.048
U-238 + daughters	0.490
Ra-226	0.486
Pb-214	0.540
Bi-214	0.432
Th-232 + daughters	0.670
Ac-228	0.319
Tl-208	0.367
Bi-212	0.024
Pb-212	0.024