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Gamma-ray measurements of natural radioactivity in sedimentary rocks from Egypt

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Abstract The aim of this study was to measure concentrations and distributions of natural radionuclides occurring in rocks. The activity concentrations ($Bq \cdot kg^{-1}$) of the naturally occurring radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in sedimentary rock samples from Eastern Desert (Um El-Huetat), Nile Valley (Gebel Owina) and from southwest Sinai (Wadi Ghweiba) were measured using a high-purity germanium detector. The samples under investigation (clay, shale and sandstone) were used as raw materials in the construction industry (bricks, ceramics, cement, fillers, etc.). Though the sediments of Egypt have already been investigated in the geological and mineralogical aspects, it is necessary to investigate the natural radioactivity in order to complete their classification. The average concentration values of ^{226}Ra, ^{232}Th, ^{40}K in the surveyed samples were 47 ± 7 , 21± 5, 393±19 $Bq.kg^{-1}$ (clay); 23 ± 5, 30 ± 6, 563 ± 24 $Bq.kg^{-1}$ (shale); and 17 ± 4, 14 ± 4, 299 ± 17 $Bq.kg^{-1}$ (sandstone), respectively. All sediment samples have radium equivalent activities ranging from 55 to 115 $Bq \cdot kg^{-1}$, lower than the limit set in the OECD Report (370 $Bq \cdot kg^{-1}$). The overall mean outdoor terrestrial gamma dose rates fluctuate from 28 to 55 $nGy \cdot h^{-1}$. The external gamma radiation dose due to natural radionuclides present in the samples have been computed and compared with the global averages. In terms of the radiation safety, the natural radioactivity of the sediment in Egypt is below the recommended limits of the gamma dose rate. Therefore, they can be used for all kinds of public buildings.

Key words Natural radionuclides, Shale, Clay , Sandstone, Radiation hazard, Egypt.

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1 Introduction

The natural radioactive elements are distributed everywhere in the biosphere with different concentrations. From the natural "risk" point of view, it is necessary to know the dose limits of public exposures. At the same time, it is necessary to measure the natural environmental radiation level provided by ground, air, water, food, building interiors, etc., for the estimation of the exposures to natural radiation sources. IAEA has published data for the doses accumulated by human beings during their life activities. The exposure to cosmic radiation is about 0.38 $mSv \cdot a^{-1}$, to terrestrial radiation 0.45 $mSv \cdot a^{-1}$ (this increases by nearly 20% for brick and concrete buildings), and to water, food and air 1.5 $mSv \cdot a^{-1}$. The exposure to X-rays diagnostics is about 0.4 $mSv \cdot a^{-1}$and to the other factors like color TV, air flights, and nuclear power plants, the exposure is about 0.1 $mSv \cdot a^{-1}$. Thus, in total human beings accumulate about 2.7 $mSv \cdot a^{-1}$ radiation from natural and man-made sources. The dose limit for exposure to man-made radiation sources is 1 $mSv \cdot a^{-1}$ [1].

Terrestrial radionuclides are distributed throughout the crust of the earth. Outdoor exposures from sources of terrestrial radiation originate predominantly

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from approximately the top 1-ft layer of the soil [2]. Formations such as limestone and sandstone have the lowest radionuclide concentrations. Some shale formations, particularly those containing a significant fraction of organic matter, can possess higher concentrations of radionuclides. Overall, igneous and metamorphic rocks comprise approximately 90% of the planetary crust. Sedimentary rocks, however, tend to accumulate at the top of the crust. Approximately 75% of the surface of the earth is covered by sedimentary rock.

From the point of view of radioactive concentration, the "normal" clays, which were used as construction materials for the residential and public buildings, etc., contain some U and Th, while the content of K is less than 4%. In cases where the concentration of these radioactive elements in clays is higher than 1×10^{-5} for U, 2×10^{-5} for Th, and higher than 5% for K, it is necessary to review the possibilities of limiting the usage of these clays as construction materials [3]. The reason for this limitation comes from the high degree of the exposures that creates radioactivity for the human beings. In the building industry, the most-used raw materials are clays (production of bricks, tiles, ceramics, fillers, etc.). Therefore, we investigated samples from clay, sandstones and shales (for comparison) from different sites of Egypt.

Uranium mineralization is known in association with some carboniferous and cretaceous black shale, in phosphorite deposits and in Oligocene sandstones in many localities in Egypt [4]. The final report of radiometric survey carried out in the Eastern Desert of Egypt (1984) reported isolated small airborne anomaly located in the plain of Wadi Ghweiba. This anomaly attracts the attention because Wadi Ghweiba is located in the zone defined to be one of the most important national developmental projects of the northern part of Gulf of Suez. Therefore, this work aimed to investigate the extension of the radioactive anomalies in Wadi Ghweiba area and to delineate the source rock types responsible for such anomalies.

The objective of the present study was to determine the specific radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in sedimentary rock samples collected from different areas, to assess any radiological hazard and to determine the gamma radiation dose rate and the annual effective dose from samples under investigation, which are used in buildings. The results obtained in the present study are also compared with the corresponding results for sediment of different origins given in the literature.

2 Experimental

The natural radioactivity due to radium, thorium and potassium contents of 43 samples of clay, shale and sandstone was measured. Twenty-three samples were collected from Wadi Ghweiba (southwest Sinai) and 20 samples from Um El-Huetat and Gebel Owina (Eastern Desert) and Nile Valley in Egypt. The collected samples were weighed individually, air-dried for 4 days, pulverized, homogenized, and sieved to pass through a 200-mm mesh. The powdered sediment samples were transferred to an especial disc (50 g) for gamma-activity analysis. Each sample was weighed and carefully sealed for 4 weeks to reach secular equilibrium between ^{226}Ra and ^{232}Th and their respective progeny. The activity of ^{214}Bi and ^{214}Pb in equilibrium with their parents was assumed to represent the ^{238}U activity, while the activity of ^{228}Ac and ^{208}Tl was assumed to represent the ^{232}Th activity. The detector (HPGe) has a photo-peak relative efficiency of about 23% and an energy resolution of 1.95 keV (FWHM) for the 1.332 MeV gamma transition of ^{60}Co. To reduce gamma-ray background, a lead chamber shield with a fixed bottom and a moving cover shielded the detector. The lead shield contained two inner concentric layers of copper and cadmium.

In order to determine the background distribution due to naturally occurring radionuclides in the environment around the detector, an empty polystyrene container was counted in the same manner as the samples. After measurement and subtraction of the background, the activity concentration was calculated. The accumulation time for gamma-ray spectra measurements ranged from 12 to 20 h depending upon the activity levels present in the samples.

3 Results and discussion

The average concentration values ($Bq\cdot kg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K in the samples measured collected from different locations are given in Table 1. From the