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Assessment of natural radiation exposure and radon exhalation rate in various samples of Egyptian building materials

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ABSTRACT

The aim of this investigation was to determine the amount of γ-decay of several building materials used in Egypt, in terms of Bq kg^{-1}, and to calculate the radiological effect caused by this radioactivity. Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in 30 samples of manufactured building materials were measured using gamma-spectroscopy system based on high-purity germanium detector with an efficiency of 40 %. The activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K, from the selected building materials, ranged from (8.15 ± 2.81 to 288.5 ± 17.49 Bq kg^{-1}), (3.59 ± 1.36 to 77.77 ± 15.61 Bq kg^{-1}) and (4.09 ± 4.72 to 1314 ± 15.30 Bq kg^{-1}), respectively. Radium equivalent activities, absorbed dose rate, Excess lifetime cancer risk and the values of hazard indexes were calculated for the measured samples to assess the radiation hazards arising from using those materials in the construction of dwellings. These results show that annual dose absorbed by inhabitants from construction materials used in Egypt (except cement bricks) are below 1.0 mSv y^{-1}. Therefore, the types used in the current study are quite safe to be used as building materials, except the cement brick, granite and ceramic samples which are critical points for safety in construction. Finally, the so-called can technique has been used to measure radium content and exhalation rates of radon in these building materials samples. Positive correlation was found between radium concentration and radon exhalation rates.

1. Introduction

Man is continuously exposed to ionizing radiation from naturally occurring radioactive materials (NORM). Natural radioactivity is widely spread in the earth's environment and it exists in various geological formation e.g. soils, rocks, plants, water, air and in building materials (Ramassay, Dheenathayalu, Ravishankar, & Ponnusamy, 2004; Rati et al., 2010). Measurement of activity concentrations of

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radionuclides in building materials is important in the assessment of population exposures, as most individuals spend 80% of their time indoors (Merle & Enn, 2012). Naturally occurring radionuclides in building materials are source of external radiation exposure in dwellings. This radiation is caused by gamma radiation originating from the uranium and thorium series and from ^{40}K (Amrani & Tahtat, 2001).

The population-weighted average of indoor absorbed dose rate in air from terrestrial source of radioactivity is estimated to be 84 nGy h^{-1} (UNSCEAR, 2000). The worldwide average indoor effective dose due to gamma ray from building materials is estimated to be about 0.4 mSv y^{-1} (UNSCEAR, 1977, 1993). The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the earth's crust are 35, 30, and 400 Bq kg^{-1}, respectively. However, elevated levels of natural radionuclides causing annual doses of several mSv have been identified in some regions around the world, e.g. in Brazil, France, India, Nigeria, Iran (UNSCEAR, 2000, 1977, 1993). This external radiation exposure, caused by gamma emitting radionuclides in building materials, can be assessed either by direct exposure measurements in the existing buildings or by radionuclide analyses of building materials with the dose rate modeling (Merle & Enn, 2012).

External gamma dose estimation due to the terrestrial sources is essential as these doses vary depending upon the concentrations of the natural radionuclides, ^{226}Ra, ^{232}Th, and their daughter products and ^{40}K, present in soils and rocks, which further depend upon the local geology of each region in the world (Rati et al., 2010). Radium is present everywhere in the earth's crust so radon is found everywhere in varying quantities. It can move freely from the place of its origin through pores in soil and cracks in walls. Radon transportation is mainly due to diffusion and forced flow (Shakir Khan, Naqvi, Azam, & Srivatsava, 2011). Radon is an alpha-emitting radioactive gas. It is a daughter product of ^{226}Ra and decay with a half-life of 3.82 days emitting alpha particles of energy 5.49 Mev. The radioactive daughter product of radon via ^{218}Po and ^{214}Po emit alpha particles. These daughter products are solid and have a tendency to attach themselves to aerosols in ambient air. When we breathe or inhale radon and its daughter product along with the normal air, most of the radon is exhaled, its daughter products get logged to the inner walls and membranes of our respiratory system and continue causing constant damage due to their alpha activity (Khan, Tariq, & Rawat, 2012).

Lung cancer, skin cancer and kidney diseases are the hazards caused by the inhalation of radon decay products. The radiological impact caused by nuclides is due to radiation exposure of the body by the gamma rays and irradiation of the lung tissues from inhalation of radon and its progeny. Therefore, keeping in view the natural risk, it is necessary to know the dose limits of public exposure (Nain, Chauhan, & Chakravarti, 2006). Indoor radon exposure has become a problem all over the world due to the fact that it accounts for approximately 60% of the total natural background radiation (UNSCEAR, 1993). Radon concentration measurements are nowadays routinely performed and different laboratories around the world have developed several types of radon radiation detectors. The suitable choice of detector depends on several factors: study purpose, sensitivity, cost, ect (Nidal, Ghassan, Mousa, & Toshiyuki, 2007).

The technique of track etch is widely applied in Europe for measuring the total indoor radon level. Kodalpha film type (LR-115) radon dosimeter is a small, black box of dimensions $4 \times 7.5 \times 0.5$ cm. The radon-sensitive part, which is the actual dosimeter, is a small film badge which is housed on the inside section of the hinged lid of the dosimeter. These film badges are LR-115 type nuclear track films produced by KODAK and they consist of a 100 μm thick polyester substrate that is coated with a 12 μm thick layer of red colored cellulose nitrate. Kodalpha film type (LR-115) has been used for radon measurement by many laboratories throughout the world and by most important radiation safety institutes like the United States of America-Environmental Protection Agency (USA-EPA) and United Kingdom-National Radiological Protection Board (UK-NRPB). Kodalpha film type (LR-115) has several characteristics: (1) very sensitive to alpha particles only; (2) can be used for short-term measurement at minimum 10–30 days of exposure and also for long-term measurement, 3 months up to 1 year; (3) insensitive to environmental changes such as humidity, water and temperature up to 60 °C; (4) suitable to be used for radon measurements in stagnant or flowing water and in oil (Nidal et al., 2007).

2. Materials and methods

2.1. Sample collection

For this study, thirty different samples of Egyptian building materials were collected. Mostly, the sample selection consisted of the commonly available materials, which were obtained from the building material stores. All samples were crushed into grains, dried, homogenized, and put into PVC Marenilli with capacity of hundreds cm^3, the average samples volume around 100 cm^3 and their masses vary from 77.45 to 151.37 g. The samples were sealed for 4 weeks to reach secular equilibrium between ^{226}Ra and ^{232}Th with their decay products.

2.2. Spectroscopic analysis

The radionuclide activity concentrations in the prepared samples were measured using an n-type coaxial high-purity germanium (HPGe) detector, Canberra model in Gamma Irradiation Unit – Nuclear Research Center – Atomic Energy Authority – Egypt. The detector has an efficiency of about 40%, energy resolution of 1.9 keV, full width at the half maximum (FWHM) for the1332.3 keV gamma line of ^{60}Co and MCA with 8000 channels. An empty Marenilli beaker was used for the same period of time to assess the background concentrations of the γ-rays. To reduce the γ-rays background from building and cosmic rays, a cylindrical lead shield of 100 mm thickness is used to shield the detector from the surroundings environment. This shield is composed of three inner concentric shells of lead, cadmium and copper.

Radon concentration and exhalation rate was measurements were done for the collected samples using the "Can technique" (Abu-Jarad, 1988). For the measurement of exhalation rate, 100 cm^3 of samples were taken. Fine quality of samples obtained by using a scientific sieve of 150 μm mesh