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Radiation exposure of workers in storage areas for building materials

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Abstract

Radon levels and radioactivity were measured in 50 shops and storage areas for building materials in Sudan. Charcoal canister and gamma spectrometry systems were used to measure radon in 55 types of natural material, and concentrations of 71–292 Bq/m^3 (mean, 154 ± 38 Bq/m^3) were found. The concentration of radium (^{226}Ra) ranged from 2.8 to 182.5 Bq/kg, of thorium (^{232}Th) from 1.2 to 302 Bq/kg and of potassium (^{40}K) from 82.3 to 1413.3 Bq/kg. Porcelain, ceramic and marble showed high values, while gravel types had low radioactivity. Radium in building materials was well correlated with radon (r^2 = 0.77). The average annual dose of workers at these sites due to inhalation of radon was estimated to be 2.8 mSv. The activity index of building materials ranged between 0.33 and 1.97 (mean, 0.77).

Keywords: Building materials; Naturally occurring radioactive material; Radon; Uranium; Thorium; Exposure; Dose

1. Introduction

Use of modern types of building materials has increased following the “urban revolution”. Some of these materials may contain naturally occurring radioactive materials, and in countries such as Sudan these materials are stored in closed rooms, generally with poor ventilation; the concentration of radon gas inside these buildings can therefore be expected to be high. Many workers spend much of their time inside these buildings, which may result in occupational exposure to radon. The health effects of indoor radon and risk assessments of exposure of radon in homes have been determined in many studies [1–3].

Increasing attention is being paid to the effects of natural radioactivity, yet exposure in stores of building materials has not been considered. The exposure of the general public to natural sources of radiation has been estimated by the United Nations Scientific Committee on the Effect of Atomic Radiation [4]. Monitoring of any release of radioactivity to the environment is important for environmental protection, and studies of natural radioactivity are necessary not only because of the radiological impact but also because it is an excellent biochemical and geochemical tracer. Although natural radioactivity is found in rock and soil throughout the earth, accession in specific areas varies within narrow limits. The new types of building materials are brought from various places around the world, and some may

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be extracted from areas with high background radiation. The contribution of building materials to indoor radon has been investigated in some previous studies in different regions [5–7].

Inhalation of radon and its short-lived daughter products is a major contributor to the total radiation dose of exposed people. In uranium mining, the lung dose due to radon progeny may be sufficiently high to increase the occurrence of lung cancer [8]. Building materials also represent a source of radon in houses. The general recommended permissible limit of exposure to indoor radon, 100 Bq/m^3 [9], can be used as a guideline. Naturally occurring raw building materials and processed products have radionuclides of three series, uranium, thorium and ^{40}K isotopes [10]. As high concentrations of natural radionuclides in building materials can result in high indoor doses, setting a reference radon level for building materials will account for contributions from other sources without exceeding the hazard level. Special attention has been paid to the radioactivity of brick components of building structures [11–13]. The level of radon also depends on the ventilation of the room: Abdallah et al. [14] showed that poor ventilation increased exhalation rates of radon and increased the level.

With recent developments in building in Sudan, little is known about the natural radioactivity of the building materials used. In general, the building materials used in Sudan are derived from rocks or soil without consideration of the radon content. The aim of the present study was to evaluate the radon levels in storage sites of building materials, the radioactivity of building materials used in Sudan and radiological risk.

2. Materials and methods

2.1. Gamma-ray spectroscopy

Two types of gamma spectrometry system were used: 3″ × 3″ sodium iodide and high-purity germanium detectors in a standard arrangement that included multichannel associated amplifiers and data readout devices [15]. The systems were calibrated against a known source, mixed gamma standard from Amersham. The high-purity germanium detector (p type), with a relative efficiency of 20%, was validated with the International Atomic Energy Agency (IAEA) reference materials RGU-1 and RGTh-1 and calibrated in terms of energy, efficiency and resolution against a mixed radionuclide standard (Amersham Buchler B1575) in the same geometry as the samples. The gamma background contribution was determined with an empty Marinelli container.

2.2. Measurement characteristics

2.2.1. Radon concentration in air

The air concentration of radon was determined by counting the gamma ray emission of radon decay products adsorbed on activated charcoal enclosed in an aluminium cylindrical canister. The canisters were heated in an oven at 60 °C for about 10 min to anneal the charcoal. At the sampling location, the cap of the canister was removed and radon allowed to adsorb onto the charcoal for 4 days. The canister was then closed, sealed and returned to the laboratory for gamma spectrometry.

Samples were collected from 50 randomly selected ceramic shops and storage sites in Khartoum State. At each site, radon was sampled about 1 m above the ground and measured directly by placing it on top of the detector with counting for at least 3 h, depending on the concentration. For radon analysis, a chamber was constructed for calibration, which contained a radium source of known activity and a set of canisters exposed to radon under secular equilibrium. A calibration factor was then obtained and used in this study [16].

2.2.2. Building materials

The shops and storage sites contained ceramic from Sudan, Saudi Arabia, Egypt, China and Spain. The other materials collected were basic building materials such as cement, ceramic, porcelain and fireclay bricks (local production); traditional materials such as clay bricks, gravel, sand and fire bricks; and material collected from major local producers in Sudan. Samples of raw materials were taken from locations representing the major sources of these materials, such as areas of clay brick production and local markets. The materials were either in powder form (e.g. cement and clay) or solid. The latter, such as bricks and ceramic were crushed into small pieces or powdered. The samples were then weighed, sealed in Marinelli beakers and stored for 30 days before counting to allow ^{226}Ra and its short-lived decay products to reach secular equilibrium.

The activity concentration (Bq/kg) of ^{232}Th was determined from the photo-peaks of ^{208}Tl (583 keV) and ^{228}Ac (911 keV), and that of ^{238}U was obtained from the gamma-lines of ^{214}Pb (352 keV) and ^{214}Bi (609 keV), whereas ^{40}K was measured directly from the photopeaks at 1460 keV.