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Radon and thoron emanation from various marble materials: impact on the workers

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Abstract

Uranium (^{238}U) and thorium (^{232}Th) concentrations were measured inside different pulverized marble material samples by using a method based on determining detection efficiencies of the CR-39 and LR-115 II solid state nuclear track detectors for the emitted alpha particles. Radon (^{222}Rn) and thoron (^{220}Rn) alpha-activities per unit volume were evaluated inside and outside the marble samples studied. Radon emanation coefficient was determined for the considered marble samples. Alpha- and beta-activities per unit volume of air due to radon, thoron and their progenies were measured in the atmosphere of a marble factory. Equilibrium factors between radon and its progeny and thoron and its decay products were evaluated in the air of the studied marble factory. The committed equivalent doses due to short-lived radon decay products were determined in different regions of the respiratory tract of workers in the considered marble factory.

1. Introduction

Humans are continuously exposed in homes and at working places to some ionising radiation in the form of alpha- and beta-particles and gamma-photons emitted by radon, thoron and their corresponding progenies coming from building materials and air pollution (cigarette smoke, fly ashes and dusts). Radon and thoron decay products have been measured in the air by beta counting using an end-window Geiger–Müller counter (Papp and Daróczy, 1997). But this technique has some limits and drawbacks: ^{208}Tl cannot be determined and the relative error of ^{218}Po and ^{212}Bi activity concentrations are much higher than that of the ^{214}Pb, ^{214}Bi and ^{212}Pb ones; long duration of counting is necessary to reach the maximum accuracy. Alpha counting applied usually for measuring radon and thoron decay products concentration presents some disadvantages such as the absorption of alpha-particles in the membrane filter of the counter. The use of gamma-ray spectrometry for measuring radon and thoron decay product concentrations in air suffers from some disadvantages such as low efficiency, high background and high cost. LR-115 II solid state nuclear track detectors (SSNTD) utilized for measuring radon concentrations in houses in Sweden (Jönsson, 1988) necessitates a calibration with known radon concentration sources.

In the present study, we used a method based on calculating detection efficiencies of the CR-39 and LR-115 type II SSNTD for alpha-particles emitted by the uranium and thorium series inside different marble materials and by radon and thoron groups in air and measuring the resulting track densities registered on the SSNTD films for evaluating uranium and thorium contents as well as radon and thoron concentrations inside and outside the studied marble samples. We determined alpha- and beta-activities

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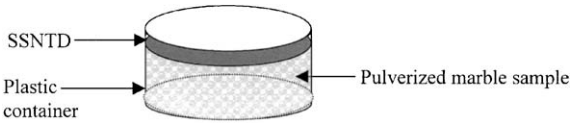

Fig. 1. Arrangement of the solid state nuclear track detectors (SSNTD) on a marble material sample in a well-closed plastic container of radius $q = 2$ cm and depth $D = 1$ cm.

per unit volume of air due to radon, thoron and their progenies in the air of a marble factory. Committed equivalent doses due to radon decay products in the respiratory tract of workers are determined. The relevant ranges of the emitted alpha-particles in air, marble materials and target tissues as well as the stopping powers of the respiratory tract for the emitted alpha particles were calculated by using a TRIM programme (Biersack and Ziegler, 1998).

2. Methodology

2.1. Determination of uranium and thorium contents in various marble material samples

Different marble materials widely used in Morocco have been pounded and homogenized. Disc-shaped Pershore Moudlings CR-39 (500 μm thickness) and Kodak LR-115 type II (12 μm cellulose nitrate on 100 μm polyester base) SSNTD films of 4 cm diameter were separately placed on each marble material sample in a hermetically sealed cylindrical plastic container for 1 month (Fig. 1). During this time, α-particles emitted by uranium (^{238}U), thorium (^{232}Th) and their corresponding decay products bombarded the SSNTD films. After the irradiation, the bombarded films were developed in a NaOH solution (2.5 M at 60 °C during 120 min for LR-115 films and 6.25 M at 70 °C during 7 h for the CR-39 films). After this chemical treatment, the CR-39 and LR-115 α-particles track densities were determined by means of an ordinary optical microscope with magnitude 40×.

By calculating first the detection efficiencies of the CR-39 ($\varepsilon_{j\,\mathrm{CR}}$ and $\varepsilon'^{\,\mathrm{CR}}_{j}$) and LR-115 type II ($\varepsilon^{\mathrm{LR}}_{j}$ and $\varepsilon'^{\,\mathrm{LR}}_{j}$) SSNTD for α-particles emitted by the uranium-238 and thorium-232 series inside a marble material sample, and secondly by measuring track density rates (tracks cm^{-2} s^{-1}) registered on the CR-39 ($\rho^{\mathrm{CR}}_{\mathrm{G}}$ (in)) and LR-115 type II ($\rho^{\mathrm{LR}}_{\mathrm{G}}$ (in)) one can evaluate the thorium C(Th) and uranium C(U) concentrations (in 10^{-6} g/g) inside the considered material sample by using a method described in detail by Misdaq et al. (2000). Indeed, we have

$$\frac{C(\mathrm{U})}{C(\mathrm{Th})} = \frac{A_{\mathrm{Th}}}{A_{\mathrm{U}}} \times \frac{\frac{\rho^{\mathrm{CR}}_{\mathrm{G}}(\mathrm{in})}{\rho^{\mathrm{LR}}_{\mathrm{G}}(\mathrm{in})} \sum_{j=1}^{7} k'_j \varepsilon'^{\,\mathrm{CR}}_{j} R'_j - \frac{S'_{\mathrm{d}}}{S_{\mathrm{d}}} \sum_{j=1}^{7} k'_j \varepsilon'^{\,\mathrm{LR}}_{j} R'_j}{\frac{S'_{\mathrm{d}}}{S_{\mathrm{d}}} \sum_{j=1}^{8} k_j \varepsilon^{\mathrm{CR}}_{j} R_j - \frac{\rho^{\mathrm{CR}}_{\mathrm{G}}(\mathrm{in})}{\rho^{\mathrm{LR}}_{\mathrm{G}}(\mathrm{in})} \sum_{j=1}^{8} k_j \varepsilon^{\mathrm{LR}}_{j} R_j} \tag{1}$$

and

$$C(\mathrm{Th}) = \frac{2 S'_{\mathrm{d}} \rho^{\mathrm{LR}}_{\mathrm{G}}(\mathrm{in})}{\pi q^2 d_{\mathrm{s}} \left[A_{\mathrm{U}} \frac{C(\mathrm{U})}{C(\mathrm{Th})} \sum_{j=1}^{8} k_j \varepsilon^{\mathrm{LR}}_{j} R_j + A_{\mathrm{Th}} \sum_{j=1}^{7} k'_j \varepsilon'^{\,\mathrm{LR}}_{j} R'_j \right]}, \tag{2}$$

where S_{d} and S'_{d} are respectively the field surface areas (for a given microscope magnitude) of the CR-39 and LR-115 II films, R_j and R'_j are the ranges, in the material sample, of an α-particle of index j and initial energy E_j emitted by the nuclei of the uranium and thorium series, respectively, k_j and k'_j are, respectively, the branching ratios corresponding to the disintegration of the nuclei of the uranium and thorium series and q is the radius of the plastic container.

2.2. Determination of radon and thoron alpha-activities per unit volume inside and outside different marble samples

According to a method developed by Misdaq et al. (2001a) when the CR-39 and LR-115 type II SSNTD are separately placed in close contact with a homogeneous marble sample in a hermetically sealed cylindrical plastic container for 1 month (see Fig. 1), one can evaluate radon (A_{c} (^{222}Rn) (in)) and thoron (A_{c} (^{220}Rn) (in)) alpha-activities (in Bq cm^{-3}) inside the sample by