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Technical note

Influence of humidity on radon and thoron exhalation rates from building materials

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HIGHLIGHTS

- Humidity has significant effect on radon and thoron exhalation rates.
- The exhalation rate tendency was the same for samples with different porosity and density.
- Humidity effect should be considered for calculation of the equivalent dose from radon and thoron.

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ABSTRACT

The contributions of radon and thoron from building materials to total radon (thoron) entry rates in dwellings range from almost zero to several percent. It is necessary to measure radon and thoron exhalation rates, among other things, to assess the radiological hazard to human health in a living environment. Brick and granite specimens were used to study the changes of these rates as a function of the relative and absolute humidities. Measurement results showed that radon and thoron exhalation rates change to humidity with the same trends as well as effective dose could be changed by the factor of 2 due to this.

1. Introduction

The earth's crust contains small amounts of the primordial radionuclides ^{238}U and ^{232}Th which decay through a chain of radioactive nuclides until they produce stable isotopes of lead. Most of the decay products are isotopes of solid elements but two are gases: ^{222}Rn (radon) from the decay of uranium and ^{220}Rn (thoron) from thorium. They can migrate to the earth's surface by transport of radon relative to the gas or liquid (molecular diffusion) and with the gas or liquid (convection or groundwater flow) (Cothern and Smith, 1987). The half-lives of radon (3.82 d) and thoron (55 s) are different and this difference is important when assessing their release from the ground and their distribution in the open air above the ground as well as in the room air of buildings. Radon and thoron enter the atmosphere mainly by crossing the soil–air, building material–air or water–air interfaces.

In recent decades concern about public exposures due to natural radiation sources has increased. The main contribution to natural radiation comes from terrestrial sources contaminated with naturally occurring radioactive materials (NORM), such as uranium, thorium and potassium as well as any of their decay products, such as radium and radon. The indoor radon concentrations mainly depend on radon that has penetrated from the surrounding soil through gaps, cracks, etc., but also on radon exhalation from building materials and radon in domestic water supplies.

Recent long-term surveys of indoor thoron and its progeny showed that doses from the thoron series should no longer be considered as negligible. In the report a dosimetric approach was used to calculate the effective dose per unit of equilibrium equivalent concentration (EEC) for thoron progeny and it was almost four times greater than that of radon progeny.

In this context the dose contributions of thoron (^{220}Rn) and its decay products can exceed the corresponding radon (^{222}Rn) values, as in the indoor environment thoron is considered more likely to originate from exhalation of building materials rather than from soils due to its shorter half-life. Consequently indoor radon and thoron concentrations should be monitored and building materials should be classified on the basis of their radon and thoron exhalation rates which can then be correlated with their activity concentration index (I) value, based on ^{232}Th, ^{226}Ra and ^{40}K concentrations.

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In this paper, the influence of relative and absolute humidities on radon and thoron exhalation rates was examined.

Table 1
Physical parameters of specimens.

Specimen	Size (cm)	Density (g cm^{-3})	Concentration (Bq kg^{-1})	
			^{226}Ra	^{232}Th
Brick	21 × 10 × 6	1.12	572 ± 4	74 ± 3
Granite	20 × 20 × 12	2.30	222 ± 2	374 ± 5

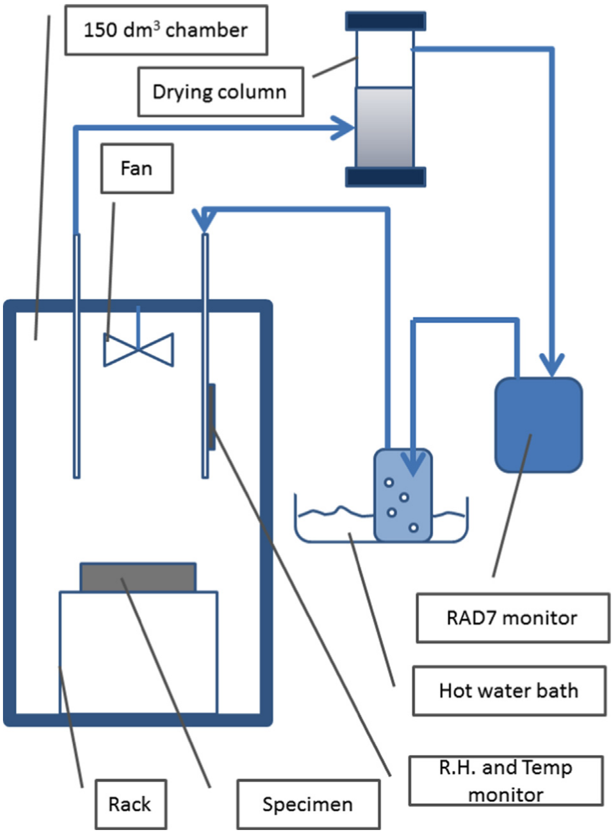

Fig. 1. Schematic of the system for exhalation rate measurement.

2. Materials and methods

Two materials, brick and granite, with high radium and thorium concentrations respectively, were used for measurements. The physical parameters and concentration of radionuclides, i.e. ^{226}Ra from the uranium decay chain (radon parent) and ^{232}Th from the thorium decay chain (thoron parent) measured by a HPGe detector system are listed in Table 1.

2.1. Measurement system

A modified standard method utilized radon and thoron gas monitor (type RAD7) was used to measure radon exhalation (*RnExh*) and thoron exhalation (*TnExh*) rates from the materials (Fig. 1). More details about the standard method and its validation can be found elsewhere (Hassan et al., 2011a).

Before the measurements the specimens were dried in a temperature controlled furnace (oven) at 110 °C for more than 24 h to ensure complete removal of moisture. Later, specimens were placed one at a time in the 150 dm^3 accumulation (measurement) chamber under a controlled atmosphere. The big volume of the chamber (150 dm^3) was required for stabilization of the air atmosphere inside. Humidity was generated by a bubbling method which utilized a hot water bath. Before starting the measurement, each specimen was kept at the desired measurement conditions for 3 days to reach a state of equilibrium between it and the chamber environment. Thirty minutes before the start of the measurement the chamber was flushed with room air using a high volume pump (10 L min^{-1}) to remove accumulated radon and thoron. The environment conditions inside the chamber were changed a few percent from the initial state but equilibrium was reached again within one to a few hours (depending on the final conditions) after starting measurements (Fig. 2). The chamber tightness was checked by an appropriate test utilizing CO_2.

The accumulation chamber was connected to the RAD7 monitor using vinyl tubing, and a gas-drying unit filled with a desiccant was installed between them, to maintain the relative humidity at $<10\%$ within the measurement system as recommended by the manufacturer. The system was a closed loop in which the gas was circulated continuously with the flow rate generated by an external pump with the same flow rate as the RAD7 pump. The flow rate was measured for the correction factor calculation for thoron concentration. The concentrations of radon and thoron released from each specimen inside the chamber were allowed to

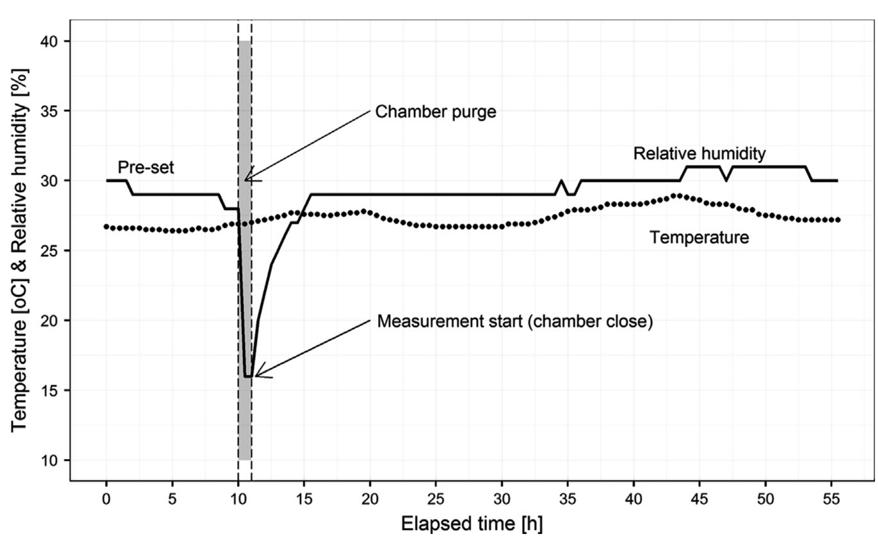

Fig. 2. Changes of relative humidity and temperature in the accumulation chamber during measurements.