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Measurement of radon emanation in construction materials

N. Lavi [a], V. Steiner [b], Z.B. Alfassi [c,*]

[a] Environmental Services Company, Tel Aviv, Israel
[b] Ministry of the Environment Protection, Jerusalem, Israel
[c] Ben Gurion University, Nuclear Engineering Department, Beer Sheva 84105, Israel

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ABSTRACT

Due to the new proposed Israeli approach for radioactivity in construction materials (IS 5098) issued in 2007, the radon emanation of a construction material, a brick in the form of a box (a rectangular parallelepiped), should be checked when its four faces are insulated in order to achieve the same simulation effect when a concrete block is embedded into a wall. A physical model was developed in order to measure the insulation level (quality) of a building product (bulk concrete, building block, tiles, etc.) when its four sides are insulated by various materials. Under the experimental conditions it was found that the insulation level for bulk concrete was $99.5 \pm 0.04\%$ which is in good agreement with the requirement of the new Israeli Standard IS 5098. The influence of aging of concrete materials on radon emanation and the emanation ratio, deduced from measurements of insulated and non-insulated materials, was investigated.

1. Introduction

In recent years there has been an increased awareness of the radiological hazards resulting from the external annual radiation doses induced by the naturally occurring radioactive materials (NORM), ^{226}Ra, ^{232}Th and ^{40}K, in conventional building materials. Much research has been carried out in order to determine the correlation between the concentration of radioactive materials in building materials and the external radiation doses to which the general public is exposed (Keller et al., 1987).

In order to limit the exposure of the public to natural sources of radiation in Israel due to building materials, there is a clear tendency to control the building materials under the supervision of the Israeli Standard Institution and the Ministry of the Environment Protection (MEP). The total chronic (prolonged) radiation dose from building materials to the general public is determined by controlling the NORM concentration as well as the emanation rate of radon. International guidelines are described in BSS 115 (1986) and International Commission of Radiation Protection (1999).

Recently, as a result of new regulations, a new Israeli standard, 5098, was issued in 2007, in order to control and to limit the total radiation dose of the general public due to construction materials to 0.7 mSv per year (Standards Institution of Israel, 2007). This regulation also includes the degree of radon emanation in addition to the concentration of ^{226}Ra.

In this work the radiation activity of natural radionuclides (NORM) as well as the radon emanation rate in concrete materials was studied, with main emphasis on the measurement of the emanation rate of radon. The studies involve several different points concerning the emanation rate:

1. The development of a method for insulation of the four sides of the building product, in order to ensure that all of the radon is emanated only through the two faces that are free for emanation of the radon, similar to the situation of a brick in a wall.
2. The determination of the radon emanation rate of concrete materials when four sides of the construction material are insulated by the insulating material, in order to achieve the same simulation effect when a concrete block is embedded into a wall.
3. The development of an insulation technique for the other two sides in order to achieve an insulation level of 99% when four sides of a concrete material are insulated.
4. The determination of the radon emanation rate of aging concrete materials. This will allow to measure and estimate the total annual effective equivalent dose deduced from concrete materials.

2. Materials and methods

Two types of insulating materials were examined, polyurethane rubber (Polytek, prepared in house by polymerization via the

* Corresponding author. Tel.: +972 8 646 1347; fax: +972 8 647 2955.
E-mail address: alfassi@bgu.ac.il (Z.B. Alfassi).

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Table 1
Determination of the insulation level of plasticine by activated charcoal canisters using an emanation standard of radon.

Emanation radon activity (Bq)	Thickness of plasticine layer (cm)	Activity measured (Bq)	Insulation level (%)
1600	0.5	11.1	99.30
	1.0	1.5	99.91

mixing of two reagents) and plasticine (commercially available for children toys from Jerusalem Pencils Israel), respectively, for the insulation level of radon gas emanation. Although both materials emit small amounts of radon due to the uranium in them, it is better than using insulation by metal sheets since they do not cover the brick completely and they require adhesive materials. The small amount of radon emanated from the insulating material was studied and subtracted from those emitted by the brick. A layer of 0.5–1.0 cm of these materials was inserted into an open charcoal canister, which was positioned together with an encapsulated emanation source of radon of 1600 Bq) in a radon gas chamber which was hermetically closed. After several days the radon activity in the canister was measured by gamma-ray spectrometry (Table 1), using the radon daughters ^{214}Pb and ^{214}Bi.

The total radon emanation from a massive concrete block ($20 \times 10 \times 10\ \text{cm}^3$) when four faces were closed by plasticine, was determined by inserting it together with a charcoal canister into a radon gas chamber which was hermetically closed (Fig. 1). The radon was captured by the charcoal canister during 5–7 days. The total radon in the canister was determined by gamma-ray spectrometry.

In order to check the radon insulation quality of the plasticine one may try to completely seal a concrete block on all its six sides. This measurement is possible but requires skill and experience. Since there is no outlet for the radon, the high pressure of the radon which is built in the pore space, close to 100,000 Bq/m^3, will leak through micro-channels in the insulating material. For this reason the measurement of the leakage of radon from a concrete block with all its six sides insulated, was done by insulating four sides (surface $20 \times 10\ \text{cm}^2$ each) with the insulating material (1 cm thick) and two sides (surfaces of $10 \times 10\ \text{cm}^2$ each) were connected to two large charcoal canisters by the insulating materials(Fig. 2). The large effective volume of the charcoal ensures a very low radon concentration at the two open sides of the block, simulating the situation when the block is embedded in a wall. This block was inserted into a radon gas chamber (hermetically closed) together

Fig. 2. Measurement of the insulation quality of plasticine on a charcoal canister using a known emanation-rate radon source.

with a charcoal canister. Since it was found that the activity due to one block is quite small, in order to increase the count rates of this canister and decrease the statistical error, 10 such blocks were positioned in the radon gas chamber. The total radon activity emanated from these 10 completely insulated concrete blocks was calculated from the measured radon activity (Bq) in the one charcoal canister that was not connected to the blocks. Additionally, the total radon activity emanated from 10 open concrete blocks was calculated from the measured radon concentration (Bq/m^3) determined by five Electret detectors (LLT).

The calculated infinite time (maximal activity) derived from the measured activity of charcoal canisters is given by the following expression (Steiner et al., 2002; Lavi and Alfassi, 2004, 2005; Steiner, nd):

$$A_{\text{Rn}} = f\frac{A_{\text{AC}}(t)\left(1+\frac{V}{V_{\text{AC}}^{\max}}\right)}{1-\exp(-\lambda t)}$$

where t is the exposure time and $A_{\text{AC}}(t)$ is the activity of the canister at the end of exposure (Bq). V is the volume of air (net) in the gas chamber, $V_{\text{AC}}^{\max}$ is the effective maximal volume of the detector and λ is the radon decay constant (0.00755 h^{-1}). The correction factor, f,

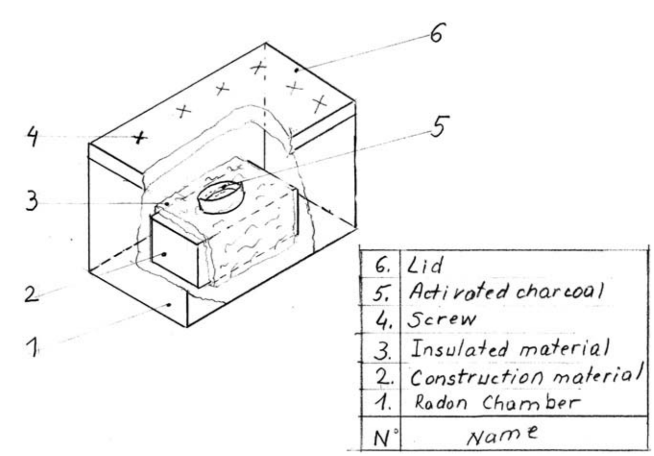

Fig. 1. Schematic picture of the hermetically closed box and inside the brick insulated on four sides and opened at two faces together with the active charcoal canister.

Fig. 3. Measurement of radon emanation deduced from ten open prisms using Electret detectors in a hermetically closed chamber.