memo

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1 Introduction

Below you find the extended abstracts that are part of the presentations given at the NCAB workshop on the 11th of December 2012.

Presentation: Radon monitoring methods

Exposure to radon in houses is monitored through physical testing of the individual building materials and measurement of radon concentrations in a representative part of the Dutch housing stock. The agreed testing programme is part of a covenant between industry and government to monitor radiation levels and maintain zero growth in radiation exposure from building materials to the general public.

Since the 1980's three radon surveys have been executed of which the last survey was completed in 2010 and executed within the framework of the Dutch covenant.The results from the last survey showed a mean radon concentration of around 15 Bq/m^3 in the Dutch housing stock. Recently, a fourth survey has been started. This survey will also investigate exposure to thoron, as there are indications that exposure to thoron is more substantial than previously thought.

The methods used for measuring the radiation properties from individual building materials are based on the NEN 5697 for measuring the activity concentrations from NORM nuclides and NEN 5699 for measuring the radon exhalation rate. The presentation discusses the monitoring methods used in physical testing as well as details from the radon surveys in the Dutch housing stock. An overview of the radon exhalation from Dutch building materials is shown in the figure below.

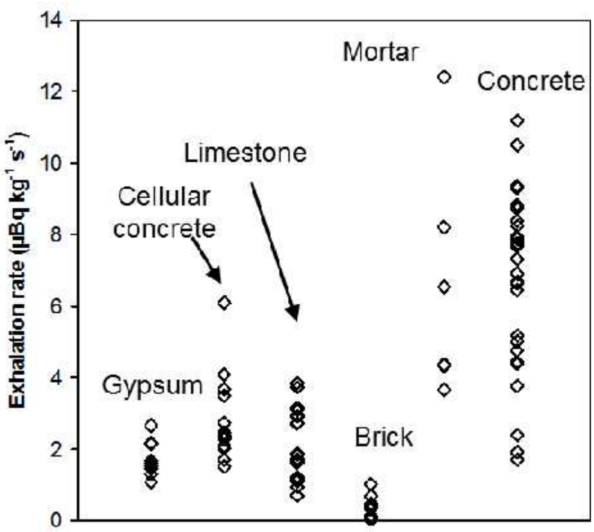


Figure 1 Overview of the radon exhalation from building materials in the Netherlands.

Presentation: Assessment model of exposure to radiation from building materials

Assessment of the radiation exposure of inhabitants in dwellings is described in the Dutch technical standard NEN 7181. The standard provides a calculation methodology to compute exposure levels based on radiation emission from building materials, building geometry and ventilation, as well as other relevant building characteristics. The bases for this calculation methodology is the radiation performance index which is computed as follows:

$$RP_i = \Delta C_{Rn;i} * DCC + E_{ext;i}$$

where RP_i is the radiation performance (Sv/y) for each room, $\Delta C_{Rn;i}$ is the radon concentration difference between indoor and outdoor, DCC is the dose conversion coefficient and $E_{ext;i}$ is the effective dose rate from external radiation. The $\Delta C_{Rn;i}$ is computed for each room in the following manner:

$$\Delta C_{Rn;i} = (S_i + A_i / \Sigma A_j * S_{or}) / 0.5 * Q_i$$

Where S_i is the source term (Bq/s), A_i is the floor area, ΣA_j and S_{or} are the terms for the other rooms and Q_i is the ventilation flow. A database with exhalation rates for most regular building materials is available. Alternatively, the source term can be computed from available experimental data. Correction factors for age, moisture and place are also available. The external radiation exposure $E_{ect,i}$ (Sv/y) for each room is computed as:

$$E_{ext,i} = \Sigma(A_n * m_n / m_{ref} * F_{dose}) / \Sigma A_n * c_{l\text{-}eff}$$

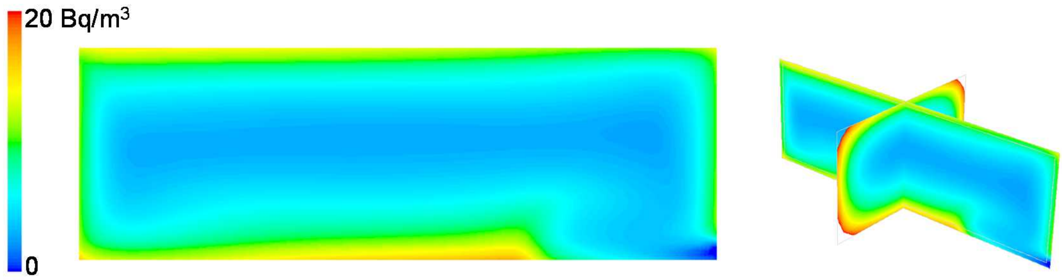
where A_n is the surface area (m^2), m is the mass per m^2 and $c_{l\text{-}eff}$ is conversion from dose rate to effective dose rate (Sv/Gy). The dose factor is computed for each substructure as follows:

$$F_{dose} = (k_{Ra\text{-}226} * a_{Ra\text{-}226} + k_{Ra\text{-}228} * a_{Ra\text{-}228} + k_{K\text{-}40} * a_{K\text{-}40})\ \rho / \rho_0.$$

The nuclide specific conversion coefficients to compute the dose factor at reference density are provided.

An additional assessment model is developed under the contract of the Dutch ministry for environment and housing, which is primarily focussed on the assessment of radiation exposure from thoron (Rn-220). The assessment model is based on a three-dimensional numerical computation and computes both radon and thoron as well as its progeny products. A snap-shot of both radon and thoron concentrations is shown in the attached figure. The figure shows a broadly uniform radon distribution, while thoron –due to its half-life of only 56 s– is predominantly found in the vicinity of the wall where the thoron is emitted.

(a)



(b)

Figure 2 Plot of the radon concentration (a) and thoron concentration (b) in a reference room.

Presentation: Contribution of coal ash used as an additive to concrete radiation levels

As part of the here presented work a total of five different concrete mixtures have been studied to determine the activity concentrations and the radon exhalation as well as an assessment of the radiological dose when these materials are used in regular dwellings.

An analysis has been carried out on the radioactivity concentrations of gamma-ray emitting radionuclides in three samples for each of the five concrete mixtures, according to the Dutch standard NEN 5697. For the determination of the ^{222}Rn exhalation rate a test is carried out for each concrete mixture according to the Dutch standard NEN 5699. The results from these experiments are as follows:

Table 1 Sample specifications, activity concentration and standard deviation expressed in Bq/kg.

Sample code	Weight (kg)	Activity concentration (Bq/kg)							
		^{226}Ra		^{228}Th		^{228}Ra		^{40}K	
		x	SD	x	SD	x	SD	x	SD
7013-A	1.443	34	2	6.1	0.5	6.0	0.4	48	3
7013-B	1.441	35	2	6.7	0.5	6.5	0.4	49	3
7013-C	1.523	35	4	5.8	0.6	5.8	0.5	46	2
7014-13	1.418	36	2	8.7	0.7	8.4	0.5	75	3
7014-14	1.544	33	3	8.5	0.8	7.9	0.8	68	5
7014-15	1.379	37	2	9.5	0.7	8.5	0.5	78	3
7015-13	1.474	36	4	9.9	0.9	10.2	0.7	48	2
7015-14	1.477	37	4	10.9	0.9	10.0	0.7	50	2
7015-15	1.512	37	2	10.9	0.7	9.8	0.5	49	3
7017-16	1.432	41	2	9.8	0.7	9.8	0.5	74	3
7017-17	1.505	40	2	8.3	0.6	8.8	0.5	73	3
7017-18	1.476	40	2	9.8	1.0	8.9	0.7	73	3
7019-20	1.544	36	2	9.2	0.6	9.3	0.5	55	3
7019-21	1.430	38	2	9.5	1.0	8.1	0.6	59	3
7019-22	1.148	47	4	10.9	1.0	11.3	0.8	72	3

Table 2 Sample specifications and exhalation rate expressed as µBq/s and µBq/kg/s.

Sample code	Weight (kg)	Exhalation rate				
		(µBq/s)		(µBq/kg/s)		(%)
		x	SD	x	SD	SD
7013	14.34	90.3	5.0	6.3	0.3	5.5
7014	14.40	87.2	19.8	6.1	1.4	22.6
7015	14.30	103.7	2.1	7.2	0.1	2.0
7017	14.42	84.4	15.9	5.9	1.1	18.9
7019	14.52	84.4	10.2	5.8	0.7	12.1

Subsequently, a dose assessment for both internal and external radiation exposure is performed for these five concrete mixtures. As part of internal dose assessment the radon and radon progeny concentrations are computed in a predefined dwelling, using advanced numerical calculation. The computational modelling is based on a room of 3×3×2.7 m^3 and an air exchange rate of 0.5 h^{-1}. A background concentration of 10 $Bq·m^{-3}$ is assumed. For the computation of the external dose a room with dimensions of 5 x 4 m^2 and 2.8 m in height is assumed, together with a 20 cm thick wall. The time spent indoors is taken as 7000 h per year, which corresponds with 80% of the total time.

The results for both external and internal dose as well as the total dose are presented below.

Table 3 Annual dose from radiation exposure.

Sample code	External dose ($mSv·a^{-1}$)	Internal dose ($mSv·a^{-1}$)	Total dose ($mSv·a^{-1}$)
7013	0.20	0.57	0.78
7014	0.23	0.56	0.79
7015	0.24	0.62	0.86
7017	0.26	0.55	0.80
7019	0.25	0.55	0.80

Computation of the external and internal dose for those concrete mixtures results in an estimated yearly external dose of up to 0.26 mSv and an internal dose of up to 0.62 mSv.