SCK•CEN

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

RADON MITIGATION BY SUB-SLAB DEPRESSURIZATION

BLG 712

S. Oberstedt and H. Vanmarcke
Studiecentrum voor Kernenergie SCK•CEN
Onderzoekseenheid Stralingsbescherming
Boeretang 200,
B-2400 Mol

RADON MITIGATION BY SUB-SLAB DEPRESSURIZATION

BLG 712

S. Oberstedt and H. Vanmarcke
Studiecentrum voor Kernenergie SCK•CEN
Onderzoekseenheid Stralingsbescherming
Boeretang 200,
B-2400 Mol

Radon mitigation by sub-slab depressurization

S. Oberstedt and H. Vanmarcke
Studiecentrum voor Kernenergie SCK•CEN, Boeretang 200, B-2400 Mol

Abstract

In a wintergarden built on radium contaminated ground, the radon concentration averaged over about 6 month was 720 Bq/m^3 exceeding the action level of 400 Bq/m^3 recommended by the Belgium authorities. With a sub-slab depressurization system the radon concentration has been lowered considerably below the limit. During installation the remediation efficiency as well as the economical aspect have been taken into consideration. A follow-up test one year after installation confirms the initial result.

1. Introduction

One of the world's largest radium extraction plants was operated from 1922 until 1969 in Olen (Belgium). Media reported in 1989 and 1990 of some very high radium contaminations in the village of Sint-Jozef-Olen. This caused anxiety among the neighbouring population and resulted in a detailed radiological characterization of contaminated areas and an evaluation of their impact on the exposure to population. The Federal Ministry of Public Health and Environment (DBIS•SPRI) assigned the measurement programme to the SCK•CEN and the Institute of Hygiene and Epidemiology (IHE).

One of the investigated exposure pathways is the inhalation of indoor radon from radium contaminated material under the dwelling. Therefore, radon measurements were performed in all of the 846 neighbouring dwellings. In 6 dwellings the average radon concentration was above 150 Bq/m^3 in one of the living areas. The dwellings were inspected with portable γ detectors.

Only in the dwelling with the highest radon concentration an enhanced dose rate was found in a wintergarden over a length of 5 m and a maximum width of 2 m. The maximum value is 600 nSv/h which is 5 to 10 times the local background. The radon concentration averaged over a period of three months in the wintergarden was 720 Bq/m^3, in the living room 370 Bq/m^3, in the cellars 120 Bq/m^3 and in the bedrooms 100 Bq/m^3. Continuous monitoring with a Lucas-type flow-through device [1] during 2 weeks showed large variations in radon concentration between 20 and 3000 Bq/m^3 depending on the ventilation and the meteorological conditions (see Fig. 1).

The exposure of the occupants is 11 mSv/y assuming a dose conversion factor of 50 μSv/y per Bq/m^3 [2] and a residence time of 30 % in the bedroom and 50 % in the living room. According the owner the low-lying ground next to his dwelling was raised including debris from the company owning the former radium plant. This debris was used afterwards as foundation of the wintergarden.

2. Sub-slab depressurization system

In collaboration with the Belgian Building Research Institute and DBIS it was decided to install a sub-slab depressurization system to reduce the radon concentration in the dwelling. The principle of operation is to prevent radon gas from entering the dwelling by extracting

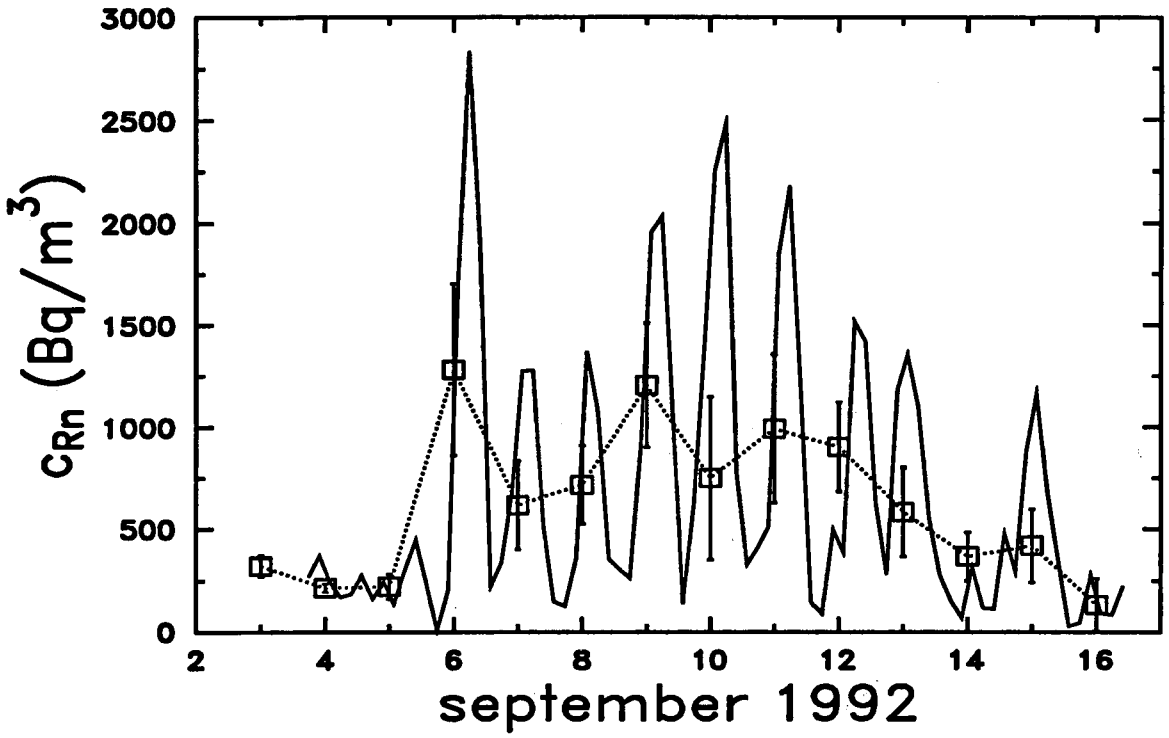

Fig. 1: Radon concentration measured in September 1992 averaged over a period of 4 h (full line) and daily average values (symbols, dotted line)

continuously soil gas via a pipe and fan system to a discharge point outside the dwelling. In the wintergarden a cavity of 0.4 $\times$ 0.4 m^2 with a depth of 0.5 m was excavated beneath the floor. The ^{226}Ra concentration of the excavated material was determined by means of high resolution γ spectrometry. Activated charcoal was added to the sample in order to adsorb the emanating radon. The spectrum was dominated by the lines of ^{226}Ra decay products. The radium concentration of the material was found to be 3000 Bq/kg, which is several orders of magnitude higher than the radium concentration of the local soil.

The cavity was filled with a coarse gravel aggregate to facilitate the extension of the pressure field. A plastic pipe with a diameter of 15 cm was placed in the suction hole which was subsequently covered with concrete. The gaps around the entry of the pipe were sealed with silicone. The fan was located on the attic of a free-standing garage. The fan outlet was away from windows and doors to prevent the radon-laden air entering the building.

The speed of the selected fan, type Turbo T2, can be controlled. At full power and 25 Pa static pressure the nominal flow rate of the centrifugal fan is 410 m^3/h. The consumption of the fan at full power is 75 W.

3. Control measurements and follow-up study

In Nov. 94 the remediation efficiency of the sub-slab depressurization system had been monitored over a period of two weeks. Furthermore, it was to know, which fan-power would already be sufficient to reach the goal, i. e. to lower the average radon concentration well below the action level of 400 Bq/m^3. Thus, a series of measurements were performed at alternating fan-power. Initially the fan was operated at full power (switch position 3) for one day, followed by a whole day fan-off (switch position 0). In the following days the fan was operated at position (1) and (2) with one day fan-off in between. The complete sequence (3)-(0)-(1)-(0)-(2)-(0) was repeated. The radon concentration was monitored with a Lucas-type flow-through monitor integrated over periods of 4 h each. The obtained average radon concentrations c_{Rn} are shown in Fig. 2 as a full line. The daily averaged radon concentrations corresponding to the different fan-power levels are given by symbols. Windy weather conditions between the 15th and 17th leads to low radon concentrations also at fan position (0).

With a rotameter the air flow rate at the end of the ventilation tube was measured for each possible switch position. In Fig. 3 the air flow rate (left y-axis) and the fan power relative to maximum power (right y-axis) is shown as a function of the switch position. Each data point corresponds to an average value drawn from 5 flow rate measurements. The fact, that we have a non-zero flow rate at zero fan power (0) is due to the chimney effect inside the pipe and the windy condition during the flow rate measurements.

In Fig. 4 the achieved average radon concentrations are shown as a function of the relative fan power. The full line indicates the radon concentration found prior to mitigation, and the dashed line represents the action level. As it is obvious from the data, already the chimney effect leads to a reduction bringing the average radon concentration below the action level. At lowest fan-power level, the remediation leads to a full-time reduction, i. e. the radon concentrations are always well below the action limit (see also Fig. 2). Moreover, higher fan power does not lead to a significant improvement (the full circle indicates the

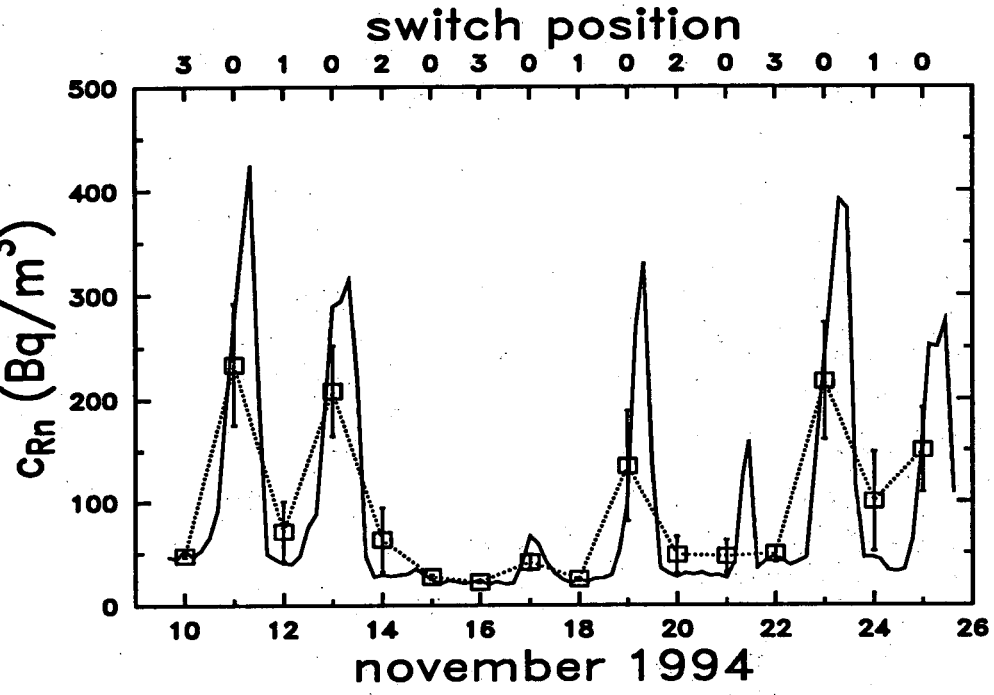

Fig. 2: Radon concentration measured in November 1994 averaged over a period of 4 h (full line) and daily average values (symbols, dotted line). Fan-off corresponds to switch position (0). Full power is switch position (3).

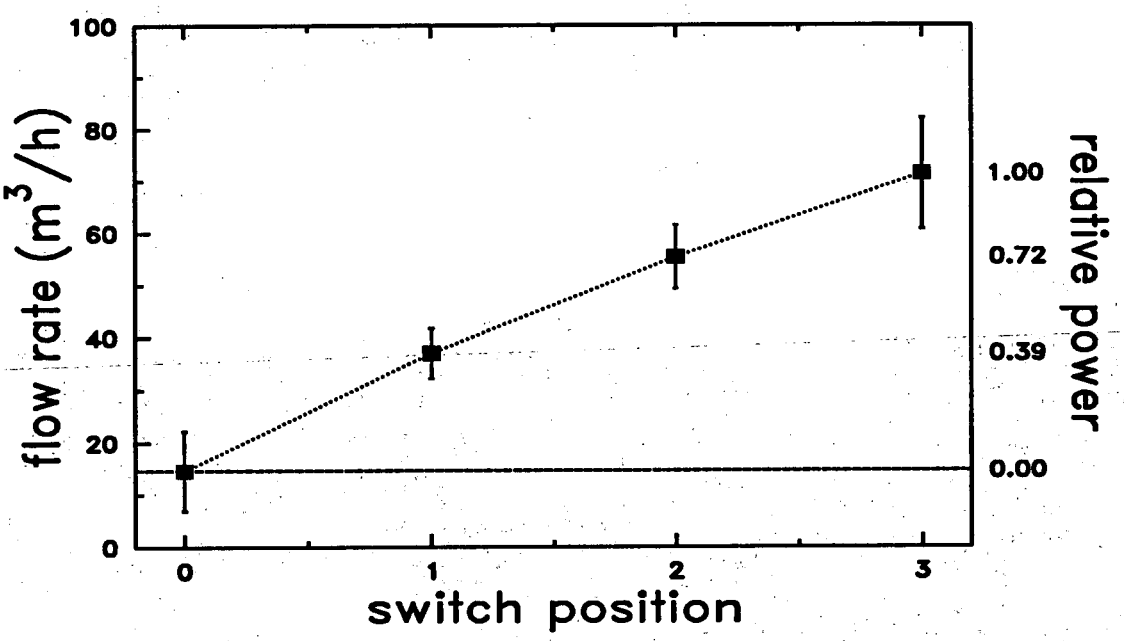

Fig. 3: Air flow rate at the and of the ventilation tube as a function of the fan switch position. The right y-axis gives the corresponding fan power relative to maximum power.

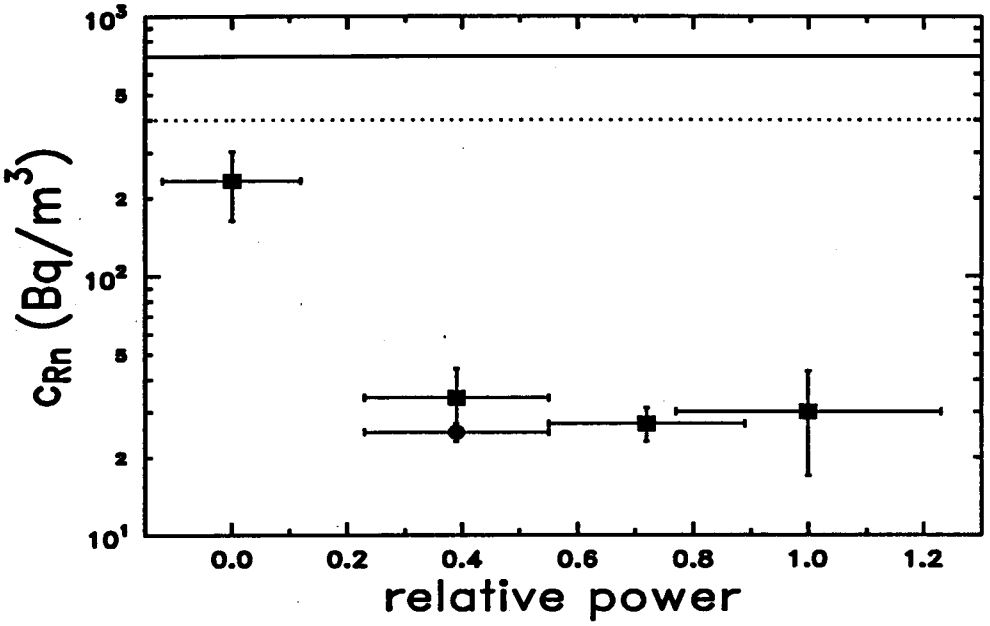

Fig. 4: Average radon concentrations as a function of the relative ventilation power (full squares). The full line indicates the radon level prior to mitigation, and the dashed line represents the action level. The full circle indicates the result from the follow-up study performed one year later.

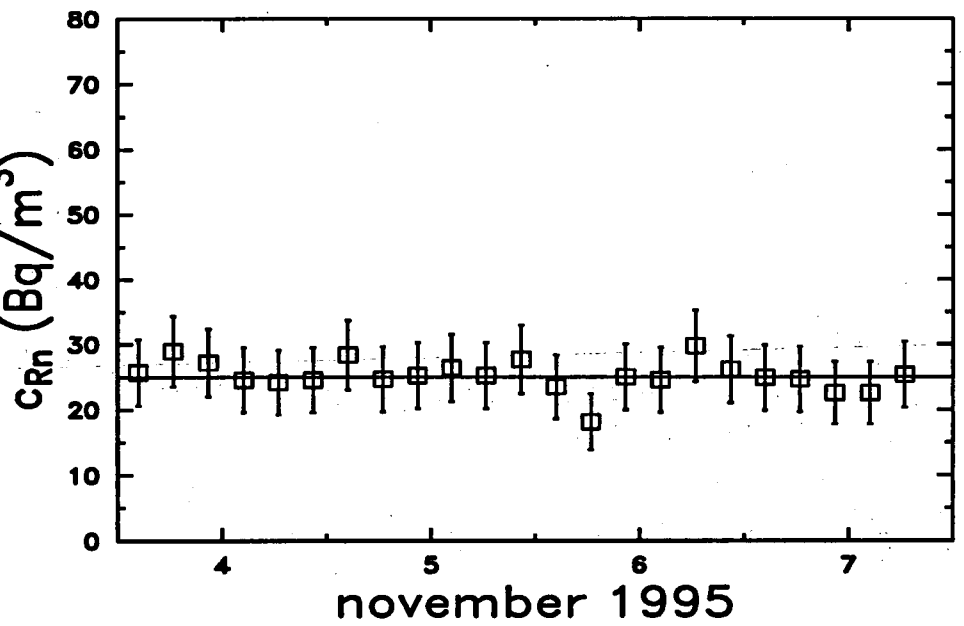

Fig. 5: Radon concentrations measured in November 1995 averaged over a period of 4 h obtained during the follow-up study one year after remediation. The full line indicates the average value at 25 Bq/m^3. Fluctuations are within $\pm$ 5 Bq/m^3.

result from the follow-up study mentioned below).

After one year, in Nov. 95, a follow-up study was performed. During four days the radon concentration averaged over a period of 4 h was measured. The corresponding data are shown in Fig. 5. The average radon concentration was 25 Bq/m^3 and clearly confirmed the previous result from Nov. 94. Although the day/night fluctuation is visible, the variation of the radon concentration did never exceed 5 Bq/m^3.

4. Summary

A successful radon mitigation study was performed and its stability in time could be demonstrated by a follow-up study one year later. The remediation efficiency is larger than 96 % at an annual consumption of 256 kWh, which in Belgium actually correspond to additional costs of less than 1500 BEF per year. This result is compatible with studies carried out in US houses [3].

References

[1] H. F. Lucas, Improved low-level alpha-scintillation counter for radon, Rev. Sci. Inst. 20 (1957) 680:683

[2] H. Vanmarcke, P. Bervens and A. Poffijn, Radon versus Radon Daughters", Health Phys. 56 (1989) 229:231

[3] D. B. Henschel, Analysis of Radon Mitigation Techniques used in Existing US Houses, Rad. Prot. Dosim, Vol. 56 (1994) 21:27