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Procedure for the characterization of radon potential in existing dwellings and to assess the annual average indoor radon concentration

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ABSTRACT

Risk assessment due to radon exposure indoors is based on annual average indoor radon activity concentration. To assess the radon exposure in a building, measurement is generally performed during at least two months during heating period in order to be representative of the annual average value. This is because radon presence indoors could be very variable during time. This measurement protocol is fairly reliable but may be a limiting in the radon risk management, particularly during a real estate transaction due to the duration of the measurement and the limitation of the measurement period. A previous field study defined a rapid methodology to characterize radon entry in dwellings. The objective of this study was at first, to test this methodology in various dwellings to assess its relevance with a daily test. At second, a ventilation model was used to assess numerically the air renewal of a building, the indoor air quality all along the year and the annual average indoor radon activity concentration, based on local meteorological conditions, some building characteristics and in-situ characterization of indoor pollutant emission laws. Experimental results obtained on thirteen individual dwellings showed that it is generally possible to obtain a representative characterization of radon entry into homes. It was also possible to refine the methodology defined in the previous study. In addition, numerical assessments of annual average indoor radon activity concentration showed generally a good agreement with measured values. These results are encouraging to allow a procedure with a short measurement time to be used to characterize long-term radon potential in dwellings.

1. Introduction

Radon (^{222}Rn) is a radioactive gas coming from the disintegration of uranium, present naturally in soil. The radon half-life of 3.82 days enables its migration from the soil to the surfaces where it tends to concentrate in enclosed spaces like buildings (UNSCEAR, 2008). In France, the estimated number of lung cancer deaths attributable to indoor radon exposure ranges from around 1200 to 2900 per year (Catelinois et al., 2006). Radon exposure is the second cause of lung cancer in the general population, after smoking. Radon is a major contributor to the ionizing radiation dose received by the general population (Who, 2009).

In several countries, legislation is under way to protect the population from radon exposure. In France, first regulations exist for some public buildings and workplaces in priority zones. In the framework of a national action plan, authorities plan to define management procedures for new constructions and in existing dwellings.

However, risk assessment due to radon exposure indoors is based on standardized measurement, to assess the annual average indoor radon activity concentration (NF ISO 11665-4, 2012, 11665-8, 2013). It is performed using passive dosimeters during at least two months of the heating period, and assumed to provide data representative of the annual average, despite that radon indoors could be very variable with time. This measurement protocol is called screening of the building. It is fairly reliable. However, the duration of the measurement and the limitation of the available period for this screening may cause uncertainty about the quality of the measurement and be a limiting factor in the radon risk management in existing dwellings, particularly during real estate transactions.

The principal source of radon in buildings is from the soil below the building (Mustonen, 1984), brought into the building by convection and diffusion (Fig. 1).

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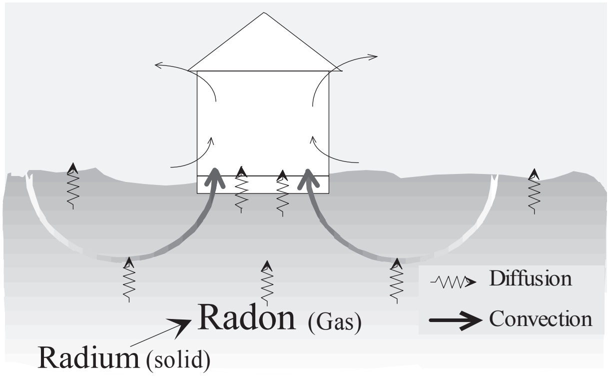

Fig. 1. Radon entry into buildings.

However, when radon transport from the ground indoors is studied, the main phenomenon considered is generally convection, and diffusion is often neglected (Nazaroff et al., 1985). The convection is due to pressure-driven flow created by several phenomena. Slight indoor depressurization could be due to a combination of temperature difference between indoors and outdoors, a wind effect on the building, ventilation and heating systems (Nazaroff, 1992; Mäkeläinen et al., 2001; Kokotti et al., 1992; Arvela, 2001). Radon flux into the building could be considered as linearly dependent (Nazaroff, 1988) or a power law function (Fronka et al., 2008) of indoor depressurization. Historically, few in situ experiments have been done using the blower door method to determine radon entry indoors (Maringer et al., 2001; Ringer, 2001; Fronka et al., 2008; Fronka and Moucka, 2008). Ringer (2001) used experimental flux data to estimate the annual average radon activity concentration using an analytical ventilation model.

More recently, and based on these previous studies, a study was undertaken in a detached dwelling to adapt and to define a rapid measurement methodology to characterize radon entry (Collignan et al., 2012). Results were encouraging because they showed that it was possible to accurately estimate the annual average radon activity concentration. However, the methodology should be tested in a range of representative situations.

In this study, the initial methodology (Collignan et al., 2012) was applied to thirteen detached dwellings identified as having a wide range of annual average indoor radon activity concentrations, using the screening defined in standardized protocol (NF ISO 11665-8, 2013). The objectives were to assess the relevance of this methodology to characterize radon entry and a radon potential with a daily test, and secondly to assess numerically the annual average indoor radon concentration based on this in-situ characterization methodology and some building parameters.

2. Material and method

2.1. Summary of experimental methodology and determination of radon potential

The principle of this methodology (Collignan et al., 2012) is to use the blower door to maintain the dwelling at successively different depressurization levels in order to heighten the convective radon flux from the ground. For each depressurization level, exhaust air flow from the blower door, depressurization level and indoor radon activity concentration close to the blower door are measured (Ringer, 2001; Fronka and Moucka, 2008; Collignan et al., 2012).

The blower door is installed on an external door or window (Fig. 2) as centered as possible in the first floor to effectively drain the air from throughout the dwelling. An AlphaGUARD© monitor is positioned close to the extraction of air of the blower door during these tests to measure continuously indoor radon, using diffusion mode of the apparatus (Fig. 2). For a given depressurization level, the indoor radon activity concentration increases and stabilizes around an asymptotic steady state value (Fig. 3). In steady state conditions, the radon flow leaving the building through the blower door corresponds to the radon entry rate.

Assuming that the radon entry rate is constant for a given pressure level, the mass balance of the radon in the building gives, in steady state conditions, neglecting the outdoor radon activity concentration, the following equation (1):

$$\Phi_{Rn} = C_{Rn}^{asympt} \times Q_v \tag{1}$$

Where Q_v (m^3/s) is the air change flow, C_{Rn}^{asympt} (Bq/m^3) the asymptotic indoor radon activity concentration, Φ_{Rn} (Bq/s) the radon entry rate representing the unknown variable.

Such tests are performed at different depressurization levels in order to be able to fully characterize the radon entry relationship, and this can be done in a one-day methodology. An example of measurement results is shown in Fig. 4 for two different depressurization levels. The fitted curves are also drawn in Fig. 4.

Results of measurements are used to calculate the radon entry rate at each depressurization level (generally two or three levels between 5 Pa and 25 Pa depressurization). Each depressurization level needs to be stabilized for approximately 2 h. For this reason, it is difficult to conduct such test with a depressurization level below 5 Pa as it could generate a lack of stabilization in the level targeted and of precision in measurements undertaken. It is also needed to purge the dwelling with external air before each test to obtain a radon level as low as possible before the test (Fig. 4). Based on these data, an interpolation is done to obtain an experimentally law

Fig. 2. Blower Door installation and continuous indoor radon measurement.