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THE INFLUENCE OF A CONTROLLED NATURAL VENTILATION ON THE INDOOR RADON DECAY PRODUCTS CONCENTRATION: A CASE STUDY

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1. ABSTRACT

Air exchange rates in occupied buildings are difficult to assess due to their dependence on a multitude of climatic parameters and inhabitant behaviour. Moreover, the assessment of the influence of the air exchange rate on the radon progeny concentration is hampered by the diurnal and seasonal fluctuations of the indoor radon levels. Experiments involving two adjacent rooms submitted to identical conditions influencing the radon concentration and showing similar temporal variations and levels of radon progeny provide a mean to assess the contribution of a controlled natural ventilation enhancement to the reduction of the indoor radon progeny concentration. First results show, that one additional air exchange per day reduces the mean indoor radon progeny concentration by about 5 %. This indicate that natural ventilation is not sufficient to reduce the indoor concentration of radon decay products to an acceptable level in areas with elevated radon source strength, especially during the winter.

2. INTRODUCTION

Exposure to radon and radon daughters are a well-known cause of lung cancer in miners[1,2]. The attention payed during the least decade to the indoor radon problem has revealed, that the activity concentration in the living area of many buildings may reach or even exceed the concentrations measured in modern mines[3,4]. Thus indoor radon progeny are believed to be the greatest "natural" radiation hazard to the general public and therefore one of the most critical indoor air pollutants. The indoor concentration of volatile substances i.e. also of radon and radon decay products is determined by the source strength, the infiltration mechanisms and the air exchange[5]. Moreover, the air exchange rate is influenced by the characteristics of a building[6] ,climatic parameters and by the behaviour of the inhabitants opening and closing windows according to a subjective feeling about the indoor air quality. Involving both the feasibility of technical solutions and the private sphere of occupants, field measurements in occupied buildings are quite delicate.
The aim of the present case study was to clarify if the assessment of the influence of the inhabitants on the indoor concentration of radon decay products is feasible. To achieve this goal, all fluctuations of other parameters influencing the indoor radon decay products concentration have to be reduced to a minimum in order to avoid misinterpretations of the experimental results. The case study involves two comparable rooms subjected to approximately the same external parameters influencing the indoor progeny concentration. Controlled changes of the natural ventilation in one of the two rooms keeping the other one as control, allow us to eliminate the major sources of errors and to test the feasibility of such a project.

3. MATERIALS AND METHODS

Continuous measurements of radon decay products were performed with Eberline WLM-1 working level monitors. Field calibration of these sampling units were accomplished with an electroplated alpha source as described earlier[7]. Measurements of air exchange rates were carried out with a tracer gas technique using nitrogen protoxyde (N_2O) as described elsewhere[8]. Both, decay and constant concentration methods were used for the air exchange rate determinations. To simulate in a realistic way the ventilation behaviour of inhabitants, owners of 100 dwellings were asked by mailed questionnaire about their ventilation attitudes.

4. RESULTS

4.1 The diurnal cycle

Figure 1 shows the diurnal radon decay products fluctuations during one week for the two experimental rooms located on the ground floor of a single family home.

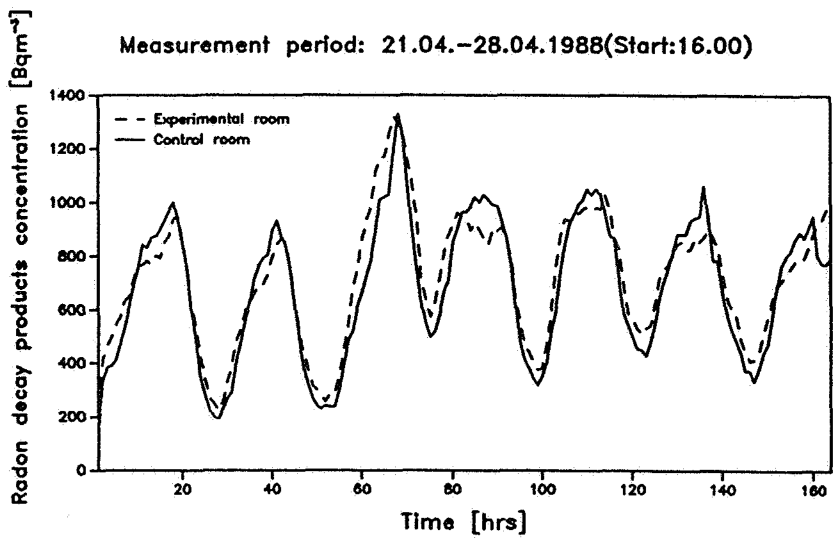

Figure 1. The diurnal fluctuations of the radon decay products concentration in the two examinated adjacent rooms

The two adjacent rooms showed almost identical pattern of radon decay products for at least three months in the absence of occupants. The diurnal cycle exhibits, for so far unknown reasons, a maximum in the early morning and a minimum in the late afternoon. Therefore the opening of a window during the decreasing phase of the diurnal cycle would overestimate the influence of the ventilation on the radon decay products concentration. Thus for quantitative assessments the time-dependent variations of the radon decay products concentration obtained for a ventilated room must be considered and compared with the values obtained for the unventilated control room.
The analysis of adjacent rooms which are submitted to identical conditions influencing the radon progeny concentration and exhibiting a comparable diurnal cycle (Figure 1) provides a mean to asses the influence of a controlled natural ventilation on the indoor radon daughters concentration.

4.2 Limitations of the radon decay products detection system

Time integrating radon progeny monitors have the disadvantage that they fail to respond quickly to fast changes in activity concentrations. In addition, because of the half-life of the radioisotopes involved, a time-lag of about 45 minutes between actual and reported radiation level occurs. However, this time-lag does not influence long time experimental records in a significant way.

4.3 Influence of the natural ventilation on the concentration of radon decay products

From the 88 responces to the questionnaire on ventilation attitudes, only 51 were filled in completely. The ventilation attitudes turned out to be highly variable for the different rooms of a building as well as for different buildings. The mean values obtained for different rooms during winter and summer reported in Table 1 give an idea about the extreme variations in different climatic periods. This ventilation behaviour during different climatic periods may partially explain the reported seasonal variations of the mean indoor radon concentrations[9].

Table 1. Mean window opening time in minutes day^{-1} ($\pm$ S. D. of the mean) for a sample of 51 homes

Season	kitchen	bathroom	living room	bedroom
Winter	30 ($\pm$ 5)	25 ($\pm$ 4)	25 ($\pm$ 3)	130 ($\pm$ 45)
Summer	300 ($\pm$ 60)	400 ($\pm$ 75)	450 ($\pm$ 67)	700 ($\pm$ 90)

Because the indoor concentration of radon decay products reach maximum values during the winter when room ventilation is reduced in order to save energy, we decided to perform first experiments with short ventilation periods of 10 minutes. Such a period provokes an enhanced ventilation of one air exchange for the experimental room compared to the unventilated control room as determined by tracer gas decay experiments.
A typical record of the influence of this controlled natural ventilation on the concentration of radon decay products in the experimental room during a period of 24 hours is reported in Figure 2.
The response of the working level monitors to changes in the ventilation rate of the experimental room showed to be fast enough to record changes in the concentration of the radon decay products even if ventilation occurs during the decreasing phase of the diurnal cycle. Therefore a quantitative assessment of the influence of the ventilation rate on the radon decay products concentration is practicable. The air exchange rates of the unventilated experimental and control room determined by tracer gas decay experiments were 0.15 ± 0.01 h^{-1} and 0.14 ± 0.02 h^{-1}, respectively. These results are in good agreement with the values of 0.13 h^{-1} and 0.12 h^{-1} obtained during a three weeks' experiment using the constant tracer gas concentration method in the absence of occupants.

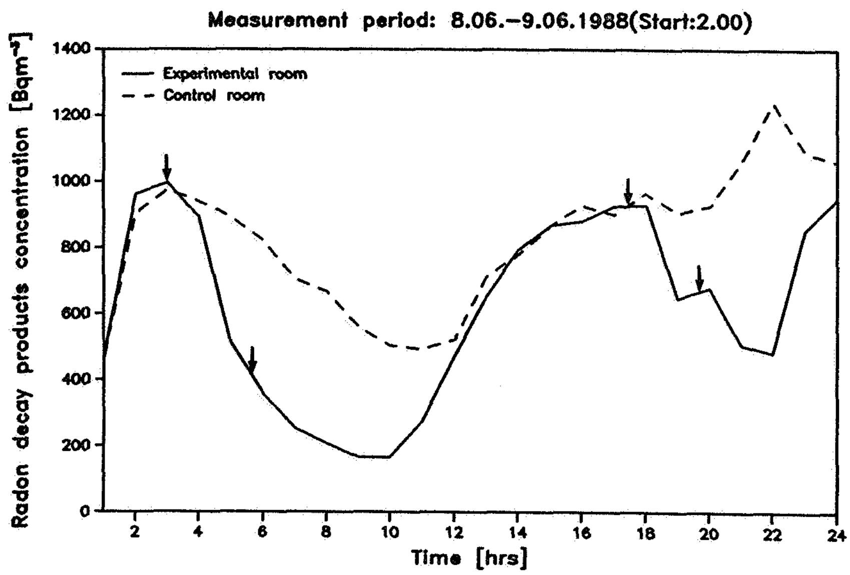

Figure 2 Influence of a controlled natural ventilation on the concentration of radon decay products. Arrows indicate opening of the windows in the experimental room during 10 minutes.

From the preliminary results of the experiments reported in Table 2 we can deduce, that one additional air exchange per day reduces the mean indoor radon decay products concentration by about 5 %. The experimental equipment is sufficient to permit an estimation of the influence of natural ventilation to the indoor concentration of radon decay products. However, for a more accurate quantification long term experiments are required.

Table 2. Influence of a controlled natural ventilation on the indoor concentration of radon decay products

Measurement period	Room	Mean rn-decay products [c] (Bqm^{-3})	Mean air exchange (h^{-1})	Reduction (%)**
08.06-09.06	1	612 (± 58)	0.32*	25
	2	829 (± 43	0.11	
21.06-22.06	1	687 (± 36)	0.27*	20
	2	860 (± 26)	0.10	
22.06-23.06	1	592 (± 51)	0.29*	20
	2	742 (± 31)	0.12	
23.06-24.06	1	788 (± 47)	0.31*	20
	2	987 (± 21)	0.12	

* Room ventilated during four periods of 10 minutes (ca. 4 additional air exhanges day^{-1})
** In room 1 as compared to the control room 2

5. CONCLUSIONS

The results of our experiments with a matched pair of rooms displaying similar diurnal variations and levels of radon decay products have shown, that the quantification of the influence of the natural ventilation is indeed possible and gives reliable results. In fact, natural ventilation reduces the radon progeny concentration indoors. However, short ventilation periods as applied here are not a sufficient mean to reduce the indoor concentration of radon decay products to an acceptable level in areas with high radon emanation into buildings.
Further experiments involving a representative sample of buildings and varying ventilation periods are required in order to generalize our findings.

Acknowledgement

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