DECREASE OF RADON EXPOSURE BY CONTINUOUSLY ADJUSTED AND CONTROLLED VENTILATION

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ABSTRACT

A new mechanical ventilation system which continuously controlled the indoor-outdoor pressure difference was installed in six houses, where the long-term radon levels ranged from 670 to 3 080 Bq/m^3. When the new system had operated for several months, the indoor radon levels decreased to levels from 120 to 600 Bq/m^3, the effective dose reductions being from 40 % to 88 %.

KEYWORDS

Radon, mitigation, exposure, mechanical ventilation, pressure difference, air leakage

MATERIALS AND METHODS

The operation of a new mechanical ventilation system responding to indoor-outdoor pressure difference has been reported earlier by us (Kokotti et al., 1994). The main reason for the development of this controlled mechanical ventilation was the need for reduction in radon levels by decreasing the convective flow due to negative pressure indoors.

Our study houses are located in the southern part of Finland, where annual average radon levels often exceed 300 Bq/m^3 in homes. The characteristics of six houses studied are presented in table 1. Five of the houses had one storey and House D had two storeys. Total living areas varied from 100 to almost 200 m^2. The air exchange rate with 50 Pa indoor-outdoor pressure difference (n_{50}) was highest at 8.6 1/h in House A. Two of the houses (D and F) were quite tight having n_{50} - values less than 4 1/h. Except for house D having mere mechanical exhaust ventilation, the houses previously had traditional mechanical supply and exhaust ventilation systems with a heat-exchanger.

Table 1. The characteristics of the houses.

House	A	B	C	D	E	F
Living area (m^2)	118	108	128	188	108	150
Volume (m^3)	293	259	331	486	259	465
n_{50} (h^{-1})	8.6	6.0	5.8	3.6	5.0	3.6

All the houses have been built on a concrete slab. The first house (A) having walls constructed from bricks and wood, is located near Helsinki. The other five houses stand on the same esker in the Lahti district. The houses B, C, E and F have outer walls constructed from bricks sprayed with concrete. Among them house F had the largest living area, and it had less air leakages than the others. House D had two storeys: The first floor, having three walls surrounded by soil, was constructed from porous bricks sprayed with concrete and the second floor was constructed from white clay bricks. The maintenance room for heating and ventilation in house D was located on the first floor, where the walls were constructed from porous bricks and pipe joints through floor and walls were available.

The initial indoor radon levels with the old ventilation systems were determined during the first study periods. After installating the new combined mechanical ventilation system, radon levels were monitored during periods of one month, when the pressure control system was on or off in turns. Continuous measurements were conducted during one week before and after control adjustment.

The long-term levels of indoor radon were analyzed by alpha track etch film in diffusion caps. Short-term radon levels were monitored continuously by using the Lucas cell flow-through active method with a Pylon AB-5 assembly, which includes detector, photomultiplier, and data collection system based on a microprocessor. The indoor-outdoor pressure differences between a living room and an attic were monitored with low differential pressure transducers. The air-exchange rates were obtained by measuring air flows in ducts with orifice plates.

During the periods with the indoor-outdoor pressure difference adjusted mechanical ventilation, the set value of indoor-outdoor pressure difference varied from -0.2 Pa to +2 Pa depending on air leakage values in different houses.

RESULTS AND DISCUSSION

In the houses studied, the efficiency of the pressure difference control to reduce radon levels varied. The highest initial concentration of radon was found to be 3 080 Bq/m^3 in house D. After providing supply air, the indoor radon level decreased to a value of 640 Bq/m^3. When a slight overpressurization (+1.5 or +1.8 Pa) was used, the radon level decreased further to a value of 370 Bq/m^3 (Table 2). Thus, a total radon level reduction of 88 % was achieved. High reduction, 86 %, was also obtained in the other tight house, F, having the maximum set value for indoor-outdoor pressure difference (2 Pa). In the other houses (A, B, C and E) having more air leakage the radon reduction ranged from 40 % to 50 %. The weather conditions disturbed the mitigation mostly in house A (n_{50}=8.6 1/h), where radon entry increased with measured indoor-outdoor temperature difference.

The radon mitigation by overpressurization of the houses is usually avoided due to probable moisture problems. However, for the new ventilation system Ahonen et al. (1994) found no correlation between pressure difference and moisture content in ceiling construction, or concentrations of microbes and volatile organic compounds.

According to Hoving et al. (1993) radon reductions from 50 % to 80% were achieved with the balanced mechanical supply and exhaust system in 18 houses in Finland. They found low ventilation rates, measured after mitigation, seem to be accompanied by also low reduction. The possible reason for different reduction rates (40 - 88 %) in the houses of this study, in addition to the different air leakage values of the houses, could be the operation time of the prior ventilation system. However, in the houses A, C and F the tenants used the ventilation twenty four hours per day, but indoor radon levels did not decrease until the control system was installed and operated for a whole day. The

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controlled ventilation system maintained air exchange rates equal or higher than 0.5 1/h during day and night. The supply air flows were equal or slightly higher, and exhaust air flows equal or slightly lower than during the traditional mechanical ventilation (figure 1). Thus, the radon reduction succeeded due to more effective dilution and balanced pressure conditions (figures 1 and 2) after installation of the new system.

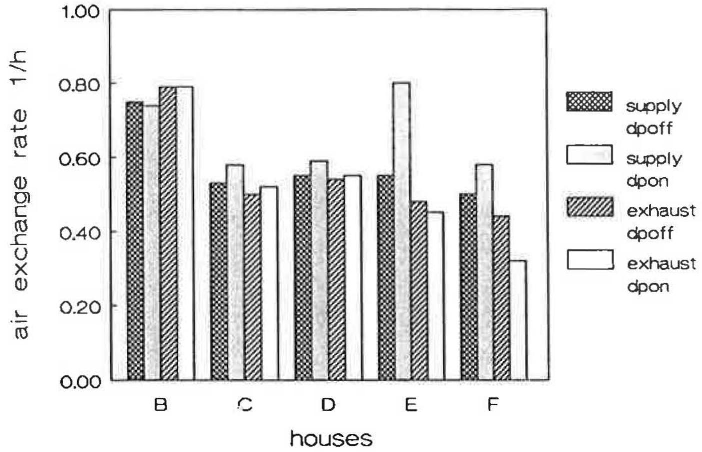

Figure 1. Air exchange rates (1/h) calculated from supply air flows (supply dpoff, supply dpon) and from exhaust air flows (exhaust dpoff, exhaust dpon) in houses B, C, D, E and F during the new mechanical ventilation operation without indoor-outdoor pressure control (dpoff) and with control (dpon).

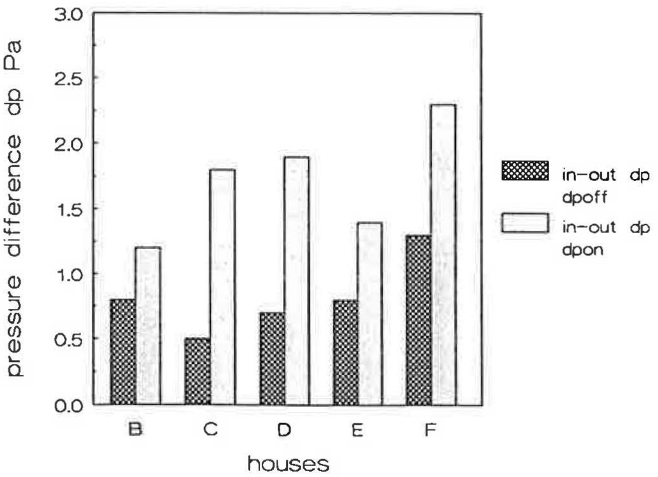

Figure 2. Indoor-outdoor pressure differences (Pa) in houses B, C, D, E and F during the new mechanical ventilation operation without indoor-outdoor pressure control (in-out dp dpoff) and with control (in-out dp dpon).

The effective dose equivalent in table 2 is calculated according to ICRP (1994) with an annual occupancy of 7000 hours and an equilibrium factor of 0.4. The conversion coefficient for one Bq/m^3 is 4.4 x 10^{-3} WLM, and dose conversion convention is 4 mSv per WLM.

Table 2. The radon levels (Bq/m^3) and effective dose equivalent (H_E, mSv) in six houses before and after operation of mechanical ventilation adjusted by indoor-outdoor pressure difference.

	before installation of new system / controlled ventilation in operation					
House	A	B	C	D	E	F
radon level Bq/m^3	670/340	870/440	795/480	3080/370	1020/600	845/120
H_E mSv	11.8 / 6.0	15.3 /7.7	14.0 / 8.4	54.2 / 6.5	18.0/10.6	14.9 / 2.1
decrease of H_E mSv / %	5.8 / 50	7.6 / 49	5.6 / 40	47.7 / 88	7.4 / 41	12.8 / 86

After mitigation, the annual effective dose in the houses studied did not exeed the value recommended by ICRP (1994), for homes of 10 mSv.

ACKNOWLEDGEMENTS

The authors would like to thank their advisor Dr. H. Arvela of the Finnish Centre for Radiation and Nuclear Safety, and their technical staff MSc T. Keskikuru, Eng. M. Konttinen, Eng. J. Niilonen and J. Saavalainen. The research was supported by the Technology Development Centre in Finland.

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