RADON STUDY IN 250 FINNISH HOUSES WITH DIFFERENT VENTILATION SYSTEMS

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The study is based on simultaneous passive measurements of both the ventilation rate and radon concentration in 250 houses with different ventilation systems. House substructure, air exchange rate and building materials were significant factors affecting the indoor radon concentration, building ground is the most important but remains to be analyzed. In blocks of flats the geometric mean of the diffusion source was 29 Bq m^{-3} h^{-1}. In 16 % of the single family houses the concentration limit of 200 Bq m^{-3} was exceeded. If the concentration limit is exceeded by a factor of two, increasing the ventilation as the only mitigation against radon seldom would give good results.

INTRODUCTION

The contribution of the natural ionizing radiation to the total radiation exposure of man in Finland is larger than in most other countries. This is mainly due to radon in indoor air. Since 1980 more than 30 000 residences have been measured in Finland.

The realistic assessment of exposures requires detailed knowledge on influencing factors. In order to examine factors affecting the variations in indoor radon concentration a model has been developed which relates radon concentration to source strength and its variations, air exchange rate and meteorological factors (1). In this study radon concentrations were measured simultaneously with air exchange rates, in order to get information about the source levels and model parameters. The analysis of some model parameters is still being done.

This study was made in co-operation with the Laboratory of Heating, Ventilating and Air Conditioning of Helsinki University of Technology. The objective of the research was to gather information about the actual ventilation and indoor air quality (air temperature, humidity and dust) in Finnish residences (2). The Finnish Centre for Radiation and Nuclear Safety has been responsible for measurements and analysis of indoor radon concentrations.

MATERIALS AND METHODS

The field measurements were made in 251 typical Finnish residences during the 1988-1989 heating season. The sample was selected randomly from buildings in the metropolitan area of Helsinki and consists of 162 residences in detached or semi-detached houses (below single family houses) and 89 residences in blocks of flats, Table 1. The ventilation systems in these residences were natural ventilation (78 residences), mechanical exhaust (108) and balanced ventilation (65). Table 1 shows the characteristics of the residences.

The average two-week period ventilation rates were measured using the PFT-technique which is an integrating constant tracer flow technique (2). The radon measurements were performed with solid state nuclear track dosimeters. Electrochemically etched Makrofol polycarbonate films sealed in a plastic cup were used. The normal measuring period for control measurements of the STUK is two months. In this study the measuring period was only two weeks. For improving the sensitivity we used two dosimeters in each room studied. The calibration factor of the dosimeters was: one track per radon concentration of 7 Bq m-3, background 4 tracks. Therefore the statistics of measurements in low concentrations is not good although two dosimeters were used.

Radon concentrations were measured also in summertime, in May-June 1989. The measuring period was one month. The air exchange rate was not measured during this period.

The results were analyzed using SAS GLM (3) procedure. The procedure uses the method of least squares to fit general linear models. The statistical methods used were regression and analysis of variance.

RESULTS AND DISCUSSION

Air exchange rates

Table 2 shows the air exchange rate in residences with different ventilation systems. In single family houses with natural ventilation the exchange rate is only slightly slower than in houses with mechanical exhaust or balanced ventilation. The mean values for single family houses and blocks of flats were 0.45 and 0.64 1/h, respectively.

Radon concentration

The mean radon concentration in single family houses was 140 Bq m-3 and in blocks of flats 65 Bq m-3. In single family houses the radon concentrations were on average higher in houses with mechanical ventilation than in houses with natural ventilation. However, on basis of statistical analysis this difference was caused by other factors than the ventilation system. House construction, building material and air exchange rate were the significant factors. Tables 2 and 3 show the results. In slope houses (explanation in Table 1) both the gap around the slab and the walls (often porous concrete) against the ground increase the flow of radon into the house. The mean concentration was 50 Bq m-3 higher than in houses with only slab on ground. The concentrations are lowest in houses with crawl space or basement.

In this study the type of building ground was not analyzed. However, radon concentration in soil and soil permeability are the most important factors affecting the indoor radon concentration. This is in agreement with the result, that the factors analyzed in this study explain only less than 30 % of the variations observed.

In blocks of flats radon diffused from building materials is the main source of indoor radon. However, in first floor flats the influx from the ground may increase radon concentrations. Table 3 shows the results.

Increasing ventilation as a mitigation

The concentration limit of 200 Bq m-3 was exceeded in 16 % of the single family houses. In 70 % of these houses the air exchange rate was below the recommended value of 0.5 1/h. By increasing the ventilation rate to 0.5 1/h the radon concentration would decrease below 200 Bq m-3 only in 10 of these 27 houses, assuming the pressure difference driving radon flow from the ground is not affected by the ventilation improvement.

Winter-summer ratio

The variables used in statistical analysis were winter concentration, building material, ventilation method and house construction. Winter concentration and building material were significant variables, Table 4. The results are in agreement with our model and previous results (1). When the winter concentration is low the contribution of diffusion source to radon concentration is high and the winter-summer ratio is near unity or lower. When the winter concentration is high the contribution of pressure difference driven flow is dominant. In this case the ratio is normally 1.5-2.5. In single family houses with concrete walls the diffusion source is higher than in houses with wooden walls, winter-summer ratio is lower, respectively.

Source strength

The diffusion source strength SD (Bq m-3 h-1) was calculated for residences in blocks of flats where the contribution of radon influx from soil is small using equation 1.

$$SD = A\ N \qquad (1)$$

A is radon concentration (Bq m-3) and N air exchange rate (1/h). The geometric mean was 29 Bq m-3 h-1.

In single family houses the average total source strength was 56 Bq m-3 h-1. In houses with wooden walls building materials contribute on average less than 20 % to the indoor radon concentration.

CONCLUSION

Careful analysis is needed in studies on factors affecting the indoor radon concentration. The effect of pressure differences caused by mechanical ventilation systems was not detected because of other significant factors. Pressure difference measurements are needed for careful analysis of ventilation systems. Improvement of ventilation can be used as a mitigation against radon mainly in cases where the ventilation rate is low. However, if the concentration limit is exceeded by a factor of two, increasing the ventilation seldom is an adequate measure.

REFERENCES

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Table 1. House characteristics.

	Houses	Flats	Total
Ventilation system:			
Natural	58	20	78
Mech. exh.	61	47	108
Bal. vent.	43	22	65
Total	162	89	251
Substructure:			
Slab on ground	55		
Crawl space	77		
Basement	8		
Slope house (1)	22		

(1) The houses are built on two levels. On one side of the ground floor the wall (often porous concrete) is against the ground. Slab on the ground.

Table 2. Air exchange rate and radon concentration, dependence on house type and ventilation system.

	Ventilation system Natural	Mechanical exhaust	Balanced ventil.	Av.
Air exchange rate 1/h				
Geom. mean				
Single family houses	0.36	0.42	0.42	0.40
Flats	0.56	0.59	0.54	0.57
Radon concentration Bq m-3				
Geom. mean				
Single family	88	111	110	102
Flats	48	51	58	52