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The Effect of Ventilation & Pressure Differences on Concentrations of Radon at Workplaces

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SYNOPSIS

The workplaces located in southern (18 places) and central Finland (8). The total amount of workrooms measured was 87. The mean concentration of radon was 254 Bq/m^3 (range from 12 to 1647 Bq/m^3) during working hours. The calculated radon entry rates varied from 2 to 4780 kBq/h. The measured air exchange rates varied from 0.1 to 13.3 1/h and calculated ventilation flow rates varied from 30 to 55200 m^3/h. Radon concentration was found to depend on the type of foundation, whereas types of ventilation or the ventilation flow rates did not correlate significantly with the concentrations of radon. The highest concentrations of radon were detected when the negative pressure differences were between 1 Pa to 6 Pa.

INTRODUCTION

Radon is a radioactive gas, which enters a building mainly from soil below the building. Radon could also be exhalated from tap water or building materials; however, those are generally only minor sources in Finland. /1,2/. In addition, indoor concentration of radon depends on meteorological factors, subgrade structures, air exchange rate, and pressure conditions /3/.

The negative pressure indoors tends to increase the intake of radon from soil through walls or floors. Kokotti et al. /4/ have found that pressure difference is the most important single factor of influencing radon entry rate. Hintenlang et al. /5/ have, however, found that the dependency of pressure difference is a complicated one having a maximum at the low negative pressure region. Balanced ventilation, when it operated at full effectiveness, has been found to decrease concentrations of radon in underground and partly underground workplaces in southern Finland /6/. Radon is a serious problem in the Finnish buildings. Radon levels exceeding 400 Bq/m^3 are commonly detected in homes, especially in the southern part of the country, with many areas of weathered granite and eskers /7/. In this area, as many as 30 % of the workplaces investigated by the Finnish Centre for Radiation and Nuclear Safety (STUK) had radon levels above 300

Bq/m^3. Finnish occupational exposure limit for radon is 400 Bq/m^3, which corresponds to effective equivalent dose of 2.5 mSv. The level of 300 Bq/m^3 is used as an action limit requiring more detailed investigations /8/.

The aim of this study was to investigate how concentrations of radon and radon entry rates depend on different type of ventilation and pressure difference at workplaces locating underground or partly underground.

MATERIAL AND METHODS

Measured workplaces

The workplaces in this study were located in southern (18 places) and in middle Finland (8 places). They included different kinds of offices and servicing rooms in schools, office buildings, telecommunication centers and rooms of the military forces. The total number of workers using the rooms was about 250. The volumes of the spaces studied varied from small office rooms of 20 m^3 to large research laboratories of 17 200 m^3.

Measurement techniques

Data concerning volumes, foundation, depth, working hours, number of employees and types and operation times of ventilation were collected by questionnaire. Radon levels were analyzed continuously near the workers' breathing zone by using the Lucas cell method /9/ with a Pylon AB-5 assembly, which includes a detector, a photomultiplier and a system of data collection based on a microprocessor. The output data of the Pylon detector were processed with SP-55 software run on a PC. The flow rate of the pump was 0.4 l/min. The interval of continuous measurements was 30 minutes (averaged to one hour). Concentrations were measured during periods ranging from two hours to several days. The integrated long-term radon levels were determined by alpha track etch films and analyzed by STUK /10/. Alpha films revealed the average radon level during one month, with integrated concentration of radon also determined at night and weekends, when the ventilation was not used at full capacity. The pressure differences across the wall, either separating or external, were monitored by an electronic manometer together with a datataker. The pressure differences were averaged from three-minute to one-hour intervals in the same way as the periods of radon levels were measured. During daytime working hours, air exchange rates were measured by the tracer gas technique and by the dilution method using difluorodichloromethane and nitrous oxide as the tracer gases and an infrared spectrophotometer, Miran 1A, as the analyzer. Ventilation flow rates were calculated by multiplying air exchange rates by volume of the workroom. The radon entry rates were calculated by multiplying the concentration of indoor radon by the measured air exchange rate and by the volume of the workroom.

RESULTS

The arithmetic mean concentration of radon during working hours was 254 Bq/m^3, and the range was from 12 to 1647 Bq/m^3. In 15 workrooms measured (17 % of the all workrooms), the concentrations of radon exeeded 400 Bq/m^3. All the violations of the exposure limit were found in the high risk area in southern Finland, where the violation percentage was 22 %. The mean concentrations measured during working hours were approximately on the same level than the local average concentrations detected earlier inhomes by Arvela et al. 1994 /7/ (table 1).

	Central Finland	Southern Finland
Homes	< 100	> 300
Workplaces		
* during working hours	90	300
* alpha film	140	550

Table 1. Measured radon levels (Bq/m^3) at workplaces (in this study) and corresponding levels at home (Arvela et al. 1994 /7/) in southern and in central Finland.

The radon levels integrated with alpha etch track film were higher than the levels measured during working hours. These integrated levels included nights and weekends, when the ventilation systems were usually operated at a lower capacity or not at all.

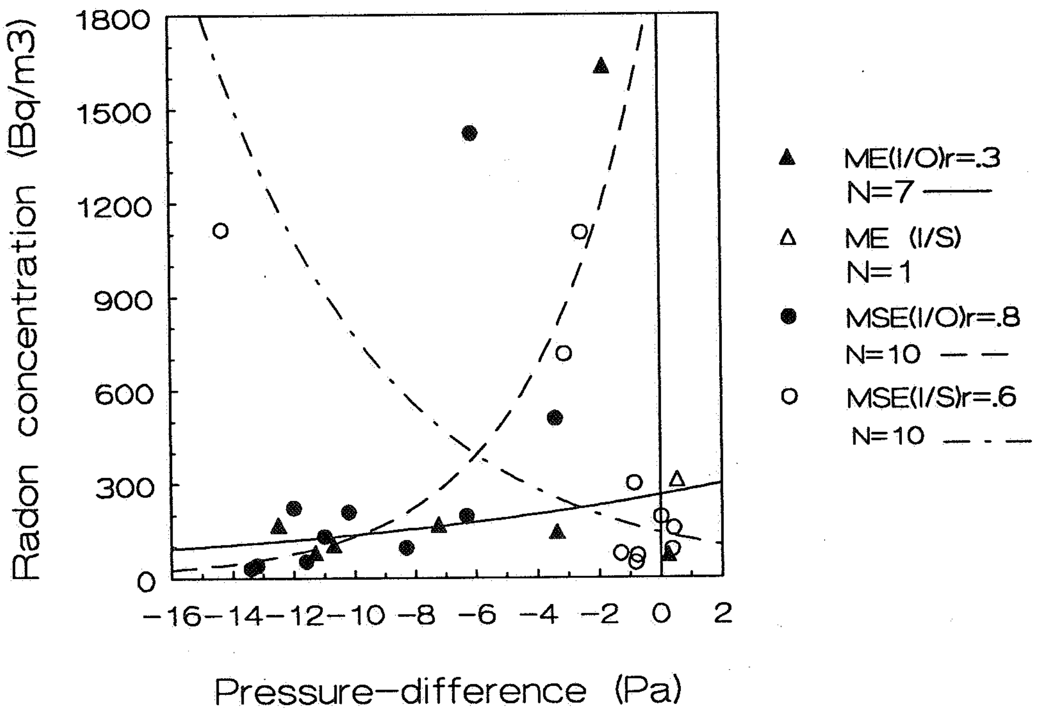

Figure 1. The radon levels (Bq/m^3) with the pressure differences (Pa) during working hours.

Pressure differences were measured either across an outdoor wall (I/O) or across a separating wall (I/S). There were 28 workrooms where pressure differences could be measured. When negative pressure differences were between 1 Pa and 6 Pa, exceptionally high radon levels (figure 1) were detected in four places ventilated with mechanical supply and exhaust and in one place ventilated with mechanical exhaust. The concentrations of radon seemed to increase exponentially (r=0.8) when the pressure difference (I/O) approached zero in spaces ventilated with mechanical supply and exhaust. On the other hand, when the pressure differences were measured across the separating wall (I/S) the concentrations of radon were found to decrease when the pressure differences approached zero (r=0.6). Radon entry rates followed the same pattern as concentrations of radon in the rooms with mechanical supply and exhaust ventilation.

The negative pressure below ten Pascals also seemed to induce high radon entry rates (figure 2). Generally, negative pressure in rooms having mechanical exhaust ventilation seemed not to effect significantly radon levels or entry rates (figure 1 and 2). The ventilation flow rates varied from 30 m^3/h to 55200 m^3/h (arithmetic mean of 1970 m^3/h). Ventilation flow rates in workrooms with the ventilation of mechanical exhaust and with the ventilation of mechanical supply and exhaust decreased exponentially with negative pressure approaching zero (figure 3). The radon entry rates varied from 2 kBq/h to 4780 kBq/h and the arithmetic mean was 480 kBq/h. The radon entry rates and the concentrations of radon did not have significant linear correlation (r=0.42) (figure 4).

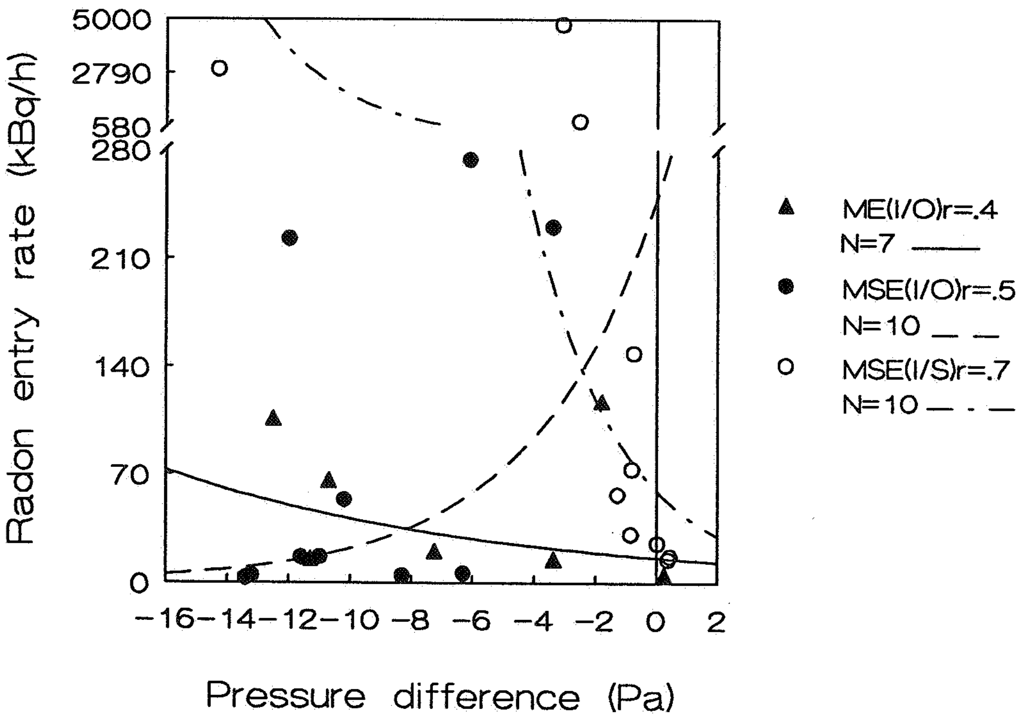

Figure 2. The radon entry rates (kBq/h) with the pressure differences (Pa) during working hours.

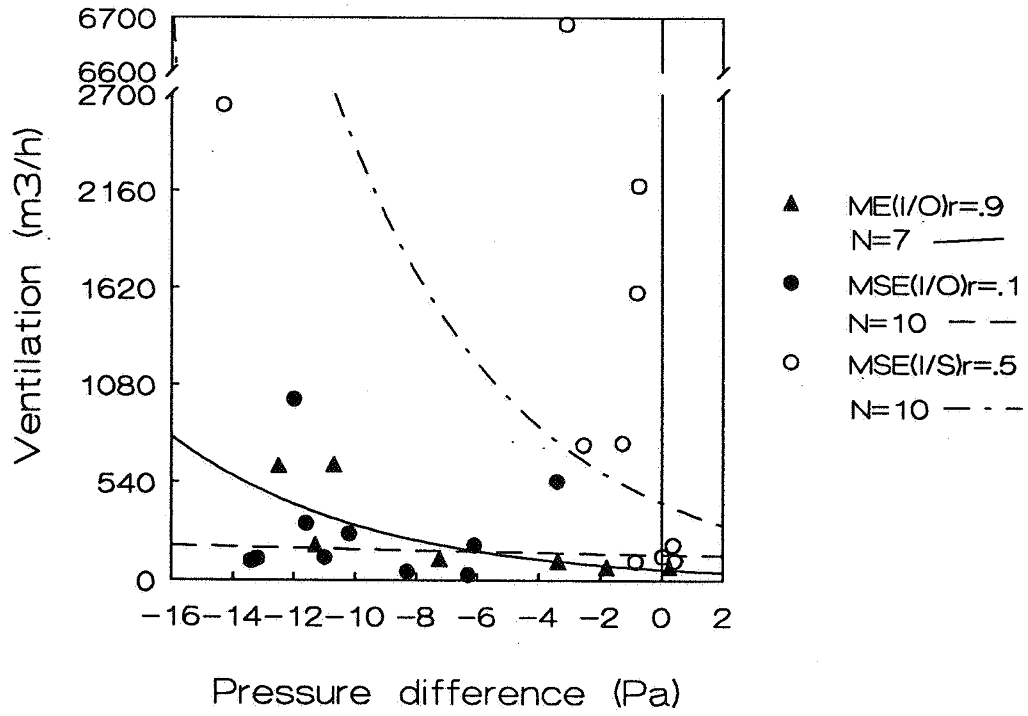

Figure 3. The ventilation flow rates (m^3/h) with the pressure differences (Pa) during working hours.

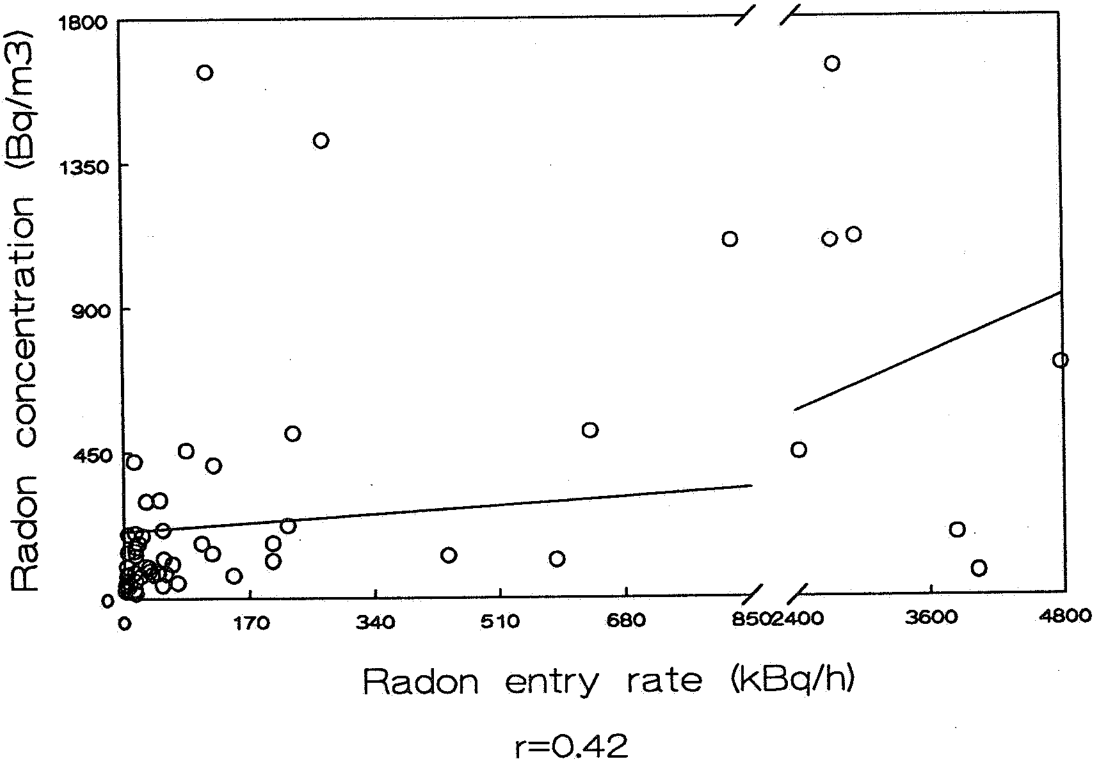

Figure 4. The radon levels (Bq/m^3) with the radon entry rates (kBq/h) during working hours.

Statistical test (Kruskal-Wallis) revealed quite significant correlation with the concentrations of radon and the type of foundations (p=0.06), but no correlation between type or flow rate of ventilation, when the whole data were considered.

CONCLUSIONS

Radon levels varied a lot due to differencies between the buildings, the ventilation systems, the foundations and the locations of places. In a high risk area, southern Finland, the radon levels at work were observed to be clearly higher than in central Finland and to be approximately at the same level as detected earlier by Arvela et al. 1994 /7/ in homes in the same area. Negative pressure differences (ranging from 1 Pa to 6 Pa) seemed to rise exponentially the radon levels and the radon entry rates in spaces ventilated with mechanical supply and exhaust. The low pressure differences (below 10 Pa) were also found to increase radon entry rates. The negative pressure (measured across the separating wall) decreased exponentially when the ventilation flow rate was decrease in rooms with mechanical ventilation.

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