Chapter 8

Indoor Radon Measurements in Finland: A Status Report

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Large-scale surveys indicate that the mean indoor radon concentration in Finnish dwellings is about 90 Bq/m^3. The percentages of concentrations exceeding 200, 400, 800 and 2,000 Bq/m^3 are 11, 3.9, 1.4 and 0.5 per cent, respectively. An updated version of the geographical distribution is presented. Sampling and data processing methods as well as the reasons for high concentrations are discussed.

Radon in indoor air is the main source of radiation exposure for the population of Finland. During the second half of the seventies, radon-rich tap water was thought to be the biggest source of radon in Finnish dwellings (Castrén et al.,1977, Castrén 1978). However, simultaneously with surveys in many other countries, large-scale surveys in Finland clearly demonstrated that a direct influx from the ground to the dwelling is responsible for the largest proportion of the radiation and for the highest radon levels in Finnish dwellings (Castrén et al.,1984, 1985).

The Finnish Centre for Radiation and Nuclear Safety is continuously conducting indoor radon surveys of dwellings. Already, the results from about 4500 houses are in our data register, and the number will be doubled this year. The present paper gives some new results of analyses of our data, an updated version of the previously published map of geographical distribution, and some of the principles of our monitoring strategy.

Methods

The radon measurements were performed with solid state nuclear track dosimeters. Up to 1984 we used open Kodak LR-115 dosimeters (Mäkeläinen, 1984), and thereafter electrochemically etched Makrofol polycarbonate sealed in a plastic cup (Mäkeläinen, 1986). Normally we use an integrating time of two months to reduce the variations due to changes in the weather. The necessity of a long integrating period is demonstrated by Figure 1, which shows the temporal variation in a typical high-concentration house. The dosimeters are calibrated in a controlled radon atmosphere in our laboratory and the calibration has been checked by international intercomparison. Simultaneous measurements have been made in some of the houses using

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different techniques and have normally been in accordance with each other (Figure 1).

The sometimes very large seasonal variation has also been corrected for. At least one measurement is supposed to be made in winter (November-March). The correction is based on the knowledge of typical winter-summer concentration ratios as shown in Figure 2.

Sampling is one of the key problems in conducting a nation-wide survey. We think a truly random sampling procedure would increase the cost and thus reduce the number of samples too much. The houses to be measured were thus selected by the person distributing the dosimeters, who tried to distribute them randomly over a given area. In most cases the area was a municipality. The municipalities were selected so as to cover the whole country evenly.

In constructing a distribution representative of the whole country, we divided the country into zones so that each zone was as homogeneous as possible with respect to the mean radon concentration of the municipalities. In the first analyses the results for each zone were simply pooled. Population-weighting was used when the zonal distributions were combined into a distribution for the whole country. Later on we also used population-weighting when combining the municipal distributions. The procedure is analogous to a stratified random sampling in which the strata are defined on the basis of the results. This sampling method makes it possible to improve the accuracy by measuring more houses in zones in which the concentrations are higher.

Results

Using the procedure described above we have constructed a distribution estimate for the concentrations in detached houses. When the dwellings in multi-family houses are taken into account, we have had to base our estimates on measurements in only 142 dwellings in 15 towns. Thus, our present estimate of the mean indoor radon concentration in Finland, 90 Bq/m^3, is still subject to revision.

According to the present data, it is estimated that the percentages of dwellings exceeding 200, 400, 800 and 2,000 Bq/m^3 are 11, 3.9, 1.4, and 0.5 per cent, respectively. There may also be concentrations exceeding 4,000 Bq/m^3 in 0.01 - 0.1 per cent of the dwellings. The scarcity of data for multi-family houses does not disturb these estimates too much because most concentrations higher than 200 Bq/m^3 are found in detached houses.

The geographical distribution is shown on a map which is updated by adding new localities or by changing the results for previous ones, if necessary. The latest updated map is shown in Figure 3. A more detailed study of the geographical distribution in a high-radon area was made in nine municipalities in the winter 1984-85 (Castrén et al.,1985). A second study, consisting of more than 3,000 houses in 32 municipalities will be completed in 1986.

Reasons for high concentrations

The main parameters determining the indoor radon concentration in detached houses are the effective radium concentration (product of the radium concentration and the emanation factor) and the permeability of the ground. The effects of other factors are not so easy to ascertain from the existing data.

The geographical distribution of the external gamma background (Figure 4) shows some correlation with the indoor radon measurements.

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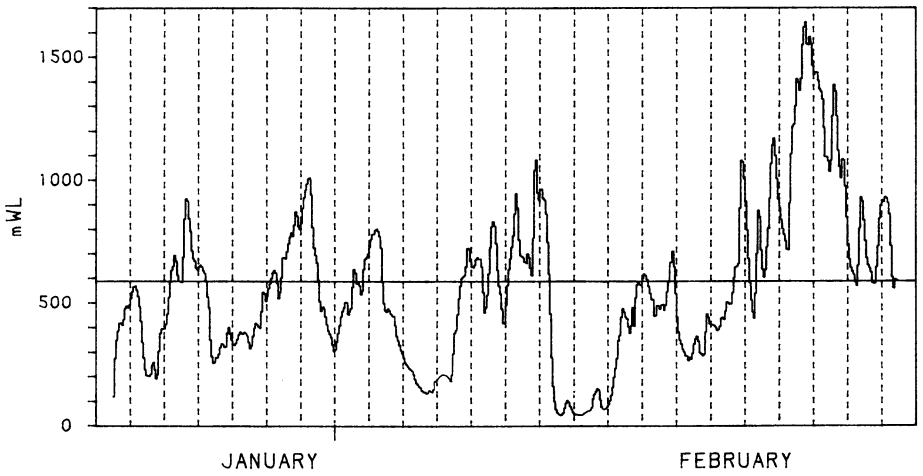

Figure 1. Variations in the hourly mean alpha-energy concentration during an integrating radon gas measurement of three weeks. The alpha-energy concentration calculated from the radon level (4860 Bq/m^3) and the typical equilibrium factor (0.45) is also given.

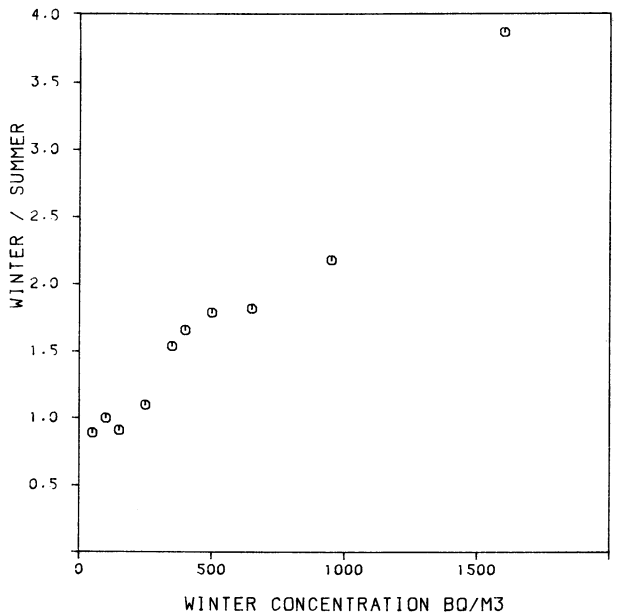

Figure 2. The measured winter-summer concentration ratios in 250 detached houses (Winqvist, 1984). The houses have been divided into ten classes (at least 20 dwellings in each class) according to winter concentration. Class boundaries are 0, 90, 160, 240, 350, 400, 500, 600, 800, 1200 and 2000 Bq/m^3.

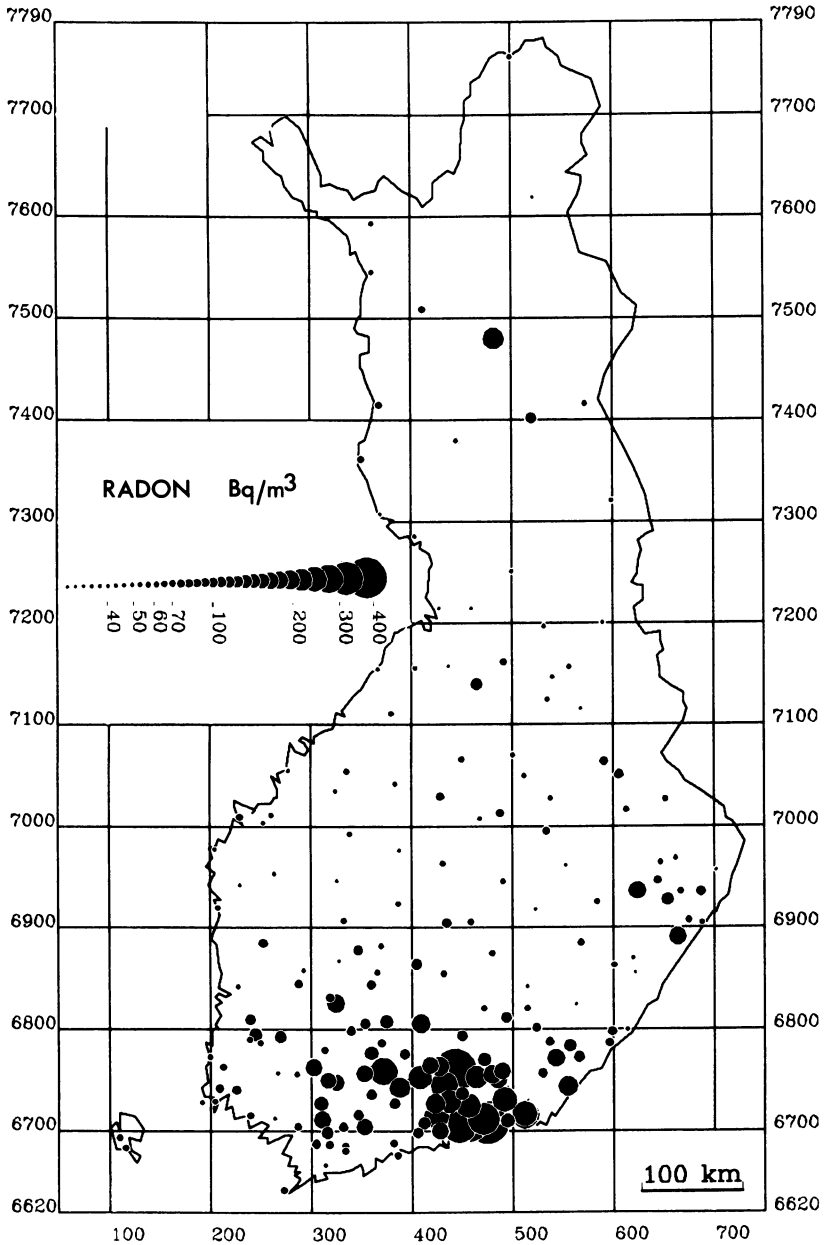

Figure 3. Radon concentration in the indoor air of detached houses. The size of the symbol indicates the magnitude of the local geometric mean. Measurements have been made in about 4,450 houses in 183 localities.

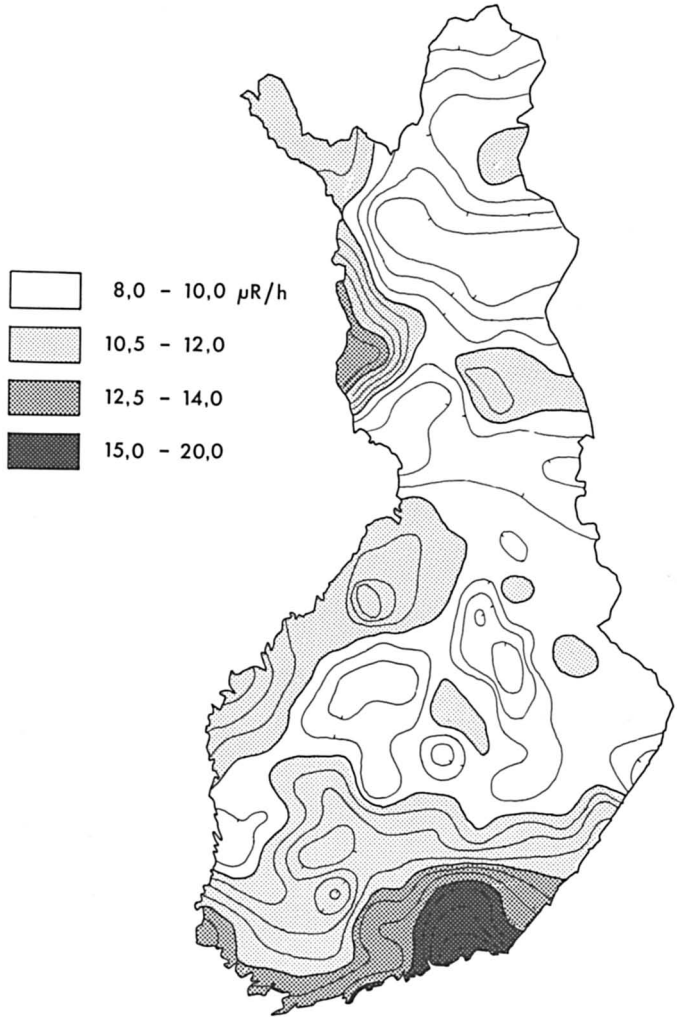

Figure 4. The distribution of the external gamma dose rate from measurements on Finnish roads (Lemmelä, 1984).

The same is true of the geographical distribution of the uranium concentration in glacial till, the most common soil type in Finland (Geological Survey of Finland, 1985). The sometimes very large effect of ground permeability is the main reason that the details of the radon concentration distribution differ from the distribution of other radiation parameters.

There is a very large seasonal variation in the houses with the highest concentrations. The appreciably higher concentrations in winter in these houses cannot be explained by lower ventilation rates. The ventilation rate in many such houses tends to be higher in winter. Therefore, the soil air influx caused by the stack effect in winter must be so much larger than it is in the summer that it overrides the effects of the higher ventilation rates. In general, the temporal and local concentration variations in this type of house are very large, and instantaneous values several times higher than the annual average can be measured. Theoretical models of the temporal variation of radon concentration in Finnish houses have also been developed in our laboratory (Arvela and Winqvist, 1986).

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