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TRACING AND DEALING WITH DWELLINGS WITH HIGH RADON AND RADON DAUGHTER CONCENTRATIONS

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Introduction

About a year ago the mass media gave publicity to the measurements being made by the National Institute of Radiation Protection in some single-family houses in a municipality in southern Sweden. The houses had been built on tailings from alum shale workings. Alum shale has been used as a raw material in Sweden since the sixteenth century. The radon and radon daughter concentrations found were considerable and for several months the fact that the carcinogenic gas radon was to be found in ordinary dwellings made headline news on the front pages of the newspapers and in radio and television programmes.

At about the same time that the matter became public, the Swedish government appointed a commission which was given the primary task of developing recommendations for tracing houses with unacceptable levels of radon daughters and developing a program for the investigations which were deemed necessary as a basis for the continued work on definite limiting levels.

The report issued by the commission proposes provisional limiting values for radon daughter exposures, for gamma radiation from the ground and for the concentrations of radioactive materials in building materials.

This report is largely based on the report issued by the Radon Commission. The proposals of the Commission and the provisional limiting values will be the subject of a debate in the Riksdag, the Swedish parliament, during the spring of 1980.

As early as in the 1950s an investigation was made into the radiation conditions in Swedish dwellings. It was found then that certain building materials, in particular aerated concrete based on alum shale, could give rise to higher radiation doses than did other materials. Thus there was at that time an awareness of the risks resulting from high radon levels although the risks were regarded as small since the ventilation in the dwellings was in general good. In connection with the energy crisis at the beginning of the 1970s, the National Institute of Radiation Protection pointed out the risks involved in excessive sealing of dwellings to save energy since this reduced the air circulation rate. This applied above all to dwellings built of alum shale based aerated concrete.

Alum shale occurs in many places in Sweden (Fig.1) and it has been exploited since the sixteenth century. The first application was for the dying of textiles and later it was used for lime-burning. It has also been used as a source of oil and it is at present the subject of an inquiry as a possible future source of uranium. Its uranium content is about 200 grams per tonne.

The tailings from the shale workings have been dumped in large heaps which exist here and there in many areas, mainly in Southern Sweden.

It was in connection with a housing area which had been planned on one of these tailings piles that this problem came to light and the National Institute of Radiation Protection advised that the plans should not be fulfilled in the manner proposed. However, it was then found that dwellings already existed on similar sites and it was therefore decided that some of these dwellings should be investigated.

In 1978 the National Institute of Radiation Protection asked the government to appoint a special commission to determine the extent of the problem of radon and radon daughters in dwellings. This commission was appointed in March 1979. The proposals of the commission were evolved in cooperation with the competent authority responsible and with other experts. The ingress to the memorandum issued by the commission includes the following passage:

> "Investigation into counter-measures against radiation risks in buildings etc. shall evolve, with the highest priority in accordance with our directives and in cooperation with the agencies concerned, a program for the investigations which are deemed necessary in order to determine the radiation levels in existing buildings."

It is also stated that:

> "In this memorandum a programme is proposed for tracing and reducing the risks for radiation from radioactive substances in the existing buildings."

In order to deal with unacceptably high health hazards as quickly as possible in certain Swedish dwellings and in the absence of further data, provisional limiting values intended to apply for a five-year period have been proposed. At the end of that period it is considered that there should be a sufficient basis of data concerning the extent of the radon problem and the consequences of lower limiting values in the future.

The main aims of the provisional limiting values are as follows:

a) To prevent the erection of buildings on ground containing large quantities of radioactive substances.

b) To prevent the use in new buildings of materials with unnecessarily high contents of radioactive substances.

c) To reduce the health hazards in existing buildings.

Provisional limiting values for the ground used for new building

With regard to gamma-radiation from the ground a provisional limiting value of 100 μR/h has been proposed. This value gives an effective dose equivalent of approximately 1 mSv/year for persons who spend 20 per cent of their time out-of-doors. The value was chosen in order to limit the risk from gamma radiation out-of-doors and also to limit the amount of radon exhaled from the ground which finds its way into buildings.

The proposal is to advise against the construction of any building when the gamma radiation exceeds 100 μR/h. This value, which includes the cosmic radiation, shall be measured above the ground surface. Further, a provisional investigatory range of 30 - 100 μR/h is proposed, the measurement in this case being made at the depth of the foundations. Within this range the radon exhalation shall be measured and recommendations regarding building work be issued.

Provisional limiting values for building materials for new buildings

For new buildings it is proposed that the quantities of radioactive substances in building materials be limited by means of limiting values for the gamma index and the radium index.

These are calculated as follows:

$$m_\gamma = C_K/10000 + C_{Ra}/1000 + C_{Th}/700$$

$$m_{Ra} = C_{Ra}/200$$

where C_K, C_{Ra} and C_{Th} are the concentrations of potassium, radium and thorium respectively in Bq/kg.

It is proposed that the provisional limiting values are that the gamma index and the radium index be less than 1.

These limiting values imply that the annual radiation dose is limited to approximately 2 mSv/year from gamma radiation and to approximately 10 mSv/year (70 Bq/m^3) from radon daughters for an air exchange rate of 0.5 per hour.

Figure 2 shows the gamma index and Figure 3 the radium index for various building materials.

Since aerated concrete based on alum shale is no longer manufactured in Sweden it is anticipated that all building materials on the market will be acceptable with these limiting values.

Provisional limiting action levels for existing buildings

For a long time the majority of Swedish dwellings will consist of buildings which already exist now.

The provisional limiting values proposed for these buildings only concern the radon daughter concentrations. It is true that high gamma radiation levels have been found, but the highest doses from gamma radiation known to exist during the course of the investigation (approaching 4 mSv/year) were not considered to involve such risks that any action was justified. Later measurements, however, have shown that gamma radiation dose-rates of up to about 6 mSv/year exist. In its forthcoming work the Radon Commission will have to decide what attitude to adopt with regard to these dose-rates.

However, the radon daughter concentrations in dwellings constitute a greater hazard than the gamma radiation and there are various methods which can be adopted to reduce them.

In making the choice of provisional limiting value, particular attention was paid to the risk involved in continuing with high radon daughter concentrations and thus to how quickly action should be taken.

As a provisional limiting value it is proposed that no-one should be exposed to more than 2000 Bq year/m^3 during the provisional period of five years. This implies, for instance, that action shall be taken to improve dwellings with radon daughter concentrations of 1000 Bq/m^3 (0.27 WL) within 2 years and dwellings with concentrations of 400 Bq/m^3 (0.10 WL) within 5 years.

It is estimated that the number of dwellings where the radon source is the building material and which would have to be improved in accordance with this scheme is between 3000 and 15000 and that the number of dwellings on radioactive ground is between 200 and 2000.

Principles established for the tracing and checking of houses with high radon daughter concentrations

One of the greatest problems is tracing the houses with excessive radon daughter concentrations. Since the radon daughter level is dependent on several factors, simple methods and rules of thumb can only be used for an initial rough identification of the houses likely to justify further investigation with more sophisticated methods of measurement combined with knowledge of the various sources of radon and the air exchange rates.

Radon in dwellings can originate from the building materials, from the ground and from the water supply. The radon from one, or possibly from several, of these sources gives rise to a definite radon daughter concentration indoors for a particular air exchange rate. This air exchange rate is determined by the ventilation system and by the meteorological conditions. Multi-family houses are usually fitted with fan ventilation systems and in such cases the meteorological conditions have little effect on the air exchange rate. Single-family houses, on the other hand, often have only natural draught ventilation and this is greatly affected by meteorological conditions. The air-tightness of the house is also a very significant factor.

The main principle in the tracing work is the successive elimination of houses in which the radon daughter concentrations are low. Tracing and checking must therefore be carried out in several stages in which the testing methods are suited to the accuracy requirements, the number of houses, available time and the costs involved. The local health authorities have the responsibility for organizing the tracing work.

In the first stage of the tracing work, information from municipal and general sources is used for a general assessment of buildings and of the ground in relevant areas. A large proportion of the dwellings can be eliminated in this stage of the tracing operation.

In the next stage, using active tracing with such methods as gamma radiation measurements from cars, questionnaires to households and study of the relevant geological conditions, the houses which in all probability have low radon daughter concentrations can be eliminated.

The next stage is to make a simple check on the houses which there is reason to believe may have higher than normal radon daughter concentrations. This can be done either with alpha sensitive track film or - in areas in which the ground and the water have not particularly high radon concentrations - with gamma measurements combined with inspection of the ventilation systems. If this first simple check indicates that there may be a risk for high radon daughter concentrations, more sophisticated methods can be used to determine the true exposures.

A summary of the methods which can be used is given below:

1. <u>Measurement of gamma radiation from a car</u>

   A measurement of the total gamma radiation determines whether the building materials is unusually radioactive. This measurement is made from a car at a distance of up to 20 - 25 meters from the house. All houses found to have enhanced gamma radiation are further checked with hand instruments to provide data on the proportions of radioactive building materials. This method is most suitable in densely populated areas.

2. <u>Measurement of gamma radiation with hand instruments</u>

   This method is most suitable in sparsely populated areas.

3. <u>Integrated measurements of radon and radon daughter concentrations using alpha-sensitive film</u>

   Alpha-sensitive film (track etch film) is exposed for three months in a dwelling. The measurements so far made with this method show large systematic uncertainties. The method can nevertheless be used as a basis for a decision concerning further checking.

4. <u>Radon daughter measurements using filters</u>

   One or more filter samples are taken in the dwelling and the radon daughter concentration is calculated - for example using Kusnetz's method. The disadvantage of this type of measurement is that it only provides an instantaneous value and it is therefore necessary to ensure that certain conditions are fulfilled with regard to the ventilation each time a measurement is made 296

5. Measurement of the radon concentration using a passive measuring device

The principle underlying these measurements is that radon diffuses into a measurement chamber in which there is a strong electrical field. The alpha decays are recorded by a thermoluminescent (TL) dosimeter. The National Institute of Radiation Protection has produced a number of radon measuring devices of this type for use in a research project. At present there are not enough of these devices available to allow them to be used in the dwelling-tracing work but there are proposals for producing larger numbers. These would be used principally in the cases in which it had been difficult to determine with other methods whether the mean exposure rate was above or below the proposed provisional limiting values.

Subsequent to the measurements, it is possible to judge whether the radon and radon daughter concentrations constitute a so-called sanitary nuisance, in other words whether a dwelling has radon daughter concentrations above the limiting value,in which case the local health authorities can recommend or prescribe various measures. As a rule these will consist of improvements in the ventilation system although other measures,for instance replacement of the filling material around a house,are conceivable depending on the source of the radon. The Radon Commission has proposed that the Swedish State should accept some responsibility for the costs involved, in the form of loans or grants.

Any corrective measures used should of course have the aim of reducing the radon daughter concentration as much as possible but in the case of major rebuilding operations requiring building permits the Radon Commission has proposed that an upper limit of 200 Bq/m^3 should be applied.

When corrective measures have been applied, the effectiveness of the measures should be checked by means of new measurements.

Figure 1. The occurrence of alum shale in Sweden.

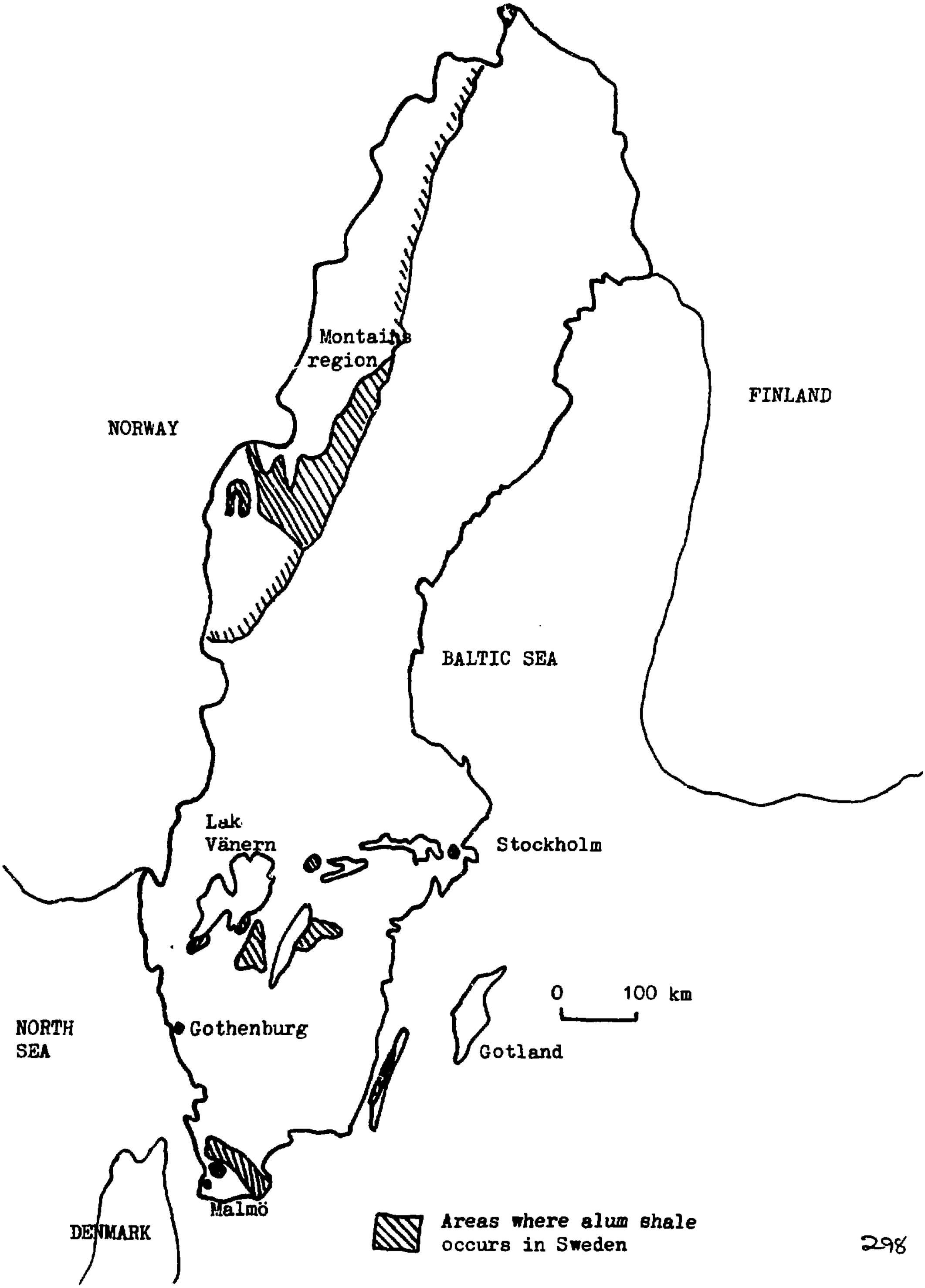

Figure 2. Gamma index for various building materials. The figure also shows the approximative value of the annual radiation dose to the gonads in the hypothetical case that all parts of a house were made of the building material in question.

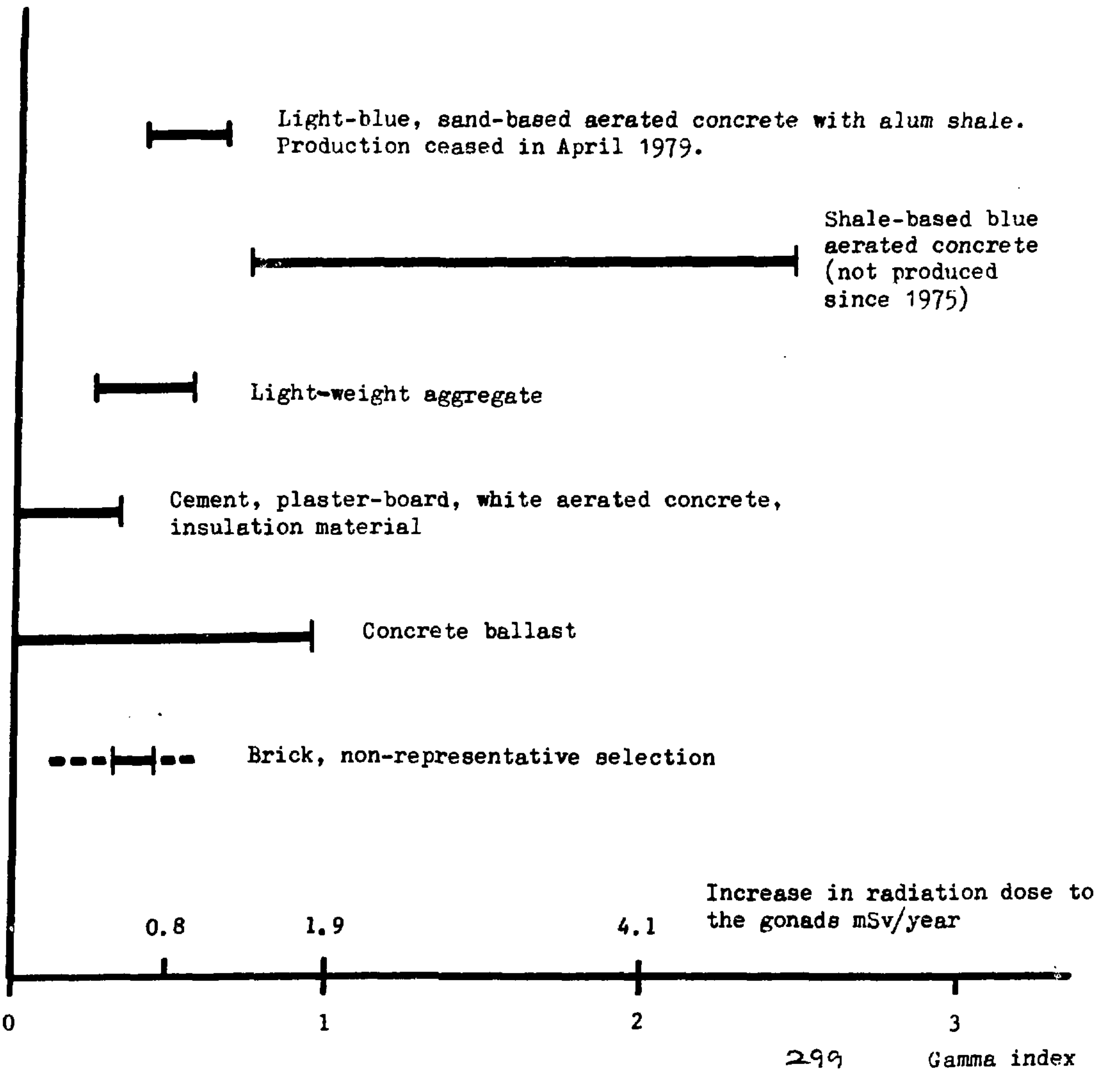

Figure 3. Radium index for various building materials. The figure shows the approximative values for the radon daughter concentration (working level ratio) corresponding to 0.5 air changes per hour. It is assumed that all parts of the house are made of the material in question.