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RADON IN THE HUMAN ENVIRONMENT - A STUDY IN "HIGH RADON AREAS" IN THE FEDERAL REPUBLIC OF GERMANY

by

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The main source of high radon concentration indoors is the exhalation of radon from the soil and the soil water. In the western part of Germany, two interesting regions, the so called "Eifel" and "Hunsrück", were selected for these radon investigations. A special method of electrostatic deposition of the first radon daughter (Polonium-218-ion) on a surface barrier detector and subsequent analysis of the measured alpha spectra allows to determine the concentration, diffusion and exhalation rate of radon from the soil, building materials and in dwellings with high accuracy. Different methods of reducing radon entry from the soil into houses were discussed and the results of a house reconstruction by sealing the ground slab with polyurethane and removing the air under the ground slab by suction were presented.

INTRODUCTION

The soil and the ground water are generally the decisive sources for high radon concentrations indoors. The average radon contribution of building materials to indoor concentrations was determined to be about 30 Bq/m^3 (1,2) and could be neglected in "high radon areas". It is unpractible to determine the indoor radon concentration in each house of the country, therefore criteria have to be found to identify special radon areas. Two different geological territories "Döttingen/Eifel" and "Ellweiler/Hunsrück" were chosen to investigate the influencing parameters and the reasons for high radon values in dwellings. In these regions instructions and measures for reducing radon entry in houses should be recommended before the construction of new buildings. At this time the actions against entry are more effective and cheaper than for existing houses.

EXPERIMENTAL METHODS

Radon-222-concentrations indoors were measured by different methods. In the village of Döttingen passive time integration radon dosemeters had been distributed to about half of all dwellings during three winter months in 1988. A dosemeter contains a polycarbonate detector foil at the bottom of the plastic diffusion chamber. It is closed by a hydrophobic fiberglass filter and consequently only radon gas diffuses into the sensitive volume. The emitting alpha particles cause tracks in the foil during the time of exposure. After electrochemical etching the radon concentration could be calculated from the track density.
In the village of Ellweiler charcoal radon dosemeters were exposed in more than half of all the houses during three days in february 1989. 70 g charcoal in a metallic box absorbed the radon gas. Taking into consideration a correlation factor for humidity and exact calibration factors, the resulting radon concentration indoors could be determined by subsequent gamma spectroscopy with sufficient accuracy.
Radon concentrations were also determined by point and continuous measurements. These measuring devices involved collecting air inside a metallic sphere and electrostatic deposition of the Polonium-218-ion onto a negatively charged surface barrier detector. The radon concentration was determined by subsequent alpha spectroscopy.
A modified arrangement with smaller spheres was used to determine the radon concentration in soil air (see Figure 1).

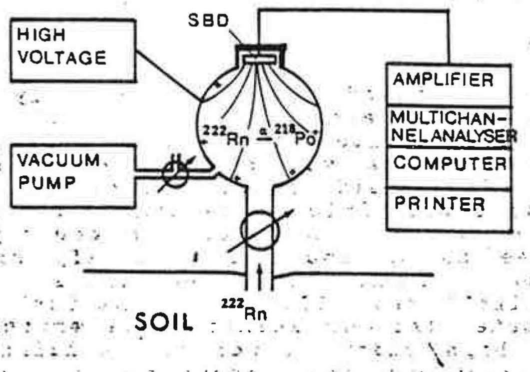

Figure 1: Measuring arrangement for the determination of radon potential of the soil (SBD: Surface Barrier Det.)

The radon exhalation rate was measured in a similar way. The exhaled radon gas from the soil passes through an insulated intermediate area and reaches the measuring chamber consisting of a metallic hemisphere with a metallic grid at its bottom. The exhalation rate was determined in several successive measuring cycles from the increase of pulse rates (3).

RESULTS

The village Döttingen is located in the "Rhenish Schiefergebirge" in an area with silt- and sandstone of low uranium content (less than 2 ppm). Three radon dosemeters were exposed in each examined house, respectively one in a cellar-, sleeping- and living room. Figure 2 shows the results of the measurements of radon concentration indoors and additionally some typical values of the radon potential in the ground.

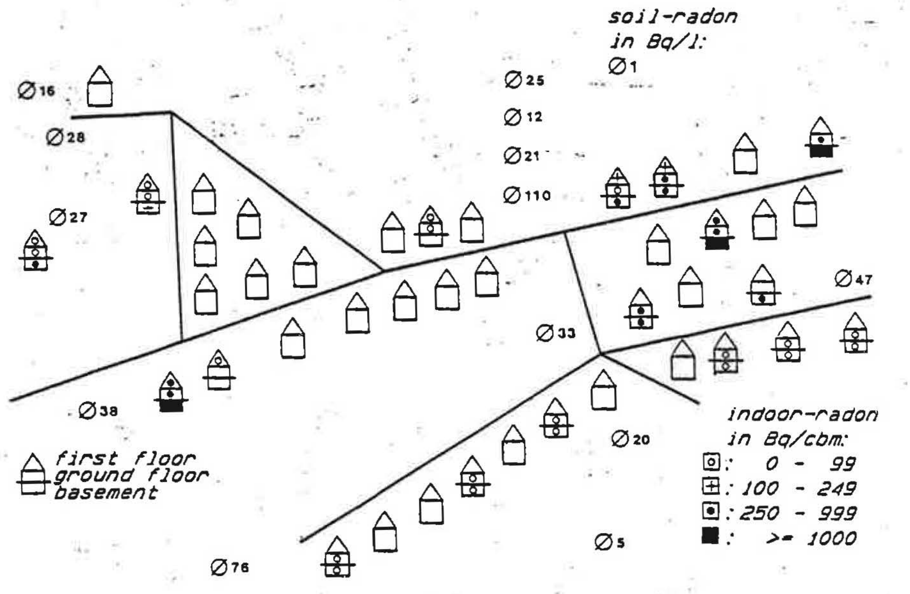

Figure 2: Radon-222-concentration indoors in Bq/m³ and soil radon in Bq/l in Döttingen/Eifel

Nearly half of the houses in Döttingen were constructed in the last twenty years and normal radon concentrations with less than 100 Bq/m³ were found in these modern buildings. The older houses are situated along the main road and showed higher radon values. Approximately a quarter of all houses are very old buildings and radon concentrations indoors up to 1000 Bq/m³ were measured. The radon potential in the soil varied between 5 and 110

Bq/l. The radon exhalation rates from the ground was determined to be in a range of 1 to 20 mBq/m²·s¹ in this region. The maximum values of indoor radon concentration, radon potential and exhalation rate were always found near the main road of Döttingen. From geological point of view postvolcanic tectonic fractures exist in the direction of this road.

The village Ellweiler is located at the border of Hunsrück in an area with deposit of feldspar and porphyry with high uranium content of the soil. A former uranium pit named "Bühlskopf" is located only 200 m north of the village. Uranium ores with a maximum uraniumoxid content of 0.2 % were exploited from this pit until 1975. The results of the measurements of radon concentration indoors with charcoal dosemeters and some values of the radon potential in the ground are shown in figure 3.

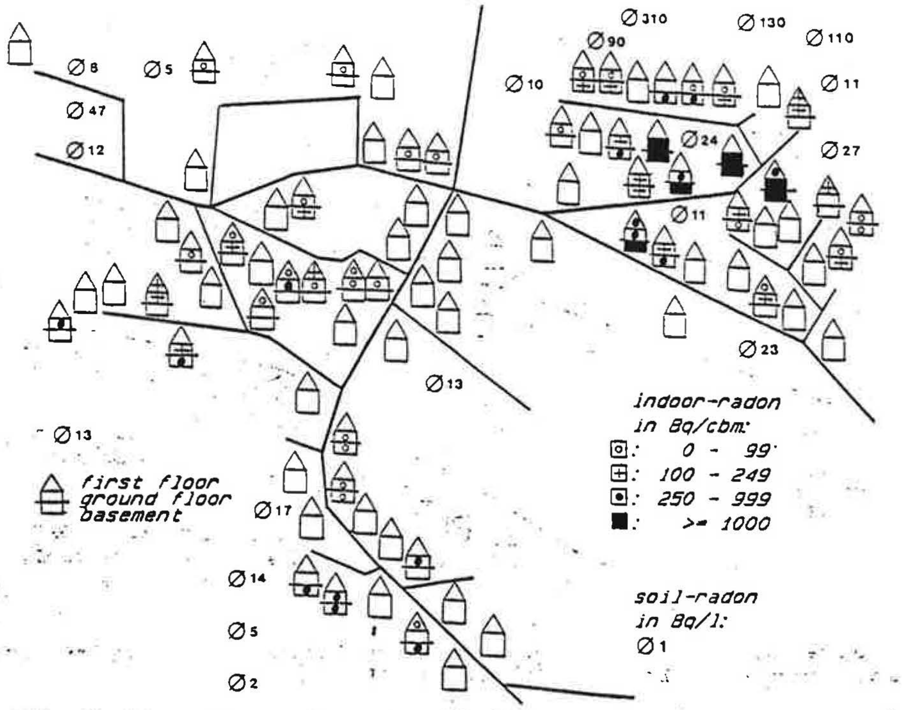

Figure 3: Radon-222-concentration indoors in Bq/m³ and soil radon in Bq/l in Ellweiler/Hunsrück

In Ellweiler normal radon concentrations of less than 100 Bq/m³ were found only in 20% of the dwellings, whereas 50% of the houses showed radon values between

100 and 250 Bq/m³. The latter figure represents the German reference values for radon concentration indoors, the so called "upper limit of the normal range". In 20% of the houses radon concentrations between 250 and 1000 Bq/m³ were measured and still 10 % of the dwellings in Ellweiler showed very high radon values above 1000 Bq/m³.
The outdoor radon concentrations vary from 20 to 50 Bq/m³ with maximum values up to 150 Bq/m³. In Ellweiler the radon potentials of the soil were determined between 2 and 310 Bq/l with large local variations. The measurements of the radon exhalation from the ground in this area yielded rates of 2 to 100 mBq/m²·s. The maximum values were always found on the southern slope of the "uranium hill", where possibly uranium ore lodes are existing.
The largest concentrations (35 kBq/m³ in a cellar room, 8 kBq/m³ in a sleeping room and 4 kBq/m³ in a living room) were determined in a house which was constructed at this part of the village in the year 1976. The radon gas from the soil entered the house via a small cellar deep in the ground. In this cellar the former massive concrete plate had been removed and after excavation a new plate had been constructed on a 0.7 m lower level without connection to the walls or the foundations. Up to 2 cm wide fissures and cracks allowed an easy radon entrance from the ground into the house. In this cellar room mitigation methods as plastic sealing and subsoil ventilation were tested. The fissures between wall, foundation and floor slab were widened and filled with polyurethane (PU) resins. Then the floor was covered with a 4 mm thick PU layer and also the cellar walls with a PU layer of 1 mm thickness. For vertical sealing of the walls a special method of high pressure packing with PU was used. The radon concentrations in the unventilated cellar decreased by a factor of about ten after these mitigation measures. Additionally a ventilation system was installed for sucking off the subsoil air. This measure reduced the room values once more by a factor of about five. After these mitigation measures the radon concentrations in this house only amounted to values of some percent of the former concentrations. In this case the radon entry points could be identified unequivocal and also the performance of the measures was simple, so the success of these mitigation measures can't be generalized.

CONCLUSIONS

The inhalation of short lived Radon-222 and Radon-220 daughters represents the largest contribution to the natural radiation exposure of the human population. Based on the UNSCEAR (4) dose conversion factor with an annual breathing volume of 5475 m³ indoors and an average equilibrium factor of 0.4, a Radon-222 concentration indoors of 2000 Bq/m³ yields an annual effective dose equivalent of about 50 mSv. Several

epidemiological studies from uranium miners (5) and other underground miners point out that the lung cancer risk is increasing at these radiation doses. From the view of radiation protection for the human population the knowledge and the exploration of "high radon areas" has a fundamental importance.
The radon potential of the soil is the decisive factor in such "high radon area". The results of these investigations point out that generally two parameters are responsible for the magnitude of the radon potential of the soil, firstly if the uranium-radium content of the ground is high and secondly if fast transport of radon through the soil (6) with water or gas is possible. For this reason a low ground water level is also an allusion to an eventual high radon concentration in the soil as well as tectonic fractures or geological anomalies.

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