Search of small radon-prone hot spots in unaffected areas on geological basis

Isabelle Gerardy[1] *(gerardy@isib.be)*, François Tondeur[1], Michel Berlanger[2], Marie-Françoise Dony[3]

1) Institut Supérieur Industriel de Bruxelles, Nuclear Unit, Brussels, Belgium
2) Institut Supérieur Industriel de la Communauté Française, Mons, Belgium
3) Institut Supérieur Industriel de la Province du Hainaut, Charleroi, Belgium

1 Purpose

Screening indoor radon measurement campaigns have allowed, in Belgium as in many other countries, to identify the main affected areas [Zh01]. On this basis, the northern part of the Walloon region, between the Haine-Sambre-Meuse line and the language border, is considered as an unaffected area. From the geological point of view, this zone is characterised by the presence of Mesozoic limestone, and Cainozoic sand or clay, sometimes covered by recent loess deposits. However, the geological map shows the presence of small areas with outcrops of older rocks. If these areas have a higher radon potential than the rest of the region, they might well remain unknown after the low-density screening campaign, because of the low probability of choosing a house in these areas in a random selection.
We have begun a series of measurement campaigns focused on these small areas. The purpose of this communication is to report on the results already obtained in two provinces: Hainaut and Walloon Brabant.

2 Methods and materials

On the basis of the geological map, areas with possible outcrop of Palaeozoic rocks from Cambrian to lower Carboniferous have been located. Volunteers for indoor radon measurements have been recruited in these areas by different means: distribution of a folder in the mail boxes (nearly 35000), telephone call, recruitment by the local authority. Two measurement campaigns have been organised till now: the first one in the Province of Walloon Brabant in 1999, the second one in the province of Hainaut in from late 2001 till early 2003. More than 1000 houses have been examined.

We have performed short-term measurements with charcoal canisters [Co86] exposed 3 to 4 days in semi-confined conditions (no opening of the windows) in the period from October to May. Usually, two measurements are done, one for a living area of the ground floor, the other for the basement if it exists. The measurement is done in the laboratory of ISIB by gamma spectrometry with a 3" NaI(Tl) detector.
For each selected area, the measurements are compared to controls obtained in the same province in areas with a Cainozoic geological context. Because of the limited number of measurements in each selected area, several indicators are used to find the possible anomalies, several of them also taking into account the data obtained in basements. The first indicator is the percentage of ground floor concentrations higher than the reference value of 400 Bq/m^3. We have shown [Ge02] that the usual criterion defining an affected area (more than 1% of long-term measurements above 400 Bq/m^3) can be extended to short-term measurements of 3-4 day by changing the percentage to 5%. The second indicator is the geometrical mean concentration for each area. As shown in [Ge02], under certain simplifying assumptions, a value higher than 67 Bq/m^3 is expected in affected areas. As a third indicator, we use the percentage of cases above 150 Bq/m^3 for the ground floor or 400 Bq/m^3 for the basement: more than 25% is considered as an anomaly. The fourth indicator is similar: more than 10% of cases above 400 Bq/m^3 in the ground floor or 1000 Bq/m^3 in the basement is seen as anomalous. A fifth indicator is the presence of very high concentrations (more than 1000 Bq/m^3 in the ground floor or more than 2500 Bq/m^3 in the basement).
In a few cases, only a part of the selected area presents indices of radon problems. In order to avoid an artificial grouping of affected houses, the subdivision of the area has only been done when supported by a difference in the geological context or a clear geographical separation.

3 Results

3.1 Results in Walloon Brabant

The results obtained in the province of Walloon Brabant have been presented in detail elsewhere [To01] and will only be summarised here.
Three areas have been selected in Walloon Brabant, corresponding to parts of the basins of three rivers: Senne, Dyle, and Gette. Palaeozoic rocks typically outcrop on a few hundred meters on both sides of the rivers, on the lower part of the valley edges. The age of the rocks extends from lower Cambrian to middle Ordovician. We

estimate that the three areas together include between 20000 and 30000 homes. No significant radon problem was found on lower Devonian formations present in the Gette and Senne basins, as well as a part of the Dyle basin. Most of the critical cases are associated with the Mousty formation (middle to upper Cambrian black shales), and a significant risk is still found on lower Ordovician.
In this area, values as high as 6300 Bq/m^3 (ground floor) and 25000 Bq/m^3 (basement) have been observed, and the geometrical mean is higher than 100 Bq/m^3 in most parts of the affected area.
A map of the affected area in the Dyle basin has been drawn on the basis of the geological map. It has been included in an information booklet edited by he provincial administration and sent by mail to all families (approximately 10000) living in the area. Despite the recommendation to proceed to radon measurements in each home, probably not more than 50 radon tests were asked following this information.

3.2 Results in Hainaut

The areas to be studied in Hainaut are smaller than in Walloon Brabant but their number is higher. Palaeozoic outcrops are a bit younger, from Silurian to Carboniferous. The upper Carboniferous is mostly present in Charleroi, where it was rather well sampled by previous studies, with no sign of radon problems, so it was discarded in the present study.
Areas in 20 communes have been selected from the geological map. In four communes, very significant cases of radon pollution have been discovered, and it was possible to draw the limits of four affected areas. Other areas show more scattered problems, that might deserve further study but probably cannot be considered as affected areas, and several areas apparently show no problem at all. The discussion will be focused here on the four affected areas: Basècles/Blaton/Quevaucamps (communes of Beloeil and Bernissart), Ecaussines, Casteau and Horrues (the last two in the commune of Soignies).
As a general rule, the affected areas only represent a part of the area selected on a geological basis. This may sometimes be related to the high variability of the local geological context, as in Ecaussines and Horrues. In the two other cases, the presence of a loess cover not represented on the geological maps may explain the absence of indoor radon problems in some parts of the selected area.

Except in Horrues, the affected areas are associated to lower Carboniferous formations (Tournaisian and Visean). In Horrues, only the Silurian formations give strong radon problems, and no significant anomaly is observed on Devonian.

Table 1 Main statistical results for the four radon-affected areas Column 3: geometrical mean in Bq/m^3. Columns 4,5,6 : percentages respectively of (4) ground floor values above 400 Bq/m^3, (5) cases with ground floor concentration above 400 Bq/m^3 or basement concentration above 1000 Bq/m^3, (6) the same as (5) but with thresholds 150 and 400 Bq/m^3 . Last column: maximum concentration observed in a ground floor and a basement.

Affected area	Number of cases	Geo. mean	% gr.fl. >400	% > 400/1000	% > 150/400	Maximum Gr.fl./basem.
Horrues	6	141	33	50	83	885 / 8920
Casteau	9	269	44	56	67	2830 / 13200
Ecaussines	20	69	5	25	40	1630 / 1690
Bl/Ba/Qu	38	69	10	21	34	1020 / 5570

The affected areas of Horrues and Casteau are very small hot spots, probably including not much more than 100 houses or perhaps less, which explains the small number of cases. The two other affected areas are more extended, though still smaller than the affected area of Walloon Brabant.

4 Discussion

This study shows that a detailed knowledge of the local geology is essential for an accurate evaluation of the indoor radon risk. The general screening campaign organised by the Ministry of Health from 1995 to 1999 , that only included 588 houses in the province of Hainaut (for 1.3 million inhabitants) and 154 houses in Walloon Brabant (0.35 million) provided a reasonable overview of the most common situations in those provinces, but missed completely the small affected areas revealed by the present work [Zh01].
Some associations between radon and a given geological formation are not unexpected. In particular, the affected area on the Mousty formation is associated to Revinian black shales in which Uranium anomalies have been observed in another region [Ch91] (42 ppm U vs. a typical average of 3 ppm in the earth crust). U-anomalies have also been noted in Visean calcareous rocks close to Visé [He79] . Tournaisian and Visean rocks have been and are still exploited as building materials. Several active or closed stone-quarries are scattered within the two main affected areas discovered by our study in Hainaut (Basècles / Blaton / Quevaucamps and Ecaussines).

To what extent they may have influenced the radon risk (by creating or enlarging faults, or by damages to the houses, …) still has to be studied.
Geological contexts similar to those associated to radon in our results can also be found in the Northern parts of two other provinces (Namur and Liège) , to which the present study should be extended in the future.

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INVESTIGATION AND REDUCTION OF PERSONNEL RADON EXPOSURE LEVELS IN BAVARIAN WATER SUPPLY FACILITIES

Markus Trautmannsheimer, Simone Körner
(Markus.Trautmannsheimer@lfu.bayern.de)

Bavarian Environmental Protection Agency,
D-86177 Augsburg, Germany

1 Purpose

Exposure to radon is normally the main contributory factor to the annual effective radiation dose of the population. Apart from the level of radon exposure in housing, there are some work places where increased exposure can be expected. Especially high radon activity concentrations have been measured in mines, visitor caves,