Stimulating radon safe building in radon prone areas by detailed scale radon hazard mapping

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ABSTRACT

Radon is responsible for more than thirty percent of the radiation exposure of the Belgian population. In order to reduce the exposure to radon, the Federal Agency for Nuclear Control (FANC) has developed a radon action plan. The objectives of the action plan are to eliminate the high existing exposure situations in public buildings, workplaces and dwellings, and to limit exposures in new buildings. Radon-safe building techniques include the application of an anti-radon barrier at the soil-slab interface and of an underlying permeable layer that can be actively or passively ventilated. A tool for decision-making, raising public awareness and aiding local governments to establish a radon safe building culture is the development of detailed scale radon hazard maps showing municipality scale variations in the geogenic radon hazard. Indoor and soil gas measurements and information on the sub-surface are used to optimise the radon hazard maps and to assess the potential radon risk in building extension zones on the scale of the municipalities. The characterisation of the building extension zones in terms of radon hazard increases the efficiency of radon reducing policies.

KEYWORDS

Radon hazard, radon mapping, radon prone areas, radon safe building

INTRODUCTION

Radon is the most prevailing source of radiation exposure in the indoor environment (ICRP 60). The link between radon and lung cancer has been first recognised through miner cohort epidemiological studies (BEIR IV; BEIR VI; UNSCEAR). More recent case-control studies highlight the linear no-threshold relation between lung cancer risk and indoor radon-concentration in dwellings (Darby et al., 2005). In order to efficiently manage the radon exposure, most European countries have adopted a radon action plan, setting out the criteria, strategies and practical aspects of radon controlling activities. The Belgian radiation protection regulation (ARBIS) foresees the control of radon exposure in workplaces and in dwellings in radon prone areas. A national radon measurement campaign during the nineties highlighted the occurrence of radon prone areas in the southern part of the country (Poffijn and Vanmarcke; Zhu et al.). Ongoing indoor radon measurements allowed assessing the radon exposure of the Belgian population (Table 1). Radon safe building in the radon prone areas is essential to significantly reduce the collective exposure to radon in the course of house stock renewal. Radon mitigation is stimulated in the radon prone areas in buildings where high radon concentrations have been measured. Increasing public awareness is achieved through information sessions for the general population and training courses for building professionals. An important tool to stimulate new builders and architects to use radon safe building techniques is the use of municipality-scale radon hazard maps indicating the geogenic hazard for indoor radon problems on the scale of the municipality. The compilation of these radon hazard maps is discussed in this paper.

Table 1:Statistics for the indoor radon exposure in Belgium.

	Population	Number of measurements	GM	AM	< 200	200-399	400-799	800 and more
Belgium	10502213	10447	59	57	97,8%	1,7%	0,4%	0,1%
Wallonia	3413978	10108	84	82	95,6%	3,2%	0,9%	0,3%
High-risk areas	376568	5605	137	169	67%	19,9%	8,8%	4,3%
Flanders	7088235	339	44	34	99,2%	0,8%	-	-

(GM: geometric mean; AM: arithmetic mean; all radon values in Bq/m³)

METHODS

Long-term (3 months) indoor radon measurements by solid state nuclear track detectors are used to track down buildings with high radon concentrations (for mitigation) and to map radon prone areas. In building extension zones outside the built-on areas, the indoor radon measurements are complemented by soil gas measurements and geological information. Soil gas is sampled at 90 cm depth and analysed by a scintillation counter. In-situ permeability is measured by a JOK-permeameter. The soil gas sampling strategy was based on an un-clustered and regularly spaced coverage of the municipalities' territory and a detailed analysis of building extension zones (Dehandschutter et al., 2008). All measurement points have been geo-coded, assigning geographical coordinates to each measurement point, as well as the local geological unit the point occurs on and introduced in a GIS Geodatabase. These geo-coded data are used to make radon hazard maps. Especially for building extension zones, soil gas measurements and geological information is used to assess the radon hazard complementary to the available indoor information.

RESULTS

In the radon prone areas of southern Belgium, about 5600 long-term indoor measurements have been collected, corresponding to a (clustered) sample density of about 10% of the house stock in these areas. Complementary to these indoor measurements, about 4000 soil gas measurements have been collected, leading to a sample density of about one per km² (Fig.1).

Table 2: Statistics of the detailed measuring campaigns in the radon prone areas.

	Number of measurements	AM	GM	Min	Max	SD	GSD
indoor	5605	169	137	6	4204	294	2,5
soil gas	4009	52	41	1	430	37	2,2

(Indoor in Bq/m³; soil gas in kBq/m³; N: number of measurements; SD: standard deviation; GSD: geometric standard deviation)

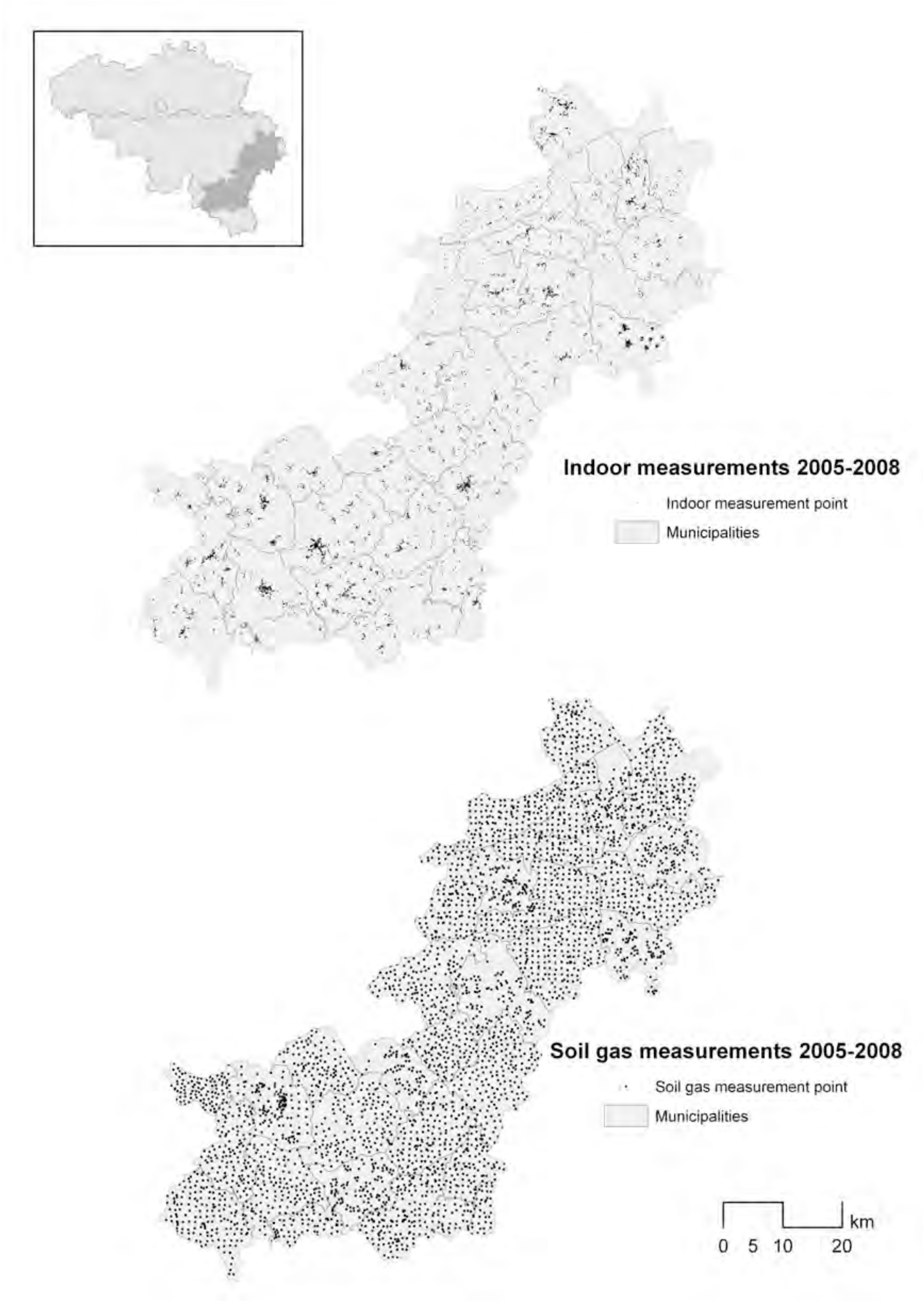
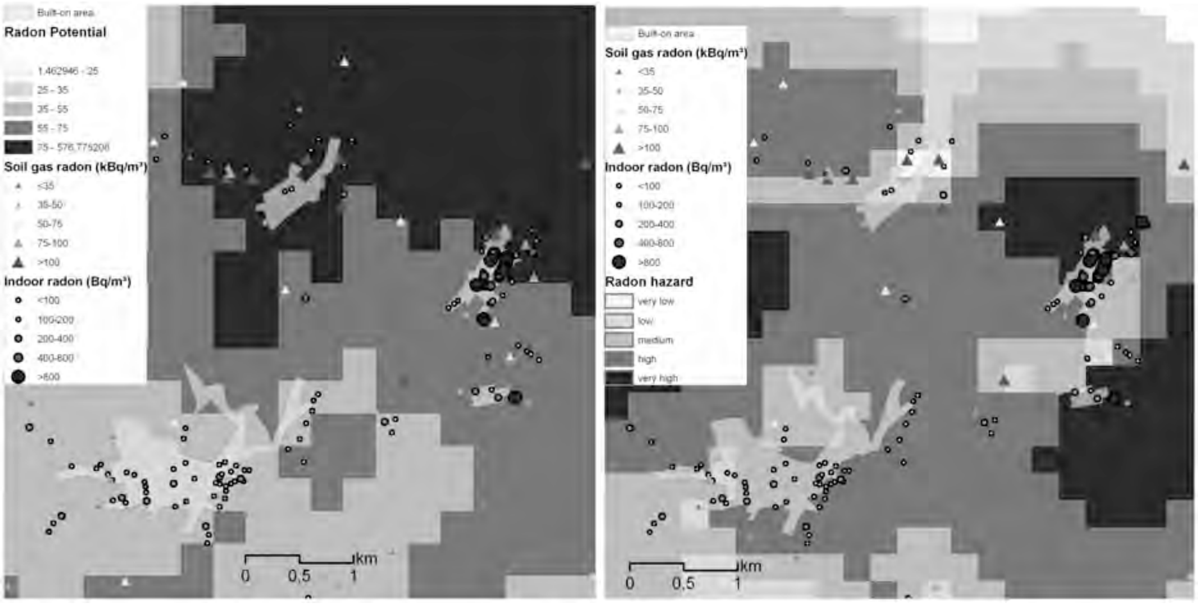


Fig. 1: Indoor and soil gas measurements of the detailed campaigns in the radon prone areas

Mapping of the radon potential RP = $(C_A-1)/(-\log k - 10)$ as defined by Neznal (Neznal et al., 2004) gives a first indication of the radon hazard outside the built-on areas (Fig. 2a). However, the radon potential does not take into account the indoor radon measurements in the neighbourhood. Therefore, a combination of the indoor, soil gas (C_A) and permeability (k) information is used to improve the assessment of the radon hazard (Fig. 2b). This combination is achieved by overlaying the up to its maximum value normalized radon potential and indoor radon grid and leads to values for the radon hazard ranging between 0 and 1.
The results have been categorised in 5 classes (very low up to very high). This combination allows taking into account the most relevant indicators for the probability of high indoor radon (neglecting the building characteristics).



(a) (b)

Fig. 2: Indoor and soil gas radon with derived radon potential (a) and radon hazard (b).

DISCUSSION

In order to make the best use of all available parameters which are influencing the indoor radon, the geo-coded indoor and soil gas radon measurements, soil permeability and geological information (lithology) are combined into a single radon hazard map. The radon hazard map does not take into account the building construction characteristics. Since only indoor radon measurements from unmitigated buildings were considered, the indoor radon map can be seen as valid for the 'average' building in the area. Currently, the influence of the transfer factor from soil to house is being studied, and will be taken into account in the further development of the radon hazard maps.

CONCLUSIONS

The long term goal of the national radon action plan is to reduce the collective dose due to radon by reducing the average radon exposure of the population to levels that can be considered as optimized. Following the EU recommendations (90/143/Euratom), the design level for new buildings is currently 200 Bq/m³. Based on the national radon map, radon prone areas have been determined where the probability to exceed the design level justifies the application of protective measures against radon in new buildings. In the radon prone areas, all relevant indicators for high indoor radon concentrations are used to assess the radon hazard. The data are combined into radon hazard maps which are used to stimulate new builders and local authorities to apply the most efficient protective measures against radon for new buildings in the radon prone areas.

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REFERENCES

90/143/EURATOM. Recommendations of the Commission, of 21 February 1990, relative to the protection of the population against the dangers resulting from indoor radon exposure. Official Journal of the European Communities L 080 du 27/03/1990, p. 0026 – 0028.

ARBIS. Algemeen Reglement op de bescherming van de bevolking, de werknemers en het leefmilieu tegen het gevaar van ioniserende straling - Règlement général de la protection de la population, des travailleurs et de l'environnement contre le danger des rayonnements ionisants (RGPRI). Arrêté royal du 20 juillet 2001. Moniteur belge, 30/08/2001, p. 28909-29368.

BEIR IV. Health risks of radon and other initially deposited alpha-emitters. US National Research Council Report, National Academy Press, Washington DC, 1988.

BEIR VI. Health effects of the exposure to radon. US National Research Council Report, National Academy Press, Washington DC, 1998.

Darby S. et al. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. British Medical Journal, v. 330, pp.223- 227, 2005.

Dehandschutter, B., Poffijn, A., Ciotoli, G., Klerkx, J. Radon mapping using indoor, soil gas and geological data. IGC33, Oslo, 2008. The presentation can be downloaded from http://radonmapping.jrc.ec.europa.eu/ under 'documents'.

ICRP 60. Recommendations of the International Commission on Radiological Protection. International Commission on Radiological Protection, Publication 60, 1990. Oxford, UK, Pergamon Press,1991, 215 p.

Neznal, M., Neznal, M., Matolin, M., Barnet, I., Miksova, J. The new method for assessing the radon risk of building sites. Czech Geo. Survey Spec. Paper 16, 48p, 2004.

Poffijn A. and Vanmarcke H. The Indoor Radon Problem in Belgium. In: Indoor Air Quality and Ventilation, Selper Ltd, pp. 339-345, 1990.

UNSCEAR. Sources and Effects of Ionising Radiation. Rapport to the General Assembly. United Nations, 2000.

Zhu H.C., Charlet J.M. and Tondeur F. Geological Controls to the Indoor Radon Distribution in Southern Belgium. The Science of the Total Environment, v. 220, no. 2-3, pp.195-214, 1998.