A PILOT STUDY ON THE AIR QUALITY IN PASSIVE HOUSES WITH PARTICULAR ATTENTION TO RADON

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Abstract

Due to economical factors and partly also to the concern about climate change, the concept of the passive house construction ("passivhaus") is becoming more and more common in Belgium and other European countries.
A pilot study in some 20 passive houses focussing on radon, airtightness and CO_2 has been organised in the southern part of Belgium, where significantly increased indoor radon levels occur regularly.
Although the airtightness observed was always much higher than by traditional constructions, the radon level in one of the houses was over 700 Bq/m³. As the installation of a geothermal heating system is quite common for passive houses, it is currently investigated if a technical problem in its installation is at the origin of the observed high radon level.
The measured CO_2 levels were slightly higher than expected and in no house the air quality could be classified as being good or excellent according to existing ventilation standards.
The observations indicate that the quality of the indoor environment in this new type of constructions has to be investigated in detail before it is becoming common practice.

Introduction

In Europe buildings account for 40% of the total energy consumption, mainly for heating purposes (Kaan, 2006). Therefore, the reduction of energy consumption and the use of energy from renewable sources constitute important measures to reduce the greenhouse gas emissions. A key part in this effort is the Energy performance of Buildings Directive (EPBD), first published in 2002 and requiring all EU countries to enhance their building regulations and to introduce energy certification schemes for buildings. With the adoption of the recast EPBD in 2010 (Directive 2010/31/EU) all EU Member States have to endorse national plans and targets in order to move towards new and retrofitted very low and close to zero energy buildings by 2020 (2018 for public buildings).

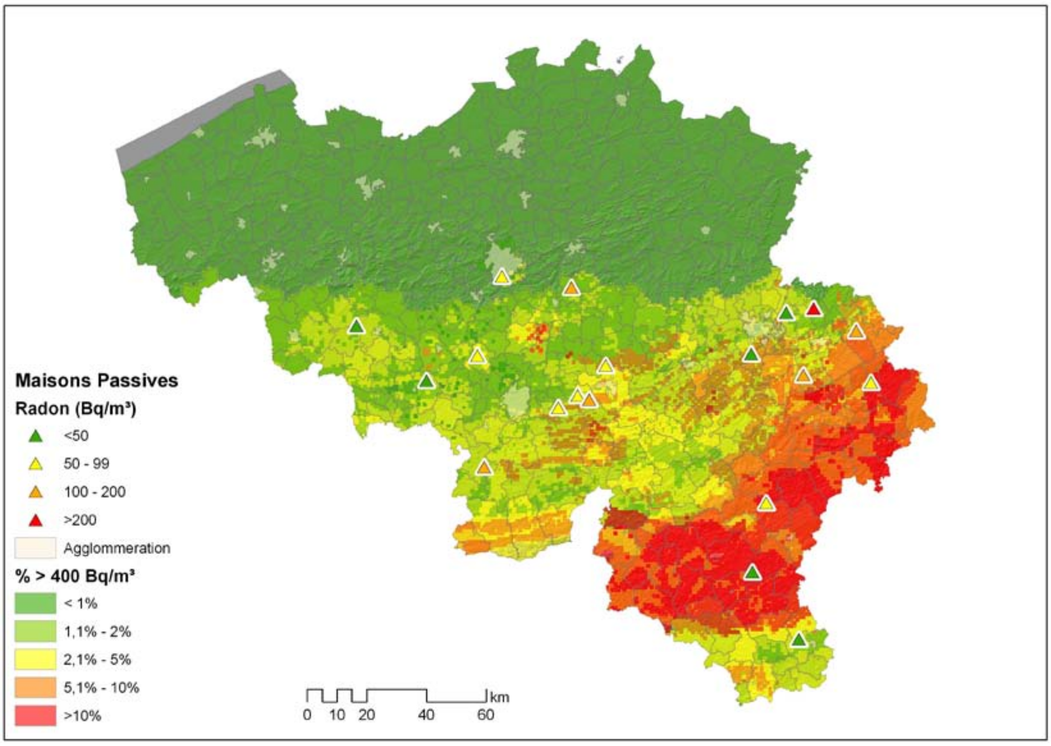
There is up to now no global definition for low-energy buildings. In general, it indicates a building having a much better energy performance than the standard efficiency requirements found in building codes. In a survey carried out in 2008 by the Concerted Action supporting the Directive on the energy performance of buildings (EPBD) 17 different terms were used to describe such type of buildings, ranging from low energy house, high performance house, passive house/Passivhaus, zero carbon house to energy positive house and 3-litre house.

The definitions for passive houses are even more heterogeneous, as in this case what is understood by it in Central/Northern Europe differs from the meaning in Southern Europe. In the southern part of Europe it means that a house has been constructed using passive technologies. In the other parts of Europe reference is made to a standard developed in Germany. In the US a house built to the Passive House standard uses between 75 and 95% less energy for space heating and cooling than current new buildings meeting today's US energy efficient codes.
In the current text we will apply the German Passivhaus standard, guaranteeing living comfort (in less than 5% of the time the temperature may rise above 25°C), with a yearly energy demand for space heating and cooling not exceeding 15 kWh/m², a limit for the annual total primary energy use of 120 kWh/m² and a certified air tightness of < 0,6/h at 50 Pa pressure difference (Hilderson, 2010).

Objectives and methodology

As certified passive houses have a much higher air tightness than most of the traditional houses, radon entry from the soil should be much lower. In this way it may be expected that even in radon prone areas, radon should be a minor problem. To verify this thesis, with the help of an architect from the Platform for Passive Houses (PMP), inhabitants of certified passive houses in the southern part of Belgium were contacted and asked for collaboration in this study.

Fig. 1 : Radon distribution in Belgium



Although most of the total of 2300 certified passive buildings in Belgium are situated in the northern part of the country, it was decided to limit the study area to the south (with currently some 300 passive buildings), where the radon-prone areas are situated, and where – even out of the radon- prone areas - from time to time high indoor radon levels have been observed in the national radon campaign (Fig.1).

In this way some 20 houses could be selected. Alpha track detectors (Radosys) have been installed for 3 months (from December 2011 till March 2012) in the living room of the participants. The inhabitants were also asked to fill a questionnaire dealing with the technical characteristics of the building. Some questions tested the knowledge about radon and the perceived health of the participants in relation to their house. Indoor CO_2, as well as relative humidity, temperature and atmospheric pressure have been measured (TESTO 435) during one hour in the centre of the living room of each house, at the end of the 3 month exposure period. For comparison purposes an outdoor CO_2 measurement was also done at the end of the visit (Tonet, 2012).

Results

As documented in Table 1, up to now passive houses made of wood with cellulose wadden for insulation material are still most popular. Only quite recently massive passive constructions appeared on the market. What is also still remarkable is the great proportion (45%) of houses equipped with a ground air heat exchange system (GAHE, known as "Canadian well") , although many studies have indicated that in a moderate climate as in Belgium, the energy saving by such a system is quite negligible (Delmotte, 2012). Moreover the microbiological risk (molds, bacteria) has often be brought to the attention of the public and building professionals.

The distribution of the radon concentration in the sample is quite comparable to the general pattern as found in southern Belgium. (see Table 2)

It should be taken into account that the size of the study is very small (n=20), so that 5% above 200 Bq/m³ just stands for 1 dwelling. It's also remarkable that the only observation above 200 Bq/m³ corresponds to a concentration of about 750 Bq/m³. Such a high concentrations is quite unexpected for two reasons: first of all passive houses are normally very airtight regarding the ground and secondly this house is not situated in a so-called radon-prone area, where radon levels over 400 Bq/m³ occur quite regularly. The cause of this unexpected high value will be investigated further when the inhabitants would be willing to do so.

Taking into account the general classification of air quality in relation to CO_2-levels (NBN D50-001; 1996), the air quality was qualified from moderate to low. This is also unexpected, as a good functioning balanced ventilation system should guarantee a sufficient air exchange rate and avoid the accumulation of whatever indoor air pollutant. Similar observations have been done in studies in Austria and Finland, where especially in the bedroom the air quality was far from good.

The correlation between radon, different building parameters and CO_2 was also evaluated. No significance correlation was ever found.

Discussion

The described study was the first carried-out in Belgium on radon and CO_2 in passive houses. As the number of houses investigated was very small, the results should be handled carefully as to eventual conclusions. It gives however some indications as to the parameters that should be investigated in a more detailed way (the construction characteristics of the ground-air heat exchanger if present) or measured in a more representative way (CO_2) in future studies. When passive houses have become the common house construction type, the current largely geology-based radon risk maps may not be anymore the most strategic tool in any radon action plan. Two points of attention are important to assure a good indoor air quality, including radon, in certified passive houses. Firstly, the building should be sufficiently air-tight in order to prevent radon and other pollutants in the soil to enter. A proper gas-barrier (such as a radon membrane) could assure this. Secondly, the building should be ventilated to a degree that indoor produced pollutants are efficiently evacuated. This could be assured by a appropriate ventilation system.

Table 1: Technical data of the investigated dwellings

ants	Number inhabitants		Volume (m³)		Surface (m²)		Construction year		B	
range	average	range	average	range	average	range	renovated	new (2006-2011)	full ground	c
20-68	3,5	3-5	552	300-990	210	124-350	10%	90%	33%	
Construction type			Insulation material						Geoth	
ood (w)	m+w	light concrete	cellulose	straw	mixture	other			GAHE*	
72%	6%	11%	61%	6%	22%	11%			45%	

*GAHE = Ground Air Heat Exchanger ("puits canadien")

Table 2 : Radon in the living space (all values in Bq/m³)

	< 50	50-99	100-200	➢ 200
Study area	32%	37%	26%	5%
Southern Belgium	33%	42%	21%	4%

Table 3: Classification of air quality according to CO_2

Air quality	**CO_2 concentration (ppm)**
Excellent (E)	< 400
Good (G)	400-600
Moderate (M)	600-1000
Low (L)	1000-3000
Bad (B)	➢ 3000

Table 4: CO_2 in the living space

Class	**E**	**G**	**M**	**L**	**B**
	-	11%	78%	11%	-
Outdoors 350 – 450 ppm					

References

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