REVERSE SEASONAL VARIATIONS OF INDOOR RADON CONCENTRATION

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Abstract. Radon concentration in indoor air of buildings, such as dwellings, schools, workplaces etc., is generally higher in autumn-winter season than in spring-summer period. This behaviour, however, is not quantitatively equal in all the buildings, and a quite large distribution of the winter/summer ratio actually occurs, depending on several factors, including building characteristics, living habits, occupancy pattern, weather conditions. In a fraction of cases, radon concentration in summer result to be higher than in winter. These "reverse" seasonal variations are particularly important if measurements of few months carried out in winter period are used to estimate the annual average, giving rise to a significant underestimate of the actual value. Some quite extreme reverse seasonal variations have been observed in some dwellings a small town near Rome, Italy. In one of these dwellings, radon concentration was monitored for three years. Some results of these measurements are reported and analysed. Moreover, possible implications on measurement protocols and regulations are discussed.

1. Introduction

Indoor radon concentrations generally vary with the season, having a maximum in winter and a minimum in summer. However, a "reverse" behaviour – with radon levels higher in spring/summer periods than in the winter/autumn ones – may also occur, and it was observed in buildings with peculiar characteristics (Wilson et al., 1991; Friedmann, 2005; Sundal et al., 2007; Moreno et al., 2009).

Two dwellings with both high reverse seasonal variability and high average radon concentration were found also in Italy, in a small town near Rome, in the framework of a survey aimed to evaluate year-to-year variations in a sample of about 80 dwellings (Bochicchio et al., 2009).

In this paper, some results of radon measurements carried out in one of this houses are reported and discussed.

2. Methods

Since 2003, radon concentration measurements were carried out by using nuclear track detectors exposed for consecutive 6-month periods. For the first four years, passive devices based on LR 115 (strippable type) detectors were used, whose track densities were measured with a spark counter. However, this measurement system has considerable deviations from a linear response also at moderate radon exposure (higher than 1 000 kBq m^{-3} h) and in cases of quite high radon exposure such devices can saturate. Therefore, since 2007 devices based on CR-39 type detectors – with a measurement system response that is much more linear at high radon exposure – were also used.

Moreover, since 2008 – in a room of the dwelling with the highest radon concentration and the highest reverse seasonal variation – radon measurements were continuously performed using a cylindrical ionization chamber (AlphaGUARD, from Saphymo, GmbH) having an active volume of 0.56 litres. For this instrument, the air to be monitored enters into the ionization chamber via a large surface glass fiber filter in diffusion mode (1-hour cycle time was used). The sensitivity of the detector is 0.05 cpm at 1 $Bq \cdot m^{-3}$ radon concentration. The background signal, due to the internal detector contamination, is less than 1 $Bq \cdot m^{-3}$. In addition to radon, this instrument allows to monitor also other environmental parameters such as temperature, relative humidity and atmospheric pressure, though integrated sensors. Some results of the radon measurements performed using AlphaGUARD monitor are reported in the next section.

3. Results and discussion

In Table 1, for each of three years with measurements, radon concentrations averaged over two consecutive 6-month periods, i.e. over "warm" (spring-summer) period and over "cold" (autumn-winter) one, are reported. For the first year, which one with the highest mean value,

radon concentrations averaged over each season (3-month period) are also reported (Table 2), showing that the highest level occurred in the spring season.

Table 1. Radon concentration averaged over warm and cold 6-month periods (for three years: from September 2008 to September 2010) in a studied house.

	1st year (Sept.08 – Sept. 09)		2nd year (Sept.09 – Sept. 10)		3nd year (Sept.10 – Sept. 11)	
6-month period	AM (Bq m^{-3})	SE (Bq m^{-3})	AM (Bq m^{-3})	SE (Bq m^{-3})	AM (Bq m^{-3})	SE (Bq m^{-3})
"warm" period (spring-summer)	2 082	51	826	17	909	20
"cold" period (autumn-winter)	432	6	372	4	404	5
Ratio between "warm" and "cold" periods	4.8		2.2		2.2	

AM: Arithmetic Mean; SE: Standard Error.

Table 2. Radon concentration and indoor temperature averaged over each of the four seasons of the first year (2008-2009) in a studied house.

3-month period	**AM (Bq m^{-3})**	**SE (Bq m^{-3})**
Autumn	405	11
Winter	458	3
Spring	3 437	88
Summer	727	30

AM: Arithmetic Mean; SE: Standard Error.

For the studied house – as well as in another one in same town, whose results are not reported here – mean radon concentration is higher in "warm" periods (i.e. spring and summer) than in the "cold" ones (winter/autumn), showing a reverse seasonal variation. The magnitude of this effect was different in the three monitored years (see Table 1), probably influenced by factors such as inhabitant living habits and weather conditions.

Notably, the house is situated on a hill slope, and houses with these characteristics were likely found to have radon concentration higher in summer than in winter (Wilson et al., 1991; Friedmann, 2005).

For houses with this unusual behaviour of radon concentration, annual radon concentration averages estimated on the basis of detectors exposed in winter season only could lead to highly underestimate the actual value. The most critical situations occur for those houses for which the "incorrect" estimation of annual radon concentration is below a reference level – i.e. a level for which some radon mitigation is required or recommended – whereas the actual one is above it.

A more complete analysis of data, including data from passive detectors exposed in this and other dwellings of the same town and data on indoor and outdoor temperatures, is on-going.

Acknowledgements

The precious collaboration of inhabitants of the monitored dwellings is acknowledged. This work was partly funded by the Italian Institute of Health and the Italian Ministry of Health, in the framework of the Italian National Action Plan.

References

Bochicchio F, Ampollini M, Antignani S, Bruni B, Quarto M, Venoso G, 2009. *Results of the first 5 years of a study on year-to-year variations of radon concentration in Italian dwellings*. Radiat. Meas. 44, 1064–1068.

Friedmann H, 2005. *Final results of the Austrian radon project.* Health Phys. 89, 339–348.

Moreno V, Bach J, Baixeras C, Font Ll, 2009. *Characterization of blowholes as radon and thoron sources in the volcanic region of La Garrota, Spain.* Radiat. Meas. 44, 929–933.

Sundal AV, Jensen CL, Ånestad KA, Strand T, 2007. *Anomalously high radon concentrations in dwellings located on permeable glacial sediments.* J. Radiol. Prot. 27, 287–298.

Wilson DL, Gammage RB, Dudney CS, Saultz RJ, 1992. *Summertime elevation of ^{222}Rn levels in Huntsville, Alabama.* Health Phys. 60, 189–197.