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Indoor radon seasonal variability at different floors of buildings

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ABSTRACT

Indoor radon concentrations have been measured with the α track etch integrated method in public buildings in the town of Pietramelara, north-western Campania, Southern Italy. In particular, our measurements were part of an environmental monitoring program originally aimed at assessing the range of seasonal fluctuations in indoor radon concentrations, at various floors of the studied buildings. However, subsequent analysis of the data and its comparison with the meteorological data recorded in the same period has shown an unexpected pattern at the different floors. In this report we present data suggesting that, besides the well-known medium and longterm periodicity, there could also be a differentiation in major meteorological controlling factors at the different floors of the buildings, a fact that does not appear to have been reported previously. While the lower floors proved to be markedly affected by rainfall, for the upper floors, instead, a different behaviour has been detected, which could possibly be related to global solar radiation.

1. Introduction

It is already several years that the international scientific community has been studying the issue of indoor radon exposure, the levels of which are generally strictly tied to the geological features of a specific area. Radon exposure variability seems to be affected by several factors: soil temperature (Fujiyoshi et al., 2006), soil permeability (King and Minissale, 1994), moisture state (Washington and Rose, 1990), temperature differences between the interior and exterior of buildings (Kitto, 2005), air pressure variations (Narasimhan et al., 1990; Robinson and Sextro, 1997; Dolejs and Hulka, 2003), materials used for building constructions and the degree of ventilation of closed environments (Baeza et al., 2003), among the most important. Furthermore, various studies have also shown a significant variability in indoor radon levels, both on a daily and seasonal basis, not always easy to quantify (Magalhães et al., 2003; Bochicchio et al., 2005; Bossew and Lettner, 2007; Moreno et al., 2008). This report summarizes the unexpected results that we have obtained during an environmental control program of public buildings in the town of Pietramelara, located in North-western Campania, in Southern Italy (Lat. N41°16′23″ Long. E14°11′15″ altitude 132 m.a.s.l.) (Fig. 1). The time series of average daily values of indoor radon concentrations have been monitored at different heights through the various floors, on a monthly basis, using the α track etch integrated method. We have chosen this area in consideration of the fact that previous studies (carried out by our research group) have detected within this area above average radon concentrations in local groundwaters (more than 200 Bq/L, compared to a local background of less than 30 Bq/L), as part of a wider anomalous area between the eastern flank of the Roccamonfina volcanic complex and the M. Maggiore mountain range located further to the east (De Francesco et al., 2010).

2. Study sites and methods

Indoor radon concentrations have been monitored from December 2004 to January 2006 in five public buildings (city hall and schools) with the track etch method, using the LR 115 type II nuclear track detector (Fleischer et al., 1975). In particular, a 3 × 3 cm strip of alpha-particle sensitive film (cellulose nitrate) has been fixed to the bottom of a plastic bell, 9 cm high and opened at the other end to allow radon entry. The time interval between measurements have been of about 1 month (see Table 1, for sampling interval variability, due to logistics). After exposure, the sensitive films have been treated with 10% NaOH at 60 °C for 90 min in the laboratory to enlarge the recorded alpha-tracks. Tracks have been counted using a microscope with a magnification of 200×. The relative uncertainty of this methodology were estimated be less

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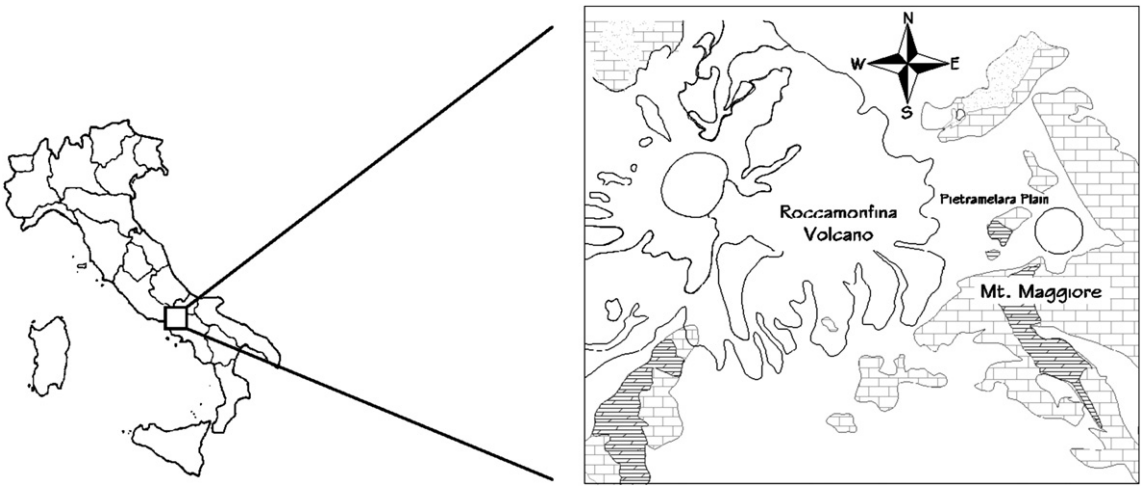

Fig. 1. Location of the investigation area.

10% (Tedesco et al., 1996). In each building one room has been chosen for each floor and, more specifically, the one which appeared to be the most attended and the most representative of the overall building. Furthermore, in workplaces detectors have been suspended at 50 cm and 180 cm from the floor, while in classrooms a height of 260 cm has been chosen in order to avoid student manipulation. All detectors have been placed adherent to the wall and beyond 1 m from the ceiling. This choice is consequent to the necessity both to protect detectors and not to cause disturb to the daily working/scholastic activities. However, as this experimental design exposes the film to thoron, in this paper we prefer to report data as "tracks/cm^2*day". As known, integrated measurements allow a longer exposure that often hides short-term fluctuations. However this feature was particularly appropriate in our monitoring program, as the principal aim was to estimate the range of seasonal fluctuations. Then, as part of the data interpretation process, geared to non-anthropic controlling factor assessment, we have compared the indoor radon concentration time series with the main meteorological parameter dataset for the same period, using an agricultural meteorological station (within 10 km from the study area) belonging to a local monitoring network (Alife station, Regione Campania, Province of Caserta, Lat. N41°20′22″ Long. E14°17′37″ altitude 110 m.a.s.l.).

3. Results

Measured radon concentrations and their time series are given in Table 1 and Fig. 2a–e, respectively. As expected, radon concentrations are generally higher at the lower floors and, within the same room, at lower heights, although in some cases our results point to an inverted stratification (see Fig. 2a and b). This last fact, in our opinion, might be ascribed to different factors (i.e., internal heating during the winter season or the high degree of attendance that would bring a sort of stirring effect) that, however, are not the primary aim of this report. However among these short-term variations radon spikes were observed in all the buildings during the autumn rain season (see Fig. 5).

Table 1
Tracks obtained into public buildings of Pietramelara. Values are expressed in tracks/cm^2*day.

		City hall				Secondary school offices		Secondary school classrooms		Primary school			Nursery school
	Building material	Tuff				Tuff and hollow brick		Tuff		Tuff			Tuff
	Floor	First		Second		First		First	Second	First	Second	Third	First
	Room	Registry		Anagraphical office		Secretary		Classroom	Classroom	Classroom	Classroom	Classroom	Classroom
	h (cm)	50	180	50	180	50	180	260	260	260	260	260	260
	Months												
1	2 Dec–5 Jan	37.0	37.9	28.7	13.8	18.8	21.3	8.1	10.3	17.7	4.2	3.1	8.6
2	5 Jan–10 Feb	10.3	18.2	5.1	2.8	7.8	20.0	4.5	5.1	4.7	4.8	1.1	6.4
3	10 Feb–10 Mar	13.6	10.7	9.6	3.7	9.5	9.5	7.0	7.1	16.0	4.5	2.4	5.3
4	10 Mar–14 Apr	16.3	7.9	6.2	13.3	22.7	19.1	7.1	7.8	7.0	7.1	6.4	6.1
5	14 Apr–12 May	16.8	17.5	12.8	8.3	14.7	11.1	nd	4.6	4.8	7.0	8.8	7.8
6	12 May–18 Jun	0.9	1.4	6.2	7.2	8.5	8.9	4.6	5.2	4.5	6.2	4.4	7.7
7	18 Jun–20 Jul	8.4	7.4	7.5	7.7	16.0	13.2	5.5	14.2	9.7	10.0	7.5	8.7
8	20 Jul–2 Sep	8.2	11.4	7.0	8.4	19.1	16.0	5.2	6.6	6.7	4.3	6.3	6.1
9	2 Sep–10 Oct	14.8	19.2	12.1	10.4	23.7	20.6	9.3	11.8	8.5	7.8	8.4	11.4
10	10 Oct–9 Nov	24.1	31.7	11.7	12.2	28.5	34.6	10.9	12.7	9.6	7.4	7.4	13.5
11	9 Nov–16 Dec	24.9	28.5	7.1	9.5	27.3	29.5	6.0	9.1	7.7	8.4	6.0	9.9
12	16 Dec–11 Jan	24.8	24.8	10.6	8.7	18.3	31.3	8.6	7.7	9.6	9.9	7.0	14.2
	Mean	**15.4**	**18.1**	**10.4**	**8.9**	**17.9**	**19.6**	**7.0**	**8.5**	**8.9**	**6.8**	**5.7**	**8.8**
	Min	**0.9**	**1.4**	**5.1**	**2.8**	**7.8**	**8.9**	**4.5**	**4.6**	**4.5**	**4.2**	**1.1**	**5.3**
	Max	**37.0**	**37.9**	**28.7**	**13.8**	**28.5**	**34.6**	**10.9**	**14.2**	**17.7**	**10.0**	**8.8**	**14.2**