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Elderly exposure to indoor air pollutants

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HIGHLIGHTS

- Elderly spend 95% of their time indoors.
- Indoor is the main site contributing for the elders' exposure to air pollutants.
- Inadequate ventilation is a significant problem in Elderly Care Centers.
- Identification of the micro-environments with highest impacts on elderly exposure.

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ABSTRACT

The aim of this work was to characterize the indoor air quality in Elderly Care Centers (ECCs) in order to assess the elders' daily exposure to air pollutants. Ten ECCs hosting 384 elderly were selected in Lisbon and Loures. Firstly, a time-budget survey was created based on questionnaires applied in the studied sites. Results showed that in average elders spend 95% of their time indoors splitted between bedrooms and living-rooms. Therefore, a set of physical and chemical parameters were measured continuously during the occupancy period in these two indoor micro-environments and in the outdoor. Results showed that indoor was the main environment contributing for the elders' daily exposure living in ECCs. In the indoor, the principal micro-environment contributing for the elders' daily exposure varied between bedrooms and living-rooms depending not only on the characteristics of the ECCs but also on the pollutants. The concentrations of CO_2, VOCt, O_3 and PM_{10} exceeded the limit values predominantly due to the insufficient ventilation preconized in the studied sites.

1. Introduction

Several works have been studied the relation between atmospheric pollutants and human health risks (Martinelli et al., 2013; Viegi et al., 2004; Jones, 1999). Although indoor concentration and number of carcinogenic air pollutants has been decreased since the 1950s (Weschler, 2009), the changes on life-style and the fact that people spend a large part of their life inside the indoor environments have promoted an increase on exposure to indoor air pollutants (Byčenkienė et al., 2009; Dales et al., 2008; Leech et al., 2002). Consequently, we are assisting an increase of studies developed by the scientific community concerning indoor air quality (IAQ) and its effects upon health (Canha et al., 2012a; Franck et al., 2011; Almeida et al., 2011; WHO, 2010; Canha et al., 2010; Saliba et al., 2009; Fraga et al., 2008; Fromme et al., 2007; Kosonen and Tan, 2004; Lee et al., 2002; Wilson, 1996; Allen and Miguel, 1995). However, the exposure assessment that should be estimated by the time spent by people in different environments and the concentration of the pollutants for the period of interest (ILO et al., 2000; Sexton et al., 1995) is rarely estimated.

According to the United Nations (2012) the percentage of total population aged 60 years or over in the Europe was 22% for the year 2012 and prospects 34% for 2050 (United Nations, 2012). Europe presents the highest percentages of old people worldwide, being Africa the continent with the lowest percentage of population with more than 60 years (United Nations, 2012). Portugal is the 8th oldest country in the world and the 6th in Europe, with 23% of population with more than 60 years old. In Portugal, the number of Elderly Care Centers (ECCs) increased 49% between 1998 and 2010 (GEP/MSSS, 2010). In general, people spend about 19–20 h indoors (Zhao et al., 2009; Bruinen de Bruin et al., 2004; Saksena et al., 2003; Klepeis et al., 2001) and these values increase considering the elders living in ECCs, since their independency is reduced (Bradshaw et al., 2012). By all of these reasons and also by the fact

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that elder people are considered a susceptible group, along children, sick and pregnant people, mitigate their exposure to air pollutants becomes increasingly important (Almeida et al., 2011; Canha et al., 2011; Pegas et al., 2011a,b).

The main goal of this work was to characterize the IAQ in ECCs in order to assess the elders' daily exposure to air pollutants.

2. Material and methodologies

The current study was carried out in 10 ECCs, located in Lisbon and Loures, District of Lisbon (Fig. 1).

2.1. Characterization of population

The present work was developed in collaboration with 384 old people living in ECCs which had a range of 7–95 occupants per institution. Table 1 shows the characterization of the studied population. Women not only were present in higher number, but also were older than men and were the ones who were bedridden in greater number (5.7% of the studied population were bedridden women).

2.2. Characterization of ECCs

Considering the particular characteristics of the surrounding environment, ECCs were classified as urban or sub-urban. Table 2 shows that four ECCs are located in a sub-urban area while six ECCs are placed in an urban area. A technical questionnaire was applied in order to characterize the buildings. This questionnaire included information about: 1) ventilation systems; 2) types of indoor materials; 3) ventilation and cleaning practices; 4) type of building construction; 5) thermal isolation of the building and 6) characterization of the building envelope. A resume of the information obtained from the application of this questionnaire is presented in Table 2.

2.3. Time-budget survey

A time-budget survey was built for 384 elders. For this a close-ended questionnaire was applied, which included information about 1) different activities developed during the day; 2) meal-times; 3) sleep times and 4) micro-environments where they spend their time. The questionnaire differentiated between time allocation on weekdays and weekends. The questionnaires were applied with the help of the ECCs supporters (e.g. socio-cultural technicians) and due to this fact the response rate was 100% for all studied sites.

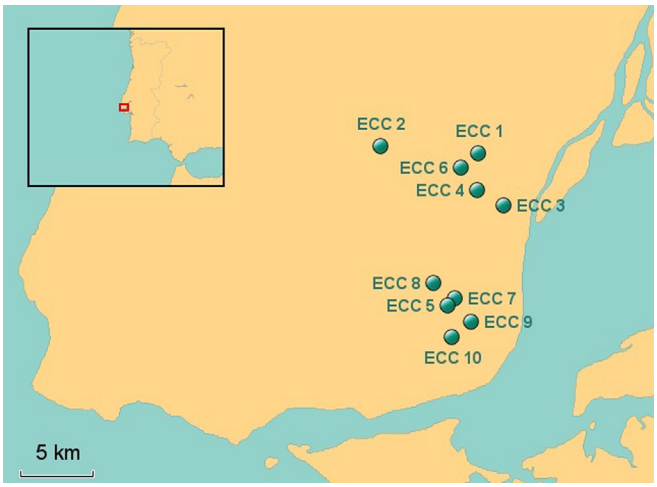

Fig. 1. Geographical distribution of the Elderly Care Centers.

Table 1
Characterization of the studied population. The results are presented in absolute values.

	Women		Men	
	N	Age (min–max)	*N*	Age (min–max)
ECC 1	26	84 (68–99)	11	81 (67–91)
ECC 2	40	87 (74–99)	11	88 (76–96)
ECC 3	39	88 (77–100)	0	N/A
ECC 4	42	84 (70–99)	24	82 (70–90)
ECC 5	9	85 (72–98)	0	N/A
ECC 6	55	81 (65–96)	40	78 (65–95)
ECC 7	5	87 (82–95)	4	82 (80–82)
ECC 8	51	80 (65–96)	0	N/A
ECC 9	6	86 (67–101)	1	86
ECC 10	20	91 (69–104)	0	N/A
Total	293 (22 Bedridden)		91 (6 Bedridden)	

2.4. Air pollutants measurement

The IAQ was assessed in ten ECCs during the occupied periods in two different indoor micro-environments: bedrooms and living-rooms. The bedrooms were chosen according to the occupancy – always two persons per bedroom. All the selected bedrooms were occupied by two elders to keep the occupancy as a constant and because this occupancy reflects the reality of the majority of the bedrooms in the studied ECCs. As the physical characteristics of all bedrooms in each ECC were equivalent it was decided to select only one bedroom per ECC and to perform longer measurements in order to identify temporal patterns. In each ECC, measurements in bedrooms were made during the night varying between 11 and 16 h, depending on ECC routine. All ECCs had one living-room except ECC 1 and ECC 2 that have two living-rooms with the same characteristics, and therefore only one of them was selected. Measurements in living-rooms were made during the day and varied between 11 and 13 h.

A set of pollutants were selected to characterize the IAQ inside those micro-environments, such as air temperature (*T*), relative humidity (RH), carbon dioxide (CO_2), carbon monoxide (CO), particulate matter in 5 different sizes ($PM_{0.3–0.5}$, $PM_{0.5–1}$, $PM_{1–2.5}$, $PM_{2.5–5}$ and $PM_{5–10}$), total volatile organic compounds (VOCt), ozone (O_3) and formaldehyde (CH_2O). For each ECC an evaluation of outdoor pollutants was also performed. The sampling campaign occurred between October to December of 2012, avoiding extreme temperatures and humidity. Table 3 summarizes the parameters analyzed both indoors and outdoors and the used equipment. All instruments were calibrated by certified entities, where they calibrate, validate and demonstrate that the instrument it is suitable for its intended purpose.

In the indoor of ECCs the measuring time ranged between 7 and 16 h and data was integrated in periods of 1 s. All results represent the air quality status for the occupied periods. Outdoor measurements were performed between 5 min and 16 h. Different methodologies were used according to 3 criteria: ECCs availability, elderly health status and equipment availability. In order to assure the comparability of the PM_{10} results provided from different devices an inter-comparison was done between the diffusion optical light equipment and the gravimetric method. Fig. 2 showed that Lighthouse overestimate the levels in comparison to gravimetric method, as already been shown by Yanosky et al. (2002), but