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# The impact of indoor air quality and contaminants on respiratory health of older people living in long-term care residences in Porto

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## Abstract

**Background:** persons who are 65 years or older often spend an important part of their lives indoors thus adverse indoor climate might influence their health status.

**Objective:** to evaluate the influence of indoor air quality and contaminants on older people's respiratory health.

**Design:** cross-sectional study.

**Setting:** 21 long-term care residences (LTC) in the city of Porto, Portugal.

**Subjects:** older people living in LTC with  $\geq 65$  years old.

**Methods:** the Portuguese version of BOLD questionnaire was administered by an interviewer to older residents able to participate ( $n = 143$ ). Indoor air contaminants (IAC) were measured twice, during winter and summer in 135 areas. Mixed effects logistic regression models were used to study the association between the health questionnaire results and the monitored IAC, adjusted for age, smoking habits, gender and number of years living in the LTC.

**Results:** cough (23%) and sputum (12%) were the major respiratory symptoms, and allergic rhinitis (22%) the main self-reported illness. Overall particulate matter up to 2.5 micrometres in size median concentration was above the reference levels both in winter and summer seasons. Peak values of particulate matter up to 10 micrometres in size (PM<sub>10</sub>), total volatile organic compounds, carbon dioxide, bacteria and fungi exceeded the reference levels. Older people exposed to PM<sub>10</sub> above the reference levels demonstrated higher odds of allergic rhinitis (OR = 2.9, 95% CI: 1.1–7.2).

**Conclusion:** high levels of PM<sub>10</sub> were associated with 3-fold odds of allergic rhinitis. No association was found between indoor air chemical and biological contaminants and respiratory symptoms.

**Keywords:** *allergic rhinitis, long-term care residences, indoor air quality, older people, respiratory health*

## Introduction

The health effects of urban air pollution in the general population are well-documented. Each year, 500,000 deaths due to pneumonia, chronic obstructive pulmonary disease (COPD) and all causes combined are attributed to outdoor air pollution worldwide [1]. Particulate air pollution has been associated

with cardiovascular morbidity and mortality, but it remains unclear which time windows and pollutant sources are most critical [2]. Cardiopulmonary conditions are highly prevalent, multifactorial, and associated with multiple comorbidities and poor outcomes, such as increased disability and decreased quality of life [3]. Older individuals spend approximately 19–20 h/day indoors [4] and have reduced physical activities,

outings and commuting [5], so being particularly at risk of detrimental effects from air pollutants, even at low concentrations, due to their reduced immunological defences and multiple underlying chronic diseases. Portugal has the 8th oldest population in the world and the 6th in Europe, with 23% of the population with more than 60 years old [6]. Furthermore, between 1998 and 2010, the number of long-term care residences (LTC) increased 49% in our country [7]. The GERIA project 'Geriatric study in Portugal on Health Effects of Air Quality in LTC' aims to provide insights into the association between respiratory health and indoor air quality (IAQ) at elderly settings, with the purpose of contributing to health improvement for the older population. This paper presents results of a substudy within the GERIA project, in Porto city LTC.

### Research aim

This study focused on respiratory health of older people living in LTC. The aims of this paper were to evaluate the influence of IAQ and contaminants on older people's respiratory health and to assess the issue in order to discuss strategies that could provide benefits.

### Data collection and methods

All LTC located within the Porto urban area and included in the 'Portuguese Social Charter' were invited to participate in our study. These institutions provide assistance in activities of daily living with medical and nursing services when required. Out of a total of 58 LTC, 36% ( $n = 21$ , with 668 residents) accepted to participate. All the participants were  $\geq 65$  years old, live in the LTC for more than 2 weeks and possessed cognitive and interpretative skills in order to receive the questionnaire. Environmental data were collected for each LTC in two seasons (summer and winter) starting from November 2011 till August 2013. Moreover, in each LTC the Portuguese version [8] of the respiratory health questionnaire BOLD (Burden of Obstructive Lung Disease) [9, 10] was administered by a trained interviewer to the older people who gave their informed consent and were able to participate ( $n = 143$ ); it was conducted from September 2012 to April 2013, along the winter season indoor air sampling. This study was approved by the Ethics Committee and the Portuguese Data Protection Authority.

### Indoor air monitoring

Indoor air assessment strategy took into account building and ventilation characteristics. Indoor air chemical and biological contaminants were measured. Carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), formaldehyde, total volatile organic compounds (TVOC), particulate matter up to 10 micrometres in size (PM<sub>10</sub>) and particle matter up to 2.5 micrometres in size (PM<sub>2.5</sub>) were evaluated. The biological contaminants were assessed for total bacteria and fungi, including fungi identification and were expressed as colony-forming units per cubic

metre of air (CFU/m<sup>3</sup>). The monitoring was performed in each LTC in the following spaces: dining rooms, drawing rooms, medical offices and bedrooms, including the bedridden subgroup (residents confined to bed because of illness or infirmity for a long or indefinite period). A total of 135 areas were evaluated. Outdoor samples were also collected for comparison to the indoor measurements. The monitoring phase included daytime air sampling (starting at 10 am and continuing for at least 4 h during normal activities) conducted discretely to minimise nuisance to normal residents' activities. National and international reference levels were presented pointing the maximum recommended safe levels.

### Respiratory health

The BOLD questionnaire was used to gather information on chronic respiratory diseases and symptoms [9]. Individuals were asked to complete a questionnaire covering respiratory symptoms, health status, activity limitation, and exposure to potential risk factors such as tobacco smoke, and previous work in dusty environments. The intent was to obtain information about respiratory symptoms (cough, sputum, wheezing, shortness of breath), exposure to potential risk factors, occupation, respiratory diagnoses (asthma, emphysema, chronic bronchitis and allergic rhinitis), co-morbidities, health care utilisation, medication use, activity limitation, and health status.

### Statistical methods

An exploratory analysis was carried out for all variables. Categorical data were presented as frequencies and percentages, and continuous variables as median and inter-quartile range (25th percentile–75th percentile) or range (min–max). Due to the fact that most of the sampling points were not the same in both seasons, the two samples were considered to be independent. Mann–Whitney and Kruskal–Wallis tests were used to compare seasonal effects assessment because of the existence of outliers, high variability and skewed distributions. Main health outcomes were wheezing, cough, sputum, asthma and allergic rhinitis. Mixed effects logistic regression models were used to study the association between these health outcomes and indoor air contaminants (IAC) (categorised above and below the reference values [11]), adjusted for age, smoking habits, gender and the number of years living in the LTC. The 95% confidence intervals (CI) were also calculated whenever appropriate. A 0.05 level of significance was used for all analyses. Data were analysed using IBM SPSS 21.0 (SPSS, Inc., Chicago, IL, USA) and STATA 12.0. (StataCorp LP, Stata Statistical Software; TX, USA).

## Results

### Environmental assessment scenario

The 21 LTC were located in the centre of Porto city and 78% of them in areas of heavy traffic. A total of 668 older people lived in these centres with a range of 7–136 occupants per

building. As regards to construction characteristics, 64% were an adaptation to LTC of an existing residential building, and 42% also had a day centre activities for non-residents older people. Most of them were built in stone masonry construction (46%) with single pane windows (87%). Only 31% had roof and walls insulation and half of the sampled buildings presented condensations and infiltrations along walls and roofs inside the buildings. All LTC were smoke-free. Regarding the ventilation type, 91% had mixed ventilation (natural ventilation in the rooms along with exhaustion systems in the kitchen and bathrooms) while 9% had only natural ventilation in all the indoor areas.

Table 1 presents the LTC indoor environmental quality descriptive statistics by season. The overall PM<sub>2.5</sub> median concentration of the 21 LTC was above national references (25 µg/m<sup>3</sup>) [11] in both seasons. When inhaled, PM<sub>2.5</sub> may

reach the peripheral regions of the bronchioles, and interfere with gas exchange inside the lungs [12]. These findings showed how this parameter is critical for air quality for its possible influence on human health particularly to older people with previous lung or heart disease [13]. Although all the other indoor air pollutants median concentrations were within the reference levels, peak values of PM<sub>10</sub> (1,730 µg/m<sup>3</sup>) in summer, as well as, TVOC (973 µg/m<sup>3</sup>; 931 µg/m<sup>3</sup>), CO<sub>2</sub> (2,313 mg/m<sup>3</sup>; 2,697 mg/m<sup>3</sup>) and bacteria (2,282 CFU/m<sup>3</sup>; 996 CFU/m<sup>3</sup>) in both seasons, exceeded the reference levels, compromising indoor air comfort and possibly worsening the already existent respiratory chronic diseases. Fungi median concentrations are slightly above references in the winter season (185 CFU/m<sup>3</sup> indoor >166 CFU/m<sup>3</sup> outdoor) and the indoor peak values in both season also raise concern (2,224 CFU/m<sup>3</sup>; 1,218 CFU/m<sup>3</sup>). Moreover

Table 1. LTC air quality and contaminants descriptive statistics by season

	N	Median [P <sub>25</sub> -P <sub>75</sub> ]	Min-Max	P	References	
					International	National
PM <sub>10</sub> (µg/m <sup>3</sup> )						
Summer	133	40 [20-70]	[20-1,730]	0.01*	150 <sup>a</sup>	50 <sup>b</sup>
Winter	132	50 [30-70]	[20-86]			
PM <sub>2.5</sub> (µg/m <sup>3</sup> )						
Summer	120	30 [20-68]	[20-2,120]	-	35 <sup>a</sup>	25 <sup>b</sup>
Winter	119	30 [20-60]	[20-43]			
TVOC (µg/m <sup>3</sup> )						
Summer	123	48 [30-90]	[14-973]	0.01*	200 <sup>b</sup>	600 <sup>b</sup>
Winter	132	78 [47-134]	[14-931]			
Formaldehyde (µg/m <sup>3</sup> )						
Summer	77	<42 [<42-< 42]	[<42-63]	-	100 <sup>c</sup>	100 <sup>b</sup>
Winter	84	<42 [<42-< 42]	[<42-320]			
CO (mg/m <sup>3</sup> )						
Summer	131	0.1 [0.1-0.6]	[0.1-7.1]	-	10 <sup>c</sup>	10 <sup>b</sup>
Winter	131	0.3 [0.1-0.9]	[0.1-3.0]			
CO <sub>2</sub> (mg/m <sup>3</sup> )						
Summer	131	721 [628-820]	[538-2,313]	0.001*	1,300 <sup>d</sup>	2,250 <sup>b</sup>
Winter	131	975 [762-1,321]	[541-2,697]			
Bacteria (CFU/m <sup>3</sup> )						
Summer	131	254 [142-392]	[6-2,282]	0.01*	-	<outdoor (until 350 CFU/m <sup>3</sup> more) <sup>b</sup> 143
Winter	127	182 [102-398]	[14-996]			48
Fungi (CFU/m <sup>3</sup> )						
Summer	126	211 [119-386]	[6-2,224]	-	500 <sup>e</sup>	<Outdoor <sup>b</sup> 230
Winter	124	185 [101-302]	[18-1,218]			166
Air temperature (°C)						
Summer	131	24 [22-26]	[14-32]	0.001*	Summer [22.8-26.1]	[18-22] up to 25 <sup>i</sup>
Winter	131	20 [18-22]	[13-27]		Winter [20.0-23.6] <sup>f</sup>	
Relative humidity (%)						
Summer	131	56 [41-63]	[21-75]	-	[30-65] <sup>g</sup>	[50-70] <sup>i</sup>
Winter	131	53 [39-61]	[5-75]			

<sup>a</sup>Environmental Protection Agency (2012).

<sup>b</sup>European Collaborative Action (1997).

<sup>c</sup>World Health Organization (2010).

<sup>d</sup>Finnish Society of Indoor Air Quality in 'The Thade Report' (2004).

<sup>e</sup>World Health Organization (2009).

<sup>f</sup>ASHRAE 55.

<sup>g</sup>IAQA 01-2003.

<sup>h</sup>Ordinance No. 353-A/2013 of December 4th.

<sup>i</sup>Decree-Law No 243/86 of 20th August 1986.

\*Significant differences in indoor measurements by Season (summer/winter).

4% of fungi samples were positive for *Aspergillus* species known potential pathogenic/toxigenic species which constitute a threat predominantly to subjects with immunity disorders [14] such as older persons. TVOC, bacteria, CO and CO<sub>2</sub> showed significantly higher indoor levels compared to outdoor, in both seasons showing predominance of indoor sources. Indoor TVOC and CO<sub>2</sub> presented significant differences between seasons ( $P < 0.001$ ). There were also significant differences between LTC evaluated spaces for TVOC ( $P < 0.001$ ), CO<sub>2</sub> ( $P < 0.001$ ) and bacteria ( $P < 0.01$ ).

**Respiratory health outcomes**

From the 668 older people living in the studied LTC, 21% ( $n = 143$ ) were within the inclusion criteria and agreed to answer the health questionnaire. Table 2 presents the general characteristics of the subjects. The sample is characterised mainly by women (85%) with most people in the age group above 85 years old (47%). Most of them are widowers (60%) living in the LTC for about 2–10 years (58%). Regarding occupation, the majority of residents were working class person who performed manual labour (57%) with elementary and middle school education (65%). Forty per cent of the residents considered themselves sick and most of them (61%) had an observed degree of physical impairment and mobility (use of mobility aids such as crutches, canes and wheelchairs) or were bedridden. Concerning the non-respondents (79%)

they were also mostly women (62%), 53% lived in the LTC in between 2 and 10 years and 46% had more than 85 years old. The known causes of this high rate of non-response were disability and disease compromising the cognitive and interpretative skills to answer the questionnaire (60%), older people refusal (32%) and to be younger than 65 years (8%). In older people respondents (Supplementary data, Table S1, available in *Age and Ageing* online), cough (23%) and sputum (12%) were the major respiratory symptoms, and allergic rhinitis (22%) the main self-reported illness. Heart troubles were reported by 37% of the residents.

**Impact of indoor air contaminants on older people respiratory health**

Table 3 represents the analysis of the mixed effects logistic regression models between the main health outcomes (wheezing, cough, sputum, asthma and allergic rhinitis) and the monitored IAC, adjusted for age, smoking habits, gender and the number of years living in the LTC. Older people exposed to PM<sub>10</sub> above the reference levels demonstrated higher odds of allergic rhinitis (OR = 2.9, 95% CI: 1.1–7.2). For each degree increase in temperature a 20% decrease in the odds of having allergic rhinitis (OR = 0.8, 95% CI: 0.6–1.0) was found. No significant associations between wheezing, cough, sputum from the chest and asthma, and environment were found.

**Table 2.** Characteristics of the subjects ( $n = 143$ )

	<i>n</i> (%)
Gender	
Female	121 (84.6)
Male	22 (15.4)
Age group	
[65–75]	19 (13.2)
[76–85]	57 (39.9)
>85	67 (46.9)
Marital status	
Single	36 (25.5)
Married	11 (7.8)
Divorced	9 (6.4)
Widower	85 (60.3)
Education	
Illiterate + read and write	22 (15.6)
Elementary & middle school	91 (64.5)
High school & university	28 (19.9)
Occupation	
Administrative and scientific	33 (23.1)
Services and seller	29 (20.3)
Blue-collar workers	81 (56.6)
Region of birth	
North of Portugal	114 (79.7)
Other regions	29 (20.3)
Years living in the ECC	
≤1 year	37 (25.9)
[2–10]	83 (58.0)
>11	23 (16.1)
Impaired physical mobility and bedridden	85 (61.2)
Self-perceived health status (consider themselves sick)	52 (40.3)

**Discussion**

Our main goal in this study was to associate the influence of IAQ and contaminants on LTC residents’ respiratory health. Our sample was very aged, with a large proportion of women. These data are consistent with a recent European study performed in several LTC [5]. The high rates of self-perceived sickness and degree of physical impairment indicate a very dependent population, living in the LTC for 2–10 years. Older people are more susceptible to the effects of indoor air pollution since they spend the large majority of their time indoors [15, 16] associated with a decline in immune defences and respiratory function [17].

In terms of IAQ scenario, the main concern issue is the overall high PM<sub>2.5</sub> concentrations both in winter and summer seasons. The comparison between national and international reference values was explored in a previous IAQ study [18]. Other studies [15, 19] have found high levels of PM<sub>2.5</sub> in similar indoor environments, and a link with lung function [20] and respiratory diseases such as COPD [21, 22] was demonstrated. PM<sub>2.5</sub> also influences blood pressure and autonomic function [23]. Although people (particularly the older people of our study) spend most of their time indoors, a major portion of indoor PM<sub>2.5</sub> came from outdoor mobile sources. In fact, the Cardiovascular Health and Air Pollution Study (CHAPS) showed that indoor-infiltrated particles from mobile sources are more strongly correlated with adverse health effects observed in the older subjects living in the studied retirement communities compared with other particles found indoors

**Table 3.** Associations between health outcomes and IAC adjusted odds ratio (95% CI)

	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Wheezing in the past 12 months		
Fungi	3.21 (0.69–14.90), <i>P</i> = 0.136	3.74 (0.78–17.78), <i>P</i> = 0.097
Age		1.04 (0.96–1.13), <i>P</i> = 0.315
Relative humidity	3.75 (0.88–16.04), <i>P</i> = 0.075	4.09 (0.93–18.02), <i>P</i> = 0.062
Age		1.03 (0.95–1.12), <i>P</i> = 0.402
Cough		
Fungi	2.29 (0.87–2.06), <i>P</i> = 0.095	2.38 (0.88–6.44), <i>P</i> = 0.088
Age		1.00 (0.95–1.07), <i>P</i> = 0.820
Allergic rhinitis		
PM <sub>10</sub>	2.44 (1.03–5.78), <i>P</i> = 0.044	2.87 (1.14–7.24), <i>P</i> = 0.025
Age		1.02 (0.94–1.09), <i>P</i> = 0.567
Gender		0.07 (0.009–0.54), <i>P</i> = 0.010
Smoked cigarettes		8.74 (1.97–38.72), <i>P</i> = 0.004
CO	1.74 (1.11–2.74), <i>P</i> = 0.017	1.62 (0.95–2.77), <i>P</i> = 0.078
Age		1.02 (0.95–1.10), <i>P</i> = 0.514
Gender		0.09 (0.01–0.72), <i>P</i> = 0.023
Smoked cigarettes		6.66 (1.47–30.15), <i>P</i> = 0.014
CO <sub>2</sub>	1.00 (0.99–1.00), <i>P</i> = 0.052	1.00 (0.99–1.00), <i>P</i> = 0.091
Age		1.02 (0.95–1.09), <i>P</i> = 0.641
Gender		0.08 (0.01–0.65), <i>P</i> = 0.018
Smoked cigarettes		7.43 (1.65–33.49), <i>P</i> = 0.009
Temperature	0.79 (0.64–0.97), <i>P</i> = 0.024	0.79 (0.64–0.98), <i>P</i> = 0.031
Age		1.01 (0.94–1.09), <i>P</i> = 0.775
Gender		0.09 (0.01–0.69), <i>P</i> = 0.020
Smoked cigarettes		7.27 (1.69–31.10), <i>P</i> = 0.007

[24]. Additionally, a recent study conducted in Belgium [25] presented high correlations between outdoor and indoor PM<sub>2.5</sub> in LTC, confirming mainly the outdoor origin of IAC. PM<sub>2.5</sub> also correlates with atherosclerosis and cardiovascular disease in a specific study [2]. Furthermore, our study indicates peak values of PM<sub>10</sub>, TVOC, CO<sub>2</sub>, bacteria and fungi exceeding the reference levels, compromising indoor air comfort and deteriorating the already existent respiratory chronic diseases.

Concerning the respiratory assessment, cough and sputum were the major respiratory symptoms and allergic rhinitis the main self-reported illness in older people living in LTC. A 2013 Australian study showed results similar to ours in older population [26] and found that people reported asthma more commonly than the diagnosis of COPD. Another Portuguese study also detected a large proportion of underdiagnosed COPD disease [8]. Underreport and underdiagnosis could justify the small rates of self-reported diseases in our study people.

We obtained a higher risk of allergic rhinitis among older people who had smoked cigarettes and were exposed to high concentrations of PM<sub>10</sub>, and temperature below the reference levels. The first result could be explained by the deposition of larger particles such as PM<sub>10</sub> in the upper respiratory system causing susceptibility to allergic reactions. Concerning indoor air temperature, the literature indicates that low temperatures may potentiate respiratory tract infections to older people [27, 28] and increase hospital admissions. The other IAC were not associated with self-reported symptoms, despite the high median values of some pollutants, such as PM<sub>2.5</sub>. Nonetheless, it is important to remind that institutionalised older people are a very susceptible population due to their compromised health.

Our study has some limitations, particularly regarding the sample size. This limitation mainly occurred due to the characteristics of the population living in the studied LTC. In this sense several older LTC residents with cognitive impairments could not participate in the sample. Regarding the LTC participation rate, there was a high number of institutions that did not accept to participate in the study. Despite this, six of the seven parishes in the city had at least one participating LTC. Also, this is a city study and may not generalise to other towns, villages or rural areas. Although the reliability of *P*-values associated to hypothesis testing is limited—as in this case—by the presence of multiple comparison, these data provide an exploratory analysis on the quality of LTC indoor conditions and its possible impact on resident's health. More studies relating indoor environment conditions in susceptible populations such as older people are welcome.

## Conclusions

Indoor environment has a potential influence in chronic respiratory symptoms on older people living in LTC due to their health susceptibility. In the LTC that participated in this study, allergic rhinitis was the main self-reported illness. High levels of PM<sub>10</sub> were associated with a 3-fold odds of allergic rhinitis. No associations were found between IAC and respiratory symptoms.

With a view to improve the LTC indoor environments, adequate measures such as local exhaust ventilation systems near cooking and gas burning devices, as well as daily slightly moist cleaning of the rooms surfaces would reduce particle

accumulation and re-suspension. Low indoor temperatures and discomfort, especially on winter season, could be prevented by simple measures such as insulating ceilings, walls and windows, maintaining natural and passive ventilation.

## Key points

- Cough and sputum were the major respiratory symptoms, and allergic rhinitis the main self-reported illness.
- Overall PM<sub>2.5</sub> median concentration was above reference levels both in winter and summer season.
- Peak values of PM<sub>10</sub>, TVOC, CO<sub>2</sub>, bacteria and fungi exceeded the reference levels, compromising indoor air comfort.
- Older people exposed to PM<sub>10</sub> above the reference levels have a higher risk of self-reported allergic rhinitis.

## Conflicts of interest

None declared.

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## Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

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## Biochemical measures and frailty in people with intellectual disabilities

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### Abstract

**Introduction:** People with intellectual disabilities (ID) are earlier frail than people in the general population. Although this may be explained by lifelong unfavourable social, psychological and clinical causes, underlying physiological pathways might be considered too. Biological measures can help identify pathophysiological pathways. Therefore, we examined the association between frailty and a range of serum markers on inflammation, anaemia, the metabolic system, micronutrients and renal functioning.

**Methods:** Participants ( $n = 757$ ) with borderline to severe ID (50+) were recruited from three Dutch ID care and support services.

**Results:** Frailty was measured with a frailty index, a measure based on the accumulation of deficits. Linear regression analyses were performed to identify associations between frailty and biochemical measures independent of age, gender, level of ID and the presence of Down syndrome. Frailty appears associated with inflammation (IL-6 and CRP), anaemia, metabolic markers (glucose, cholesterol and albumin) and renal functioning (cystatin-C and creatinine).

**Discussion:** These results are in line with results observed in the general population. Future research needs to investigate the causal relation between biochemical measures and frailty, with a special focus on inflammation and nutrition. Furthermore, the possibility to screen for frailty using biochemical measures needs to be used.

**Keywords:** *frailty, people with intellectual disability, physiological measures, inflammation, nutritional status, older people*

### Introduction

Although people with Down syndrome and people with severe intellectual disabilities (ID) have shorter life

expectancies than the general population, the average life expectancy of people with ID is increasing [1]. As a result, frailty, a state in which older people are prone to negative health outcomes including disability, hospitalisation,