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Geriatric Study in Portugal on Health Effects of Air Quality in Elderly Care Centers

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Universidade do Porto
September 2015

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Contents

Presentation of the Study

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As people have become increasingly aware, the age of the European population is rising and the percentage of adults aged 65 years and older is expected to increase. In addition, older people spend about 20 hours per day indoors, and some spend essentially their time in elderly care centers (ECC). In this sense, the study of indoor environments and how elder people may be particularly at risk of adverse health effects from pollutants, even at low exposures, due to multiple underlying chronic diseases is becoming an important issue to be addressed by research. Such conditions are highly prevalent, multifactorial, and associated with multiple comorbidities and poor outcomes, such as increased disability and decreased quality of life.

The importance of this topic was heightened in 2012 by the World Health Day in 2012 Ageing and health with the theme "Good health adds life to years" and also the 'European Year for Active Ageing and Solidarity between Generations'. Accordingly, this project is suitable to integrate these initiatives and to ensure greater recognition of what older people bring to society and create more supportive conditions for them. To our knowledge, this is the first study in Portugal to assess effects of indoor air contaminants on health status and quality of life in older persons living in ECC.

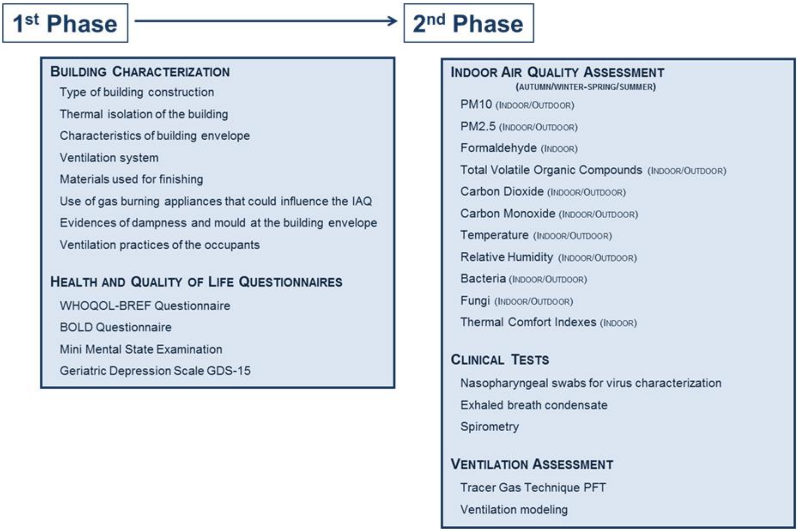
The aim of GERIA project is to carry out a risk assessment, often difficult for older people, involving the identification of multiple factors potentially affecting health and quality of life, the quantification of human exposure to pollutants, and the evaluation of the individual's response to these stimuli. The results of this project contribute to the understanding of health effects due to indoor environment variables and to provide health benefits to ECC residents with relatively simple measures.

The primary long-term purpose of the GERIA study is to improve the health of older persons living in ECC. The GERIA study aimed at:

- Measure air quality and thermal conditions in ECC;
- Assess the relationship between indoor air quality and thermal conditions on cardiorespiratory health of ECC residents (aged 65 years and older);
- Evaluate the association of indoor air pollution with health-related quality of life of older persons;
- Identify a subgroup of older persons particularly susceptible to adverse effects of air pollutants, thus posing the basis for preventive interventions.

The GERIA Project took place in the two main Portuguese cities, Lisbon and Oporto. Within the 1st phase of this study, 53 ECC (33 in Lisbon and 20 in Oporto) were selected through proportional stratified random sampling (by parish) from the 151 included in the Portuguese Social Charter (95 in Lisbon and 56 in Oporto). These 53 ECC were attended by 2,110 residents (1,442 in

Lisbon and 668 in Oporto). The 2nd phase completed a thorough analysis based on the 1st phase preliminary study. Eighteen ECC where further studied in detail.



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On the Relation between Buildings Characteristics and Ventilation

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Introduction

The indoor environment in elderly care centers (ECC) has received increased attention in the past decades. Several studies indicate that ECC residents spend an average of 19 to 20 hours indoors. In addition, elderly can have a weakened immune system and age related health problems which increments their vulnerability to health problems associated to indoors air pollution. Although it is well known that poor ventilation of enclosed spaces contributes to spread bacteria and viruses, the studies reporting on the measurement of ventilation rates in ECC in Portugal are scarce. Thus, the development of a relation between air quality, ventilation and health is considered crucial from this point of view.

In the aim of GERIA Project, after an initial survey on the Indoor Air Quality (IAQ) and building physical characteristics of 54 ECC located in Lisbon and in Oporto [1], which provided evidence that IAQ may be inadequate [2, 3], an experimental survey was conducted to determine the ventilation characteristics of a reduced number ECC. To better understand the origin of the found poor air quality, the effective total air change rate (ACH) was estimated using a passive tracer gas technique which uses perfluorocarbon tracer gases (PFT-method) [4].

Study Design

The observational survey was carried out during February and March 2014, during which time ventilation measurements were performed in 15 ECC, four of which are located in Oporto and eleven in Lisbon. In average, six rooms, including living rooms and sleeping rooms, were monitored during a period of two consecutive weeks in each ECC, according to type and feasibility from the point of view of application of the PFT technique. Before performing the measurements, information on parameters that can impact the comfort and ventilation characteristics was collected, including type and year of construction of buildings, structural characteristics of the walls, state of maintenance (pathologies related with the presence of fungi and/or mould), type of windows and shading characteristics, type of ventilation system, heating and air conditioning devices and user habits regarding ventilation strategies.

In order to perform the measurements, PFT sources (miniature container with liquid tracer compound) were positioned in each room, with tracer gas emission rates adjusted to the room volumes (Fig. 1a). The tracer gas diffused out of the sources with a known constant rate and was mixed into the room air. To measure the time averaged concentration of the tracer gas in rooms an integrating sampling was performed, using diffusive samplers (miniature tubes packed with activated carbon as adsorption material) (Fig. 1b). Given that rooms under investigation were not isolated but connected to the rest of the building by corridors or connecting rooms, in order to distinguish between inflow of outside “fresh air” and inflow of “old” air from the rest of the building, a second tracer gas was spread in the spaces outside the measured rooms.

a) b)

Figure 1. Example of the tracer gas sources a) and samplers b)

Indoor air temperature and relative air humidity has been measured in each ECC using between one and three dataloggers, according to the number of rooms. The outdoor temperature, relative humidity and wind velocity was obtained from the meteorological stations of Oporto and Lisbon.

Concerning user behavior, the occupants and the ECC qualified personnel were asked to behave as they normally would with respect to ventilation.

The PFT sources and samplers were supplied by PENTIAQ A.B. Sweden, which was also responsible for performing the analysis of the passive samplers at the end of the measurement period. They estimate that the precision including the repeatability and reproducibility is within 10% and that systematic errors will probably yield less than 5% deviation from the true value.

Experimental Survey of Ventilation using PFTs

The effective total air changes per hour (ACH) was determined using passive samplers and homogeneous emission of PFTs, as described in ISO Standard 16000-8 [5]. The use of PFT technique for determining air infiltration rates into homes and buildings has been reported by numerous studies [6] while the applicability and the effectiveness of the method have been discussed elsewhere [7, 8].

The PFT technique has several advantages over other methods given that any building can be tested, regardless of the ventilation principle (mechanically ventilated, naturally ventilated or a mixture of both). Also, the test can be performed during use and occupancy of the building and is applicable regardless of the use of the building (dwelling, office building, school, industrial building etc.). In addition to this, given that PFTs exist only at very low concentrations in the ambient environment and that are easily detected (to a few parts per billion or less), the amount of tracer gas required to carry out airflow measurements is reduced to the size of very small injection units. This allows measurements of ventilation rate in buildings to be performed without the need for analytical equipment on site. Also, the samplers and sources are free-standing units that can be used for long-term monitoring of airflows in occupied buildings without interfering with the activities of the occupants. However, the main disadvantages of the PFT technique are related to the complex configuration of buildings (multiple rooms connected with each other through multiple corridors) in which case the emission of tracer gas might not result homogeneous in the whole building. The other disadvantage could be that the results in terms of ACH obtained following measurement conducted over a period of time are average values, and therefore do not allow to draw any conclusions regarding characteristics of specific periods of time during the measurement period (such as night periods or when the building is not occupied).

Results

A total number of 203 sleeping rooms and 23 living rooms (96 in Oporto and 792 in Lisbon) corresponding to 888 nursing home residents were studied over the measurement period. Table 1 shows the main characteristics of the 15 ECC studied. For the discussion of the buildings with respect to type of ventilation, type of windows and gaskets and buildings age please refer to Chapter 6 - Ventilation Strategies for Indoor Air Quality Improvement.

Table 1. Main characteristics of the 15 ECC

ECC no.	Building no.	Unit/floor no.	Age (years)	No. of Residents	Rehabilitation year	Window type[1]
L01	-	1; 2; 3	2	39	2011	Sliding, Tilt and turn
L02	-	1; 2a; 2b	363	125	n.d.	Tilt and turn
L04	-	-	58	23	2012	Tilt and turn, Bottom hung, Sliding
L05	-	1; 3	242	49	2012	Bottom hung
L08	-	2; 3; 4	483	46	2012	Bottom hung
L10	-	-	68	14	2007	Bottom hung
L12	-	1; 2; 3; 4; 5	13	36	n.d.	Tilt and turn
	1	0a; 0b; 1a; 1b				
L17	2	0a; 0b	n.d.	332	n.d.	Sliding
	3	0; 1				
L20	-	1; 2	18	43	n.d.	Bottom hung
L22	-	0; 1; 2; 3	363	45	n.d.	Bottom hung
L24	-	-	17	40	2011	Sliding
P04	-	-	68	20	2008	Sliding

[1] Portuguese translation: sliding - correr; tilt and turn - oscilobatente; bottom hung - batente

ECC no.	Building no.	Unit/floor no.	Age (years)	No. of Residents	Rehabilitation year	Window type[1]
P05	-	1; 2	12	35	2011	Bottom hung
P07	-	1; 2	83	14	2011	Bottom hung, Sliding
P17		1	8	27	n.d.	Tilt and turn

n.d. - no date

As it can be seen from Table 1, the ECC under analysis may consist of different buildings (second column), units and floors (third column) where ventilation was assessed independently. Each ECC was assigned the letter P or L according to location, corresponding to Porto and Lisbon, respectively. According to Table 1, a total number of 39 building units were assessed from the point of view of air change rate.

Figure 2 shows the air change rates of the 39 building units under investigation. With some exceptions, most of the building units have ACH values close or above 0.4 h^{-1} (outdoor air intake) the threshold indicated by Portuguese regulation to avoid poor IAQ [9]. Building units with very low ACH values were recorded for L05, L08, L12, L24 e P07, as shown in Figure 2. In case of ECC L05, several sleeping rooms have no windows. In other cases, one possible reason maybe that the buildings are located in an urban environment with significant obstacles to wind development which affects natural ventilation.

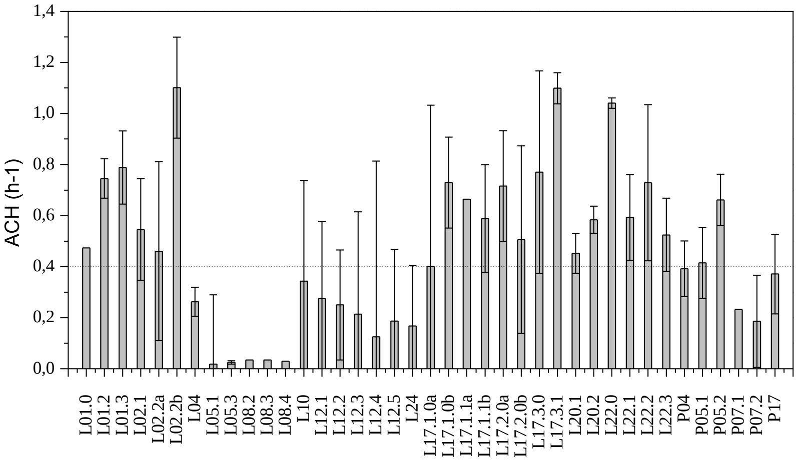

Figure 2. ACH values of the 39 building units under analysis

Figure 3 shows the box plot data of ACH according to type or rooms a) and type of windows b). As expected, the ACH values recorded for sleeping rooms (median level=0.25 ACH) are lower than the correspondent values in living rooms (median level=0.47 ACH), as shown in Fig. 3a). The windows in sleeping rooms are left opened during shorter periods of time to avoid problems with thermal and acoustic comfort. On the other hand, Fig. 3b shows that building units with sliding windows (median level=0.58 ACH) and bottom hung windows (median level=0.45 ACH) have ACH values higher than building units with tilt and turn windows (median level=0.25 ACH). These observations are consistent with the conclusions drawn from a parallel research which aimed at the evaluation of the ventilation rates using CO_2 from building residents and the concentration decay method and the constant emission method. This study is described in detail in Chapter 6 - Ventilation Strategies for Indoor Air Quality Improvement.

The reason why sliding windows are responsible for higher ACH values is because they are provided with plush gaskets. Windows with plush gaskets allow higher air permeability rates than those achievable with windows with rubber gaskets which are typically in bottom hung and tilt and turn windows. Although bottom hung windows may also be provided by rubber gaskets, in the case of wood traditional window frames, which were found in several building units, they are missing.

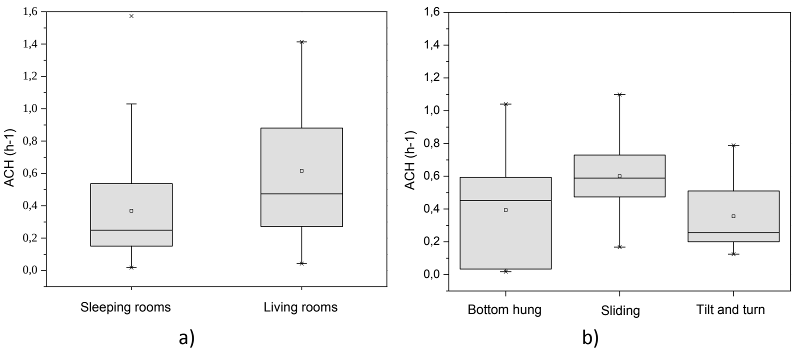

Figure 3. Box plot data of ACH according to type or rooms a) and type of Windows b).

Conclusions

The application of the PFT technique has shown that the majority ECC under analysis have satisfactory ventilation rates. Regarding the ECC where the ventilation rates recorded were very low, one should identify and implement the strategies to improve the quality of ventilation to avoid the deterioration of IAQ which in turn may affect the health of the residents.

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Assessment of Indoor Environmental Quality

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Introduction

According to the study Alliance for Health and the Future [1] there is an increase of very old population (aged >80 years) in European Union that will reach 34,7 millions by the year of 2030.

In general, people spend more than 80% of their time indoors and this figure increases in the case of elderly people. They are also at a greater risk for adverse health effects from exposure to indoor air pollutants because their immune systems become less effective with age. So, it is essential to understand how environmental factors influence elder's health and wellbeing.

The aim of this study was to characterize indoor environmental quality in a representative sample of elderly care centers (ECC) in order to associate it with ventilation, health and comfort of elderly people.

Material and Methods

Indoor air quality (IAQ) parameters were measured twice, during winter and spring/summer seasons, from 18 ECC located in Lisbon. The winter campaign took place between the beginning of November 2013 and middle March 2014, and the spring/summer campaign between middle April and end of July 2014. The study included the evaluation of chemical parameters - carbon monoxide (CO), carbon dioxide (CO_2), formaldehyde, total volatile organic compounds (TVOC) and particulate matter PM_{10} (fine particles with an aerodynamic diameter smaller than 10 micron) and $PM_{2,5}$ (fine particles with an aerodynamic diameter smaller than 2.5 micron); microbiological contaminants (total bacteria, Gram-negative bacteria and fungi) and thermal comfort parameters (air temperature, radiation temperature, relative humidity, air velocity).

In each ECC living rooms and bedrooms were monitored, including the bedridden subgroup, with a total of 116 rooms evaluated. To point out the influence of indoor sources, each indoor sampling was coupled to a sample collected outside the studied building (outdoor reference).

In bedrooms, carbon dioxide monitoring was performed in two different periods: during the night and the day with Indoor air quality monitoring. In each ECC living room, carbon dioxide and carbon monoxide were monitored during occupation periods using the Indoor Air Quality Meter (TSI, model 7545, USA), sampling periods of 30-45 minutes and with readings taken every minute.

Formaldehyde was collected by active sampling on impingers, using personal pumps (model 224E PCX8, SKC) at an airflow of 1L/min and analyzed according to NIOSH 3500 method using visible spectrometry (UV4, UNICAM).

PM_{10} and $PM_{2,5}$ were collected by active sampling on pre-weighted PTFE filters mounted on PM_{10} and $PM_{2,5}$ collectors (Personal Environmental Monitors, SKC), using personal pumps (model 224E PCX8, SKC) operating at 2L/min, followed by gravimetric analysis for particle mass according to the method IP-10A by SKC (2004) – "Determination of fine particulate matter in indoor air using size specific impaction".

Duplicate samples of TVOC were collected on TENAX Tubes (Ref. 25054, Supelco) using SKC personal pumps calibrated to 0.05 L/min and analyzed after thermal desorption according to ISO 16000-part 6, using gas chromatography (Perkin Elmer, ATD 400). The equipment for indoor air quality assessment was placed at the breathing zone of the occupants for chemical parameters, with caution to avoid contamination.

Duplicate samples of viable airborne bacteria and fungi were collected indoors and outdoors using the Microbiological Air Sampler (MAS-100, Merck), with a sampling flow rate of 100 L/min. Malt Extract Agar (MEA) supplemented with chloranphenicol, Trypticase Soy Agar (TSA) supplemented with cicloheximide, and MacConkey agar plates were used as collecting media for fungi, total bacteria and gram-negative bacteria, respectively. Field blanks and laboratory positive and negative controls were included in each campaign. Microbiological air samplers were placed at the breathing zone of occupants, with caution to avoid plate contamination.

After incubation at 25°C during 4-5 days for fungi and at 37°C for bacteria during 24-48 hours, plates were counted and adjusted using a Feller table supplied with the samplers. Results were expressed in CFU/m^3 (colony forming units per cubic meter of air), and after 3-4 additional days fungi were identified based on macroscopic and microscopic criteria as described in reference mycology manuals and atlas.

Whole-body thermal comfort evaluation was based on PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indices, according to the ISO 7730:2005 [2].

Thermal sensation relates essentially to the heat balance of the body as a whole. PMV index predicts the thermal sensation of a large group of persons in the same measured or estimated conditions of thermal environment, physical activity and clothing, using a 7-point scale ranging from -3 (cold) to +3 (hot), PMV=0 for neutral sensation. PPD index is calculated from PMV, predicting the percentage of people likely to feel unsatisfied with a given environment.

Environment thermal parameters – air temperature, mean radiant temperature, air velocity and air humidity - were measured in bedrooms and living rooms, placing the sensors at abdomen level, according to ISO 7726:1998 [3].

Metabolic heat production from physical activity was estimated in 41 W/m2 for women and 44 W/m2 for men, using the tables for estimation of metabolic rate by task-components provided in ISO 8996:1990 [4].

ISO 9920:1995 [5] was used for estimating clothing insulation for men and women, based on type of clothing used in bedrooms and in sitting rooms. In bedrooms' values of 1.7 clo and 1.2 clo were estimated for winter clothing worn by women and men, averaging 1.5 clo; for spring time 0.9 clo and 0.7 clo were estimated, averaging 0.8 clo. In sitting rooms clothing insulation was estimated in 0.7 clo in spring, and 1.0 clo in winter.

All the analyzers/equipments employed in the present study were calibrated in accordance with the standards in use at the laboratory.

Statistical analysis

An exploratory analysis was carried out for carbon dioxide, carbon monoxide, formaldehyde, PM_{10}, $PM_{2,5}$, TVOC, viable airborne bacteria and fungi, and thermal parameters (air temperature, air velocity, relative humidity and mean radiant temperature). Categorical data were presented as frequencies (percentages), and continuous variables as mean and standard deviation (SD) or median and inter-quartile range (25th percentile - 75th percentile), as appropriate. Mixed effects regression models were used to take into account the correlation structure between measures within the same nursing home. Crude odds-ratios with corresponding 95% confidence intervals were calculated. The level of significance was $\alpha=0.05$. Data analysis was performed using the software SPSS 22.0 (SPSS for Windows, Rel. 22.0.1. 2013. SPSS Inc., Chicago, Il, EUA) and Stata (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP.).

Results and Discussion

Thermal comfort

In the winter season, 69% of the rooms are comfortable with 17.2% classified in category A (<6% dissatisfied), 40.5% in category B (<10% dissatisfied) and 11.2% in category C (<15% dissatisfied). The remaining 31% of the rooms (35.2% of the bedrooms and 16.0% of living-rooms) cannot be classified as comfortable because they do not fill the requirements for PPD and PMV in the different categories. Considering that there were no complaints of local discomfort, the respective index was not calculated and was assumed that complies with category A (Table A1, Annex A - ISO 7830).

Table 1. Classification of the thermal environment (ISO 7730)

		Comfort Category			
		Category A	Category B	Category C	Not Classified
Winter	Bedrooms (n=91)	15 (16,5%)	35 (38,5%)	9 (9,9%)	32 (35,2%)
	Living-rooms (n=25)	5 (20,0%)	12 (48,0%)	4 (16,0%)	4 (16,0%)
Spring/Summer	Bedrooms (n=91)	13 (14,3%)	16 (17,6%)	14 (15,4%)	48 (52,7%)
	Living-rooms (n=25)	5 (20,0%)	10 (40,0%)	5 (20,0%)	5 (20,0%)

In the spring/summer season, 54.3% of the rooms are comfortable with 15.5% classified in category A (<6% dissatisfied), 22.4% in category B (<10% dissatisfied) and 16.4% in category C (<15% dissatisfied). The remaining 45.7% of the rooms (52.7% of the bedrooms and 20.0% of the living rooms) cannot be classified as comfortable.

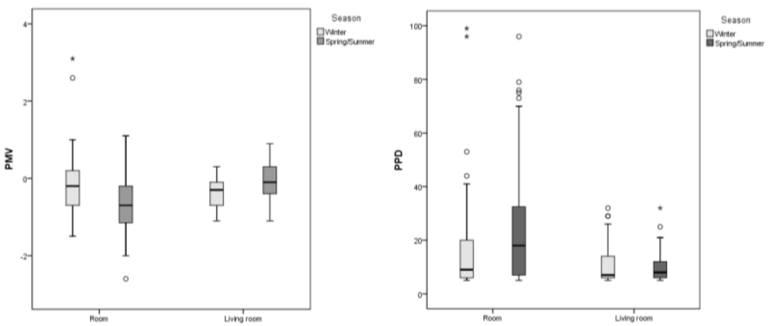

Figure 1. Distribution of Predicted Mean Vote and Predicted Percentage of Dissatisfied by room and season

The results presented in Figure 1 (on the left) indicate that nearly all the non comfortable rooms, in both seasons, are due to cold environments (PMV<-1). Analyzing thermal comfort index PPD (Figure 1, on the right) it is noted a smaller percentage of dissatisfied in living rooms during the spring/summer season with a reduction of 14.8% in average when compared with bedrooms ($p<0.001$). In winter the odds of having a comfortable environment is 4 times higher in living-rooms than in bedrooms ($p=0,046$) and there is also a weak evidence of a mean reduction in 4.5% of the PPD ($p=0,053$).

Indoor Air Quality Monitoring

The results obtained in indoor air quality monitoring as well as paired outdoor concentrations and reference concentrations according to the Portuguese regulation [6] are summarized in Table 2.

Table 2. Chemical and microbiological contaminant concentrations in 18 ECC presented by season.

		Indoor			Outdoor			Reference
Parameter	Season	n	Median	P_{25}-P_{75}	n	Median	P_{25}-P_{75}	
CO_2 nocturne (ppm)	Winter	61	1502	1196-1803				
	Spring/Summer	61	1216	973-1598				
CO_2 diurnal (ppm)	Winter	116	1156	914-1432	18	567	555-592	1625
	Spring/Summer	116	756	644-924	17	540	531-558	
CO (ppm)	Winter	116	0.1	0.0-0.4	18	0	0.0-0.1	9
	Spring/Summer	115	0.1	0.0-0.1	17	0	0.0-0.2	
HCHO (mg/m^3)	Winter	116	0.016	0.010-0.020	18	0.010	0.010-0.010	0,1
	Spring/Summer	116	0.017	0.010-0.027	18	0.013	0.009-0019	
TVOC (mg/m^3)	Winter	115	0.110	0.068-0.239	18	0.066	0.043-0.069	0,6
	Spring/Summer	116	0.067	0.060-0.100	18	0.065	0.060-0.070	
$PM_{2,5}$ ($\mu g/m^3$)	Winter	109	14.4	13.3-68.1	17	30	13-81	50
	Spring/Summer	116	27.5	11.5-73.8	18	37	11-75	
PM_{10} ($\mu g/m^3$)	Winter	111	52	14.2-101.5	17	33	13-60	100
	Spring/Summer	116	41	14.5-75.8	18	43	31-83	
Bacteria (CFU/m^3)	Winter	114	366	210-570	18	84	20-111	Outdoor +350
	Spring/Summer	116	288	134-536	18	62	52-93	
Fungi (CFU/m^3)	Winter	116	295	192-429	18	266	171-745	Outdoor
	Spring/Summer	116	420	268-741	18	533	274-972	

Median carbon dioxide concentrations were below the recommended limit of 1625 ppm (for old and naturally ventilated buildings) in both seasons, however the average concentrations obtained during routine activities in each room were above this reference in 19% of the rooms in winter, and in 3% in spring/summer (Figure 2).

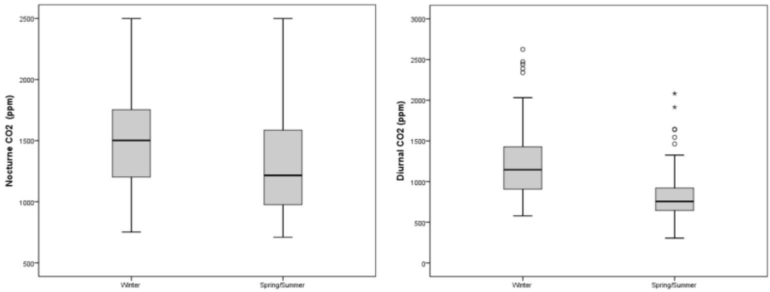

Figure 2. Distribution of nocturne and diurnal carbon dioxide concentrations by season

There were statistically significant differences between carbon dioxide concentrations in winter when compared with spring/summer, with a mean reduction of 167 ppm, in nocturne carbon dioxide ($p=0.030$), and a mean reduction of 417 ppm in diurnal carbon dioxide ($p<0.001$), reflecting better ventilation in the spring/summer season during both, day and night.

Carbon monoxide concentrations obtained indoors comply with reference levels in both seasons.

Formaldehyde concentrations were below 0,1 mg/m^3 in more than 97% of the rooms, in both seasons, what seems to be a good result considering that formaldehyde can be released from cleaning/disinfectant household products and emitted from new furniture.

TVOC concentrations were lower than the reference level (0,6 mg/m^3) in all the rooms studied during spring/summer and was exceeded only in one out of 116 rooms in winter. In spring/summer TVOC concentrations there is a mean reduction 0,066 mg/m^3 in relation with winter concentrations ($p=0.002$).

There are no statistically significant differences in $PM_{2,5}$ and PM_{10} concentrations between seasons. The mean PM_{10} concentrations obtained were above reference levels (100 µg/m^3) in 24% and 19% of the rooms and $PM_{2,5}$ were above the reference (50 µg/m^3) in 28% and 32% of the rooms, in winter and spring/summer, respectively. Median $PM_{2,5}$ concentrations are higher outdoors in both seasons and median PM_{10} concentrations are higher indoors only in winter (Table 2). The relation between particulate matter concentration and type of floor covering materials (wood and cork, tile and PVC) was also explored but there are no statistically significant differences.

Indoor median bacterial concentrations were below the reference level (outdoor concentration + 350 CFU/m^3) both in winter and in spring/summer, with higher concentrations in winter. Nevertheless, more than 35% of the rooms exceeded the reference, but Gram-negative bacteria concentrations are low (data not shown) in all the studied rooms.

Regarding fungal contamination, indoor concentrations were below the outdoor concentration in more than 60% of the rooms regardless the season.

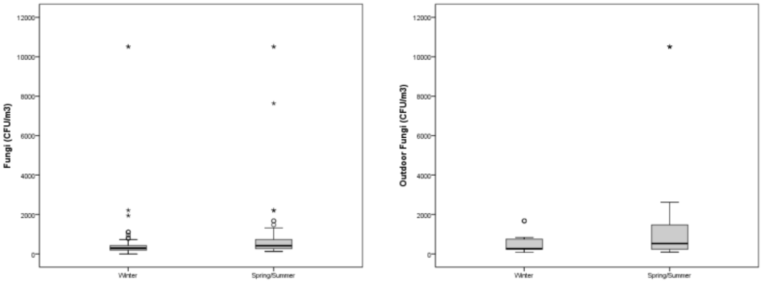

Figure 3. Indoor and outdoor fungal concentrations by season

The higher concentrations of fungi obtained in spring/summer (Figure 3) may be the result of the mean increase of 1062 CFU/m^3 in outdoor concentrations in spring/summer, when compared with winter ($p=0.048$). As expected, the relative abundance of different fungi species tends to follow the pattern found in outdoor air (data not shown).

Conclusion

Considering the obtained results for indoor air contamination and thermal comfort in 18 ECC located in Lisbon it is possible to conclude that:

- Thermal comfort was not been reached in more than 30% of the rooms;
- In winter, carbon dioxide concentrations were above de reference in 20% of the rooms;
- PM_{10} and $PM_{2,5}$ mean concentrations were above the reference levels in approximately 25% and 30% of the rooms, respectively;

- Microbiological contamination (total bacteria and fungi) was above the reference levels in more than 35% of the rooms.

Thermal comfort should be improved by the means of controlling thermal parameters or adjusting clothing to environmental characteristics.

High levels of carbon dioxide and bacteria are usually a sign of overcrowding and/or inadequate ventilation.

Bearing in mind that particulate matter have been reported to be associated with increased cardiovascular mortality and morbidity [7], the sources of contamination should be identified and adopted source control mechanisms.

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Quality of Life

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Introduction

The age of the European population is rising, and the percentage of adults aged 65 years and older is projected to increase from 16% in 2000 to 20% in 2020 [1]. Increased spontaneous demand, by older adults, for health care prevention and maintenance programs requires greater investment into aging accommodations. Institutions such as elderly care centers (ECC) have the potential to influence people's lives socially, physically, and psychologically [2]. ECC is considered a facility where users of 65 years or older reside permanently in a substitute environment and are offered shelter and elderly care.

Over the last few decades, concern about the quality of life (QoL) in this population has increased. More specifically, health-related quality-of-life involves perceptions of wellbeing and functioning in physical, mental, social, and daily life activities that comprise a summary quantification of perceived health. The QoL group of the World Health Organization (WHO) has defined QoL broadly as "an individual's perception of his or her position in life in the context of the culture and value system where they live, and in relation to their goals, expectations, standards and concerns". When studying older people living in ECC facilities, there has been a tradition to include QoL as an outcome parameter. Active aging implies growing old in good health and as a participative member of society, feeling fulfilled, autonomous in daily life, and more involved as citizens. No matter how old, the elderly plays an active part in society and enjoy a good QoL. The challenge is to make the most of the potential that older citizens harbor no matter their age [3]. Aging is associated with a decline in immune defense and respiratory function, and predisposition to respiratory infections [4]. In this population, the majority of situations of dependence are associated with chronic conditions that can be exacerbated by indoor environmental settings. Much can be done to cope with this decline. Rather small changes in the environment may make a great difference to individuals suffering from health impairments and disabilities.

Older individuals spend approximately 19-20 h/d indoors [5] and may be particularly at risk of detrimental effects from air pollutants, even at low concentrations, due to their reduced immunological defenses and multiple underlying chronic diseases. Due to these conditions, elderly are more susceptible to the effects of air pollution, and since they spend the large majority of their time indoors, monitoring IAQ in ECC is a public health priority [6]. In addition to IAQ, thermal comfort (TC) is a key indoor factor that might affect comfort, health and performance. Exposure to poor IAQ may produce or exacerbate eye irritation, nausea, upper respiratory complications, cognitive impairment, asthma, respiratory infections, cardiovascular disease, chronic obstructive pulmonary disease and cancer [7]. Thus, IAQ is a special concern for ECC residents, important for both health and QoL.

Research to understanding such effects, especially taking into account that older individuals often have multiple diseases and live in restricted indoor environments that place them at increased risk of exposure to indoor pollutants, is an important endeavor and a natural shift in the focus of IAQ and TC studies. With this purpose the GERIA project aimed to characterize the ECC indoor environment and explore the influence of the indoor settings in the residents' QoL. Our study focused on the assessment of indoor environmental variables that might influence elderly comfort and wellbeing and interact with their already existent chronic diseases.

Methods

Within the scope of this study, 53 ECC (33 in Lisbon and 20 in Oporto) were selected through proportional stratified random sampling (by parish) from the 151 included in the Portuguese Social Charter (95 in Lisbon and 56 in Oporto). These 53 ECC were attended by 2,110 residents (1,442 in Lisbon and 668 in Oporto).

The Portuguese version of the WHO Quality of Life WHOQOL-BREF questionnaire [8] was administered by a trained interviewer to the older people who gave their informed consent and were able to participate. The questionnaire was conducted along the winter season environmental sampling campaign. All the participants were ≥65 years old, lived in the ECC for more than 2 weeks and possessed cognitive and interpretative skills in order to complete the questionnaires. This study was approved by the Ethics Committee and the Portuguese Data Protection Authority.

The WHOQOL-BREF questionnaire instrument is a 26-item version of the WHOQOL-100 assessment. Its psychometric properties were analyzed using cross-sectional data obtained from a survey of adults carried out in 23 countries. It applies the definition of QoL advocated by the WHO, which includes the culture and context which influence an individual's perception of health. The first two questions evaluate self-perceived QoL and satisfaction with health. The remaining 24 questions represent each of the twenty-four facets of which the original instrument is composed (WHOQOL-100), divided into four domains: physical health (7 items), psychological health (6 items), social relationships (3 items) and environment health (8 items). These four domain scores denote an individual's perception of quality of life in each particular domain. Domain scores are scaled in a positive direction (higher scores denote higher quality of life). The mean score in each domain indicates the individuals' perception of their satisfaction with each aspect of their life, relating it with QoL. The mean score of items within each domain is used to calculate the raw domain score. Considering the 4-20 scale, the midpoint where QoL is judged to be neither good nor poor is 12.0 [9] (which correspond to 50 in the 0-100 scale). In the present study we considered the 0-100 scale.

QoL has to be seen from a holistic perspective and interventions may not be limited to one aspect, as Kelley-Gillespie [10] concludes when developing an integrated conceptual model of QoL for older adults [11].

Median, 25th and 75th percentiles were estimated for every WHOQOL-BREF domain. Spearman correlations coefficients were computed to evaluate the linear relationship between scales. The internal consistency reliability of the WHOQOL-BREF was assessed by Cronbach's coefficient alpha. The floor and ceiling effects were measured for the scales domains with floor effect being the percentage of subjects with the lowest possible domain scores and the ceiling effect being the percentage of subjects with the highest possible domain scores. A low quality of life domain score was considered if the WHOQOL-BREF transformed score was <50 in the 0-100 scale.

Results and Conclusions

The overall questionnaire´s answer rate was 44% (931/2,110). The main reasons to not participate in the study were lack of collaboration due to incapacity (75%), elderly refusal (9.5%), to be younger than 65 years (9.5%) and institution refusal (6%). Even though, in the analysis were considered only the WHOQOL-BREF questionnaires with less than 20% of missing answers (n=887).

The surveyed sample included 79% females and 21% males, with a mean age of 84 years (SD 7 years). There was no statistical difference between respondents and non-respondents ($p=0.534$) in what concerns gender. The mean age of non-respondents was 83 years (SD 11 years) and despite being similar to the respondents, it was statistically different ($p=0.004$).

The internal consistency of the WHOQOL-BREF for the whole questionnaire was 0.86. The Cronbach's coefficient alphas for the different domains were: 0.78 for the physical health, 0.80 for the 0.59 for the social relationships psychological health, and 0.73 for the environmental. The Spearman correlations estimates between the four WHOQOL-BREF domains were: physical health/psychological health $r_s=0.65$ ($p<0.001$), physical health/social relationships $r_s=0.35$ ($p<0.001$), physical health/environmental health $r_s=0.52$ ($p<0.001$), psychological/social rs=0.42 (p<0.001), psychological health/environmental health rs=0.56 (p<0.001) and social relationships/environmental health rs=0.41 (p<0.001).

Most domains had no marked floor or ceiling effects, exception to WHOQOL-BREF social relationships (ceiling effect of 2.9%). The floor effects were 0.2%, 0.1%, 0.2% and 0.1% for the physical health, psychological health, social relationships and environmental health domains, respectively. Ceiling effects were 0.4%, 0.8%, 2.9% and 1.3% for the physical health, psychological health, social relationships and environmental health domains, respectively.

Overall median scores for the different domains were modest (Table 1), with the exception of social relationships domain where a median of 75 (P_{25}-P_{75}: 58.3-75.0) was found. Overall QoL and health perception was low, particularly for respiratory diseases.

Table 1. Quality of Life (WHOQOL-BREF) assessment

	Total of participants (%)	**Median (P_{25} - P_{75})**
WHOQOL-BREF score		
Overall perception of QoL and health		50.0 (37.5 – 75.0)
< 50	560 (63.1)	
≥ 50	313 (35.3)	
NA	14 (1.6)	
Physical health		64.3 (47.3 – 75.0)
< 50	248 (28.0)	
≥ 50	603(68.0)	
NA	36 (4.0)	
Psychological health		62.5 (50.0 – 75.0)
< 50	242 (27.3)	
≥ 50	619 (69.8)	
NA	26 (2.9)	
Social relationships		75.0 (58.3 – 75.0)
< 50	60 (6.8)	
≥ 50	525 (59.2)	
NA	302 (34.0)	
Environmental health		62.5 (56.3 – 71.9)
< 50	111 (12.6)	
≥ 50	647 (72.9)	
NA	129 (14.5)	

NA: not available; QoL: Quality of life; P_{25}: 25th percentile; P_{75}: 75th percentile

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Viral Role in Acute Respiratory Infections in Elderly Care Centers

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Introduction

The GERIA project ("Geriatric study in Portugal on Health Effects of Air Quality in Elderly Care Centers") is a multidisciplinary project with the purpose of studying the health impact of indoor air environment in residents in elderly care centers (ECC). One of the key points of this project was the study of the role of viral respiratory infections at these centers during the 2013/14 winter. Therefore, the aim of this study was the etiology and clinical consequences of these infections in a resident population of ECC.

In order to better clarify the role of the respiratory viruses in severe infections, atypical bacteria were also searched in the subset of patients who died and/or were hospitalized.

Study design

Eighteen ECC in Lisbon participated in this study, covering a population of 1022 elderly. Before starting the study, open sessions were realized in all ECC and conducted by a virologist of the GERIA team.

The study included staff´s phone contact to the research team whenever an elderly had symptoms of respiratory infection. The criteria for respiratory infection were: at least one systemic symptom (fever or feverished, malaise, headache and myalgia) plus at least one respiratory symptom (cough, sore throat, shortness of breath and coryza) [http://ecdc.europa.eu/en/healthtopics/influenza/surveillance/Pages/influenza_case_definitions.aspx].

Biological samples

Sample collections were performed by members of the research team within the first 48 hours after the phone call, at the elderly centers. Two swabs were collected from each patient, nasopharyngeal and oropharyngeal and immediately pooled into viral transport medium (Vircell's Transport Medium for virus, Chlamydia and Mycoplasma).

Patients' informed consents were obtained (or of their legal representants), and the study was approved by the Ethics Committee of Nova Medical School, Lisbon. The clinical evolution of each patient was sought by a phone call to the respective center staff some weeks after the specimen collection.

Methods

PCR for respiratory viruses: after extraction, in house real-time PCR and RT-PCR techniques were performed for influenza A/B, respiratory syncytial virus, parainfluenza types 1/3, parainfluenza types 2/4, adenovirus, enterovirus, rhinovirus, human metapneumovirus, group 1 coronaviruses and group 2 coronaviruses and bocavirus [1,2].

TaqMan array cards: "in-house" array cards for several respiratory viruses and atypical bacteria were used in severe cases that were negative for respiratory viruses by PCR. The panel included Adenovirus, Bocavirus, Influenza A (including H1, H3, H7, H9 and B), Parainfluenza 1-4, Respiratory syncytial virus, Enterovirus, Rhinovirus, Human metapneumovirus, Coronavirus, *Legionella pneumophila, Mycoplasma pneumoniae, Chlamydophila pneumoniae* and *Coxiella burnetii.*

PCR for *Legionella pneumophila*: an "in house" real-time PCR technique was performed for confirmation of the positive samples for *Legionella* by array tests [3].

Genetic characterization of influenza strains was performed at the National Institute of Health Doutor Ricardo Jorge.

Results

Between November 2013 and April 2014, 188 episodes of acute respiratory infection from 163 patients were reported to the research team (48 men and 115 women, with average age 81.2 (range: 59-101) and 84.6 (range: 62-101) respectively). These patients were from 14 institutions, since four institutions did not report any episode.

There was a significant difference between centers, concerning the rate of "number of episodes/number of residents".

One hundred and fourteen of these episodes were positive by PCR and/or array for at least one respiratory virus (mixed infections with two and three viruses were detected, respectively in seventeen and two episodes). Rhinovirus were detected in 53 samples, followed by influenza A(H3) (26), human bocavirus (19), group 1 coronaviruses (14), human metapneumovirus (11), respiratory syncytial virus (5), group 2 coronaviruses (3), and parainfluenza types 1/3 (1) (Figure 1).

Regarding the severity of the infections, most were clinically mild, but dyspnea was reported in episodes at time of collection (47/188), and the clinical situation deteriorated in 29 patients. Of these, 15 hospitalizations were reported, and 3 of them died. Six additional deaths in non-hospitalized patients were reported, giving a total of 9 patients dying with acute respiratory infections during this study. All of the samples from these patients with severe infections were tested by the array cards technique and 7 were positive for *Legionella pneumophila* (in three different ECC), and 5 of them subsequently died.

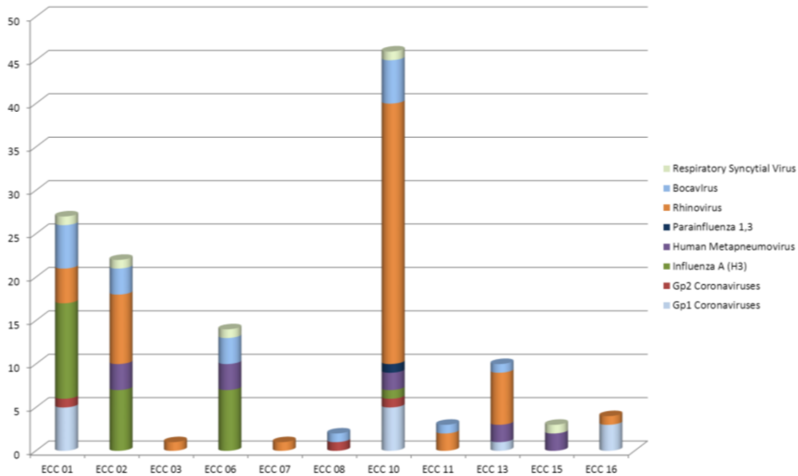

Figure 1. Distribution of the respiratory viruses by ECC

Information was obtained from 159 residents (159/163) about their vaccination status for influenza viruses. The rates of influenza A(H3) infections among vaccinated and unvaccinated residents were quite similar.

Conclusions

One hundred and fourteen out of 188 episodes of acute respiratory infection reported were positive for at least one respiratory virus.

In our study, the vaccination rate was 79%, therefore close to the estimated level of protection to influenza outbreaks. However, influenza A(H3) was the second most prevalent virus and the rates of influenza A(H3) infections among vaccinated and unvaccinated residents were quite similar, suggesting a low efficacy of the vaccine. Concerning the genetic characterization of the influenza strains, samples of the same household share identical sequences, indicating a probable common source of infection.

Overall, the methodology used in this study to detect viruses and atypical bacteria, allowed us to detect an etiologic agent in 63% of the acute respiratory episodes. Most of the respiratory viruses searched in this project were detected, confirming the diversity on the etiology of acute respiratory infections in elderly patients [4]. *Legionella pneumophila* was associated with 5 (5/9) fatalities.

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Ventilation Strategies for Indoor Air Quality Improvement

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Introduction

The indoor air quality (IAQ) does not only depend on the existence and intensity of the pollutant sources (human occupancy, materials emissions and dwellings equipment's emissions, etc.), but also on the site's ventilation (ventilation rates and its efficiency) and the outdoor air quality [1]. Human behaviour may significantly influence the ventilation in the occupied locations and, in some cases, the control of the pollutant source [2]. Several studies have revealed the existence of high levels of carbon dioxide (CO_2) in buildings. For example, in schools such levels are caused not only by high occupation density but also by insufficient ventilation [3-6]. This aspect is also being reported in Portuguese schools [7, 8], where it has been observed that the children activities contribute to an increment of suspended particles in the environment. High CO_2 levels often become associated with high levels of other pollutants [9, 10]. The existence of high levels of pollutants in kindergartens and nurseries [11-13] has also been internationally reported, although, in some cases, this indicates that there may exist even higher exposures to some pollutants in dwellings [13]. The studies in elderly care centres (ECC) are rare, perhaps because the premise that in these places problems associated to IAQ are less important, due to minor occupation density. The most common studies in this field are related to comfort analysis [14].

The result of human metabolism CO_2 measurement, in the absence of other sources (for example combustion) may be used as a way of evaluating the indoor degree of stale air from anthropic origin. Technical international documents, like the ASHRAE 62.1 [15], recommend that the CO_2 level in indoor environments should not exceed 700 ppm above outdoor ambient levels for the odours originated by human metabolism can go unnoticed. This complies with the 1000 ppm (1800 mg/m^3) limit considered in the previous Portuguese building code, “Regulamento dos Sistemas Energéticos de Climatização de Edificios” [16]. The actual regulation in Portugal [17] states a reference limit of 1250 ppm (2250 mg/m^3).

In this document the results of building characteristics found in ECC are reported, such as air permeability of the building envelope and ventilation systems in winter and summer situations. The results of measurements of CO_2 concentration during the day in sitting rooms (short term measurements during approximately 30 minutes) and in nocturne period in sleeping rooms are also presented. Furthermore, the CO_2 levels are used to assess the ventilation rates, either in the nocturne period or in the morning “aeration” of the rooms.

Methodology

General

In the framework of GERIA Project, using the tool available from the Office of Strategic and Planning of the Ministry of Solidarity, Employment and Social

Security (http://www.cartasocial.pt/), 33 ECC in Lisbon were randomly selected in the preliminary phase (but only 18 were studied for IAQ). In the framework of ventilation analysis and IAQ a survey of the characteristics of building stock was made and the measurement of CO_2 concentration, temperature and relative humidity in several sleeping rooms and sitting rooms were collected in two phases: (phase 1) in the 33 ECC including 74 sleeping rooms and 40 sitting rooms (measurement campaign carried out between September 2012 and February 2013) and, later, (phase 2) in a sampling of 18 ECC including 95 sleeping rooms (the measurement campaigns were conducted between November 2013 and March 2014 and between April 2014 and July 2014). In phase 2, 15 sleeping rooms presented measurements with errors, thus just 80 were considered.

Characterization of the building stock

Survey of the building characteristics

This survey aimed to evaluate the construction characteristics and use of 33 ECC that may have influence on ventilation and on IAQ. This survey was always performed by the same technician to keep the consistency of the survey procedure. In the survey were defined thematic groups as follows:

- General information – Identification, general characterization of the building (type of building, number of floors, deployment, year of construction, building occupancy, total area and heated area) and building envelope (zone characterization and pollutants sources);
- Air conditioning of the building – fuel used;
- Water heating – Device type and place;

- Cooking – Place and fuel;
- Other pollutants sources;
- Associated pathologies as fungi and mould;
- User habits – HVAC use (heating and cooling), ventilation (fall/winter, spring/summer);
- Users opinion – Comfort and perception of IAQ.

Monitoring the indoor environment

In the framework of the survey, measurements of CO_2 levels, temperature and relative humidity in the indoor and outdoor environment were made. In this study the level of CO_2 was used as indicator of the pollution in the indoor air caused by human breathing. The recording of the measurements in sleeping rooms was carried out overnight about 12 hours on average and in sitting rooms was carried out during the day for 30 minutes. The measuring devices have the following expanded uncertainty estimates: (i) for CO_2 of U_{CO2}=62 ppm for one measurement of 1000 ppm and U_{CO2}=175 ppm for one measurement of 3000 ppm and (ii) for temperature of U_T=1.16°C. The goal is to find the eventual association between air quality and respiratory health conditions (which is targeted by the selection of higher occupancy and construction envelope less permeable to air).

Assessment of ventilation rates

Concentration decay method and the constant emission method

To evaluate the ventilation rates the concentration decay method and the constant emission method were used. To minimize the impact on routines of users, CO_2 originating from the human breath was used as a tracer gas.

Synthesis of the results

This study allowed identifying the main characteristics of the envelope of the buildings used for ECC in the city of Lisbon. It was seen that (table 1 and 2):

- About half of the ECC (64%) were constructed before 1950 and have aluminium windows which indicates that they were refurbished;
- More than 75% of windows are aluminium-type windows; 50% of the windows are casement windows;
- At least 20% of the windows do not have gaskets;
- 32% of the sleeping room have the blind box included in the external wall which are known as having high air permeability;
- 49% of the sleeping rooms and 80% of the sitting rooms do not have any type of blind box;
- In this sampling no influence on the blind box type was found on the CO_2 concentration.

Table 1. Age of construction

Year of construction		Absolute frequency	Relative frequency
18th Century		3	9%
20th Century	**<1950**	18	55%
	>1950	7	21%
21st Century		5	15%

Table 2. Windows characterization

		Sleeping rooms		Sitting rooms	
		Absolute frequency	Relative frequency	Absolute frequency	Relative frequency
Window frame material	Wood	17	23%	6	15%
	Aluminium	57	77%	31	78%
	Steel	0	0%	3	8%
Opening mode	side-hung casement	38	51%	20	50%
	Sliding	22	30%	13	33%
	bottom hung casement	4	5%	3	8%
	Tilt and turn	10	13%	3	8%
	Fixed window	0	0%	1	3%
	Without gaskets	19	26%	8	20%
Gasket type	Rubber gasket	25	34%	15	38%
	Plushes gasket	30	41%	16	40%
	Inside	24	32%	2	5%
Type of blind box	Outside	14	19%	6	15%
	Without	36	49%	32	80%

These observations can be interpreted as:

- In rehabilitation of the old buildings and in the construction of new buildings the bedrooms and the sitting rooms were not provided by ventilation systems. Ventilation is carried out opening the windows or doors or by the gaps of the opening joints when the windows and doors are closed;

- In new windows, provided with gaskets in the opening joints, the air permeability is lower and is expected that indoor air quality is lower;
- As CO_2 concentration, in this sample, is not influenced by the blind box type, it is expected that their joints are sealed and not contributing to the overall air permeability of the room.

Furthermore, the indoor environment pollution of anthropic origin was assessed through the measurement of the CO_2 levels, which was used as surrogate marker. The following conclusions can be withdrawn:

- In 42% of the bedrooms, in phase 1, the average level of CO_2 during overnight period is above 1250 ppm (figure 1);
- In phase 2, more than 68% of the sleeping rooms during winter and in more than 58% during summer the peak concentration levels of CO_2 are higher than 1250 ppm (maximum concentration). This limit is also exceeded in average during the overnight period in 45% (winter) and 37% (summer) in sleeping rooms without sanitary facilities (figure 2);
- There is no significant decrease in CO_2 concentration in rooms with sanitary facilities (figure 2);
- Only 15% of the sitting rooms presented average CO_2 concentration levels above 1250 ppm (figure 3).

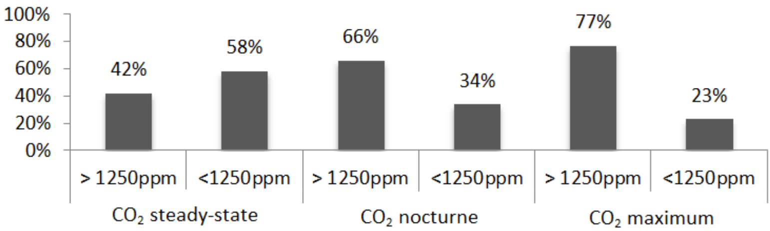

Figure 1. Overall measurement results of CO_2 concentration in sleeping rooms (phase 1)

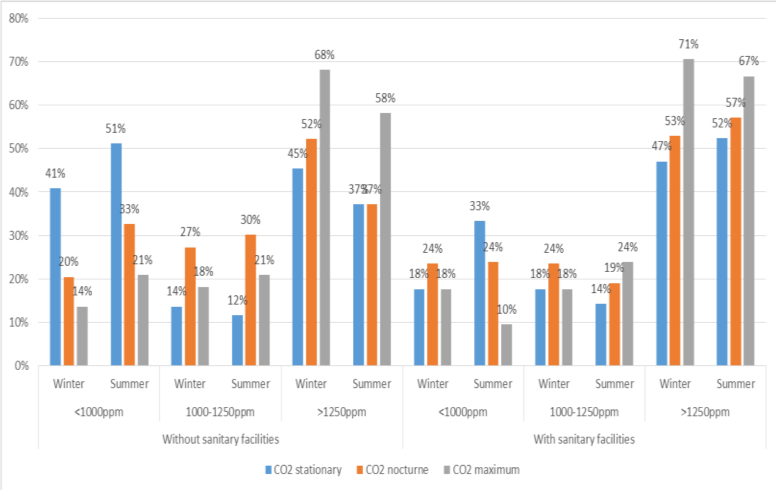

Figure 2. Distributions of the different CO_2 levels

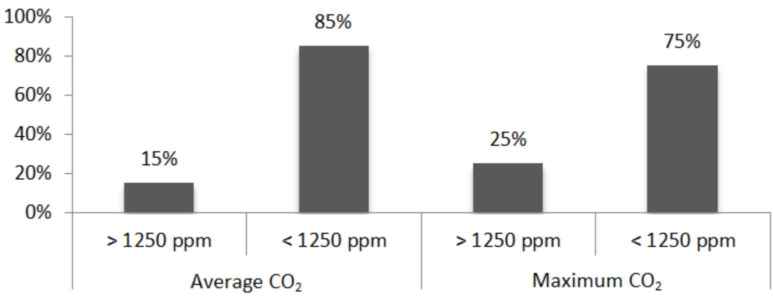

Figure 3. CO_2 concentration measurement results for sitting rooms

These CO_2 concentration levels are quite high and indicate that ventilation rates shall be improved in bedrooms. Sitting rooms do not show clearly ventilation problems.

The ventilation rates were also estimated using the continuum evolution concentration of CO_2 levels over time.

- In phase 1, 50% of the bedroom ventilation rates stay bellow 0.6 rph and 23% stay above 0.9 rph (figure 4);
- In phase 2, at least 37.5% (6 rooms) of sleeping rooms have ventilation rates below 0.4 rph and at least 80% have ventilation rates bellow 0.60 rph (figure 5);
- In phase 2, in winter, one room presented a ventilation rate higher than 1 rph (figure 5).

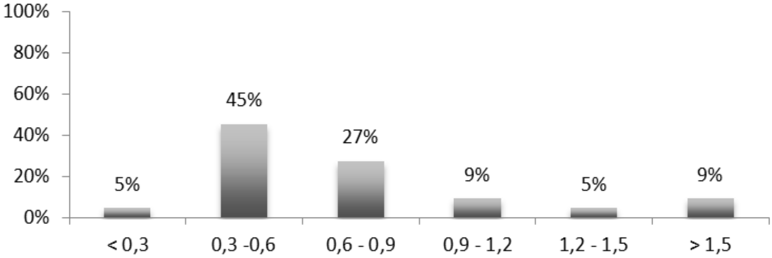

Figure 4. Phase 1 sleeping rooms ventilation rates

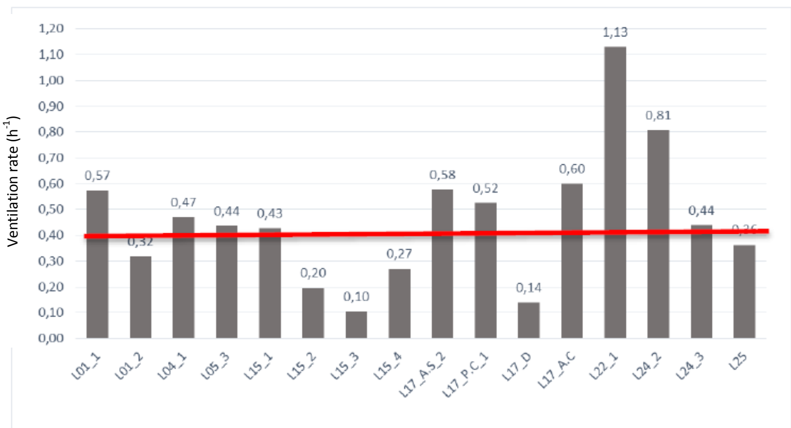

Figure 5. Results of ventilation rates in winter using constant emission method (phase 2)

These observations show that in most rooms there is a ventilation rate too low, that impair the indoor air quality, and in some cases (one) the ventilation rate is too high, that can cause discomfort problems. It is clear that ventilation systems shall be applied in to rooms in order to provide air with a more regular flow rate, avoiding discomfort or poor indoor air quality.

Engineering rules for application of ventilation systems to ECC and, especially, to bedrooms shall be developed and applied. In the context of this work a set of rules is proposed.

Recommendations on Ventilation

General principles

It must be ensured permanently that there is a healthy indoor environment, comfortable and suitable for the development of activities in ECC. For this purpose, it should be ensured adequate quality of indoor air.

The indoor air quality must be ensured by using the following strategies:

i. Unpolluted outdoor air intake;
ii. Limitation of emissions from indoor sources;
iii. Indoor pollutants captured near intense sources and exhausted to outdoor;
iv. Dilution of emissions from indoor diffuse sources through appropriate ventilation flowrate;
v. Use of displacement ventilation in order to maximize the effectiveness of ventilation;

vi. Exhaust of the polluted indoor air in a way that minimizes the possibility of re-entry into the building itself or neighbouring buildings.

Strategies intended to minimize the discomfort of the occupants against the admission of significant flow of air at outside temperature should be used. These strategies will vary with the type of ventilation system and can be of the following types:

i. Conditioning the intake air in the spaces;

ii. Outside air inlet shall be located in a way that the incoming jets flow outside the occupied zone;

iii. Restrict the envelope air permeability in order that strong wind does not cause excessive ventilation flowrate;

iv. Provide the service rooms (kitchen, laundry, etc.) with compensation openings for outside air intake, if necessary, in order to avoid excessive ventilation flow in the main rooms (bedrooms, sitting rooms, activity rooms, offices, canteens, etc.).

The application of these strategies implies that the outside air intake is essentially made in the main rooms where people are staying for long and where pollution sources are weaker. Complementary the exhaust should occur in service rooms (kitchens and sanitary facilities) or other rooms with strong pollution sources. The ventilation system should be designed to avoid pollutant contamination from service rooms to main rooms. When the joint ventilation scheme is insufficient to prevent such contamination, complementary strategies shall be used, for example:

i. Increasing the distance between service rooms and main rooms and/or closing connection doors;

ii. Design and build a separate ventilation system for service rooms.

A ventilation system able to keep the indoor air quality in all rooms shall be designed, built and properly maintained. This ventilation system shall minimize discomfort and shall respect energy conservation principles. The design ventilation flowrate must be reached even with windows and doors closed, as far as possible. This ventilation system shall be designed to take into account the interactions between the different building compartments and the natural actions of wind and temperature difference between indoor and outdoor. These ventilation systems may be natural, mechanical or mixed.

In buildings in use which are not equipped with efficient ventilation systems, procedures involving the opening of doors and windows (which should be limited in time to minimize discomfort) shall be used in order to keep adequate indoor air quality.

Design flowrates

Minimum design flowrates shall be determined following the regulation RECS [17], Portaria n.º 353-A/2013 [18] and Despacho (extrato) n.º 15793-K/2013 [19].

Existing buildings

In existing buildings practices that allow ventilation with minimum impact on indoor comfort (during the period of rooms occupancy) should be adopted.

Whenever it is not raining and when the outside temperature allows the following practices are recommend:

i. Keep the windows totally or partially opened whenever the outside temperature and the lack of rain allows.

ii. Prefer the use of bottom hung casement windows (or tilt and turn windows in ventilation mode) because the impact of outside air flow in the occupied zone is lower.

iii. Keep the internal doors open when this is compatible with the privacy.

Whenever it is not possible to keep the windows opened all time the following practices are recommend:

i. Keep the external windows and internal doors opened in order to generate air drafts between different facades for about one hour (this may be performed during the cleaning period of the bedrooms or sitting rooms). This procedure should be done when there are no occupants in rooms or when they are staying in other compartments. This procedure is intended to prevent that the polluted air is kept indoor day after day. It should be done long before the occupants return to the room so that the unpolluted air can reach the temperature equilibrium (and thus have a smaller impact on thermal comfort). In the summer this procedure can be used to cool down the indoor environment.

ii. Use the lunchtime period, when occupants leave the sitting rooms and bedrooms to generate air drafts between different facades for about one hour.

iii. Keep the internal doors open when this is compatible with the privacy.

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Impact of Indoor Air Quality on Health

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Introduction

In GERIA, one of the main purposes was to study to which extent the indoor air quality (IAQ) in elderly care centers (ECC) was related to the respiratory health of the residents, particularly the elderlies.

Methods

In order to assess the association between indoor air quality and respiratory health, we collected data through a questionnaire comprising different sections. These sections intended to evaluate the presence of chronic respiratory diseases, cognitive and depression status. The instruments used were the Bronchial Obstructive Lung Disease (BOLD) study questionnaire, the Mini Mental State Examination (MMSE) and the Geriatric Depression Scale

(GDS-15). Indoor air quality was assessed during Phase II of the GERIA study according to a methodology previously described in this book.

The considered outcome variables were the presence of chronic bronchitis, frequent cough, current wheezing, asthma, allergic rhinitis and spirometric parameters, namely forced expiratory volume in one second (FEV_1). Median bedroom´s steady carbon dioxide (CO_2) measured at night, total volatile organic compounds and $PM_{2.5}$ (fine particles with an aerodynamic diameter smaller than 2.5 micron) concentrations were the studied exposures. Gender, age, education level, marital status, smoking habits, past occupational exposure to dust, attending nursing home time, presence of cognitive impairment, presence of depression, indoor humidity and temperature, were considered as potential confounders.

In order to evaluate the association between IAQ and health outcomes regression models that considered the structure of dependence between individuals within the same ECC were used. Parameters of these models were estimated through mixed effects models. Crude and adjusted odds-ratios with 95% confidence intervals were calculated.

Results

In Phase II, frequent cough was the most common reported symptom (21%), followed by wheezing in the previous 12 months (16%). Allergic rhinitis and asthma were the most reported diseases (16% and 7%, respectively).

Indoor air quality data was available for 813 nursing home residents. Median bedrooms steady CO_2 measured at night was 1189 ppb (P_{25}-P_{75}: 1004-1443 ppb). Median exposure to total volatile organic compounds (TVOC) and $PM_{2.5}$ was 105 μg/m^3 (P_{25}-P_{75}: 7-212 μg/m^3) and 32 μg/m^3 (P_{25}-P_{75}: 13-82 μg/m^3) respectively.

In the preliminary analysis, after adjusting for confounders, we found associations between steady CO_2 (measured in the nursing home residents' bedroom, at night) and some of the respiratory outcomes. In this sense, each increase of 200 ppm of steady CO_2 was associated with:

- 27% more odds of reporting asthma (p=0.076);
- 29% more odds of report wheezing in the previous three months (p=0.010);
- 28% more odds of being hospitalised in the previous three months (p=0.035);
- 3.7% mean reduction of the FEV_1 (p=0.026).

Conclusion

The results so far showed that there is a relationship between bedroom ventilation during the night and the presence of respiratory symptoms, respiratory diseases and lung function defects.

Summary of Conclusions and Recommendations for Improvement in Respiratory Health in Elderly Care Centers

Síntese das Conclusões e Recomendações para a Melhoria na Saúde Respiratória em Equipamentos Residenciais para Pessoas Idosas

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The GERIA Project - Geriatric Study in Portugal on Health Effects of Air Quality in Elderly Care Centers - took place in the two main Portuguese cities, Lisbon and Oporto. Within its 1st phase, 931 residents from 53 elderly care centers (ECC) were studied. The 2nd phase completed a thorough analysis based on the preliminary phase study, which involved 817 residents from 18 ECC in Lisbon.

The primary long-term purpose of the GERIA study was to contribute to improve the health of older persons living in ECC.

O Projeto GERIA - Estudo Geriátrico dos Efeitos na Saúde da Qualidade do Ar Interior em Lares da 3ª Idade de Portugal - teve lugar nas duas principais cidades portuguesas, Lisboa e Porto. Na sua 1ª fase, foram estudados 931 residentes de 53 equipamentos residenciais para pessoas idosas (ERPI). A 2ª fase completou uma análise exaustiva com base na fase preliminar do estudo e envolveu 817 residentes de 18 ERPI, em Lisboa.

O objetivo principal do projeto GERIA foi contribuir para a promoção da saúde das pessoas que residem em ERPI.

GERIA provides valuable information on the main characteristics of indoor air, its pollutants and buildings that have influence in indoor air quality (IAQ). Thermal comfort, levels of carbon dioxide, microbiological agents and particulate matter where somewhat unacceptable in 20 to 35% of the ECC rooms studied. The majority ECC had satisfactory ventilation rates, although most of the buildings were old and with windows that did not provide indoor comfort.

It was possible to evaluate the impact on health and quality of life of indoor environment pollutants and the individual's response to these. Health perception was low, particularly for those with respiratory diseases, but most of the residents had a favorable perception of their overall quality of life (QoL), which included ECC environmental conditions.

Health problems were analysed according to the registration of

O projeto GERIA fornece importantes informações sobre as principais características do ar interior, seus poluentes e edificado que têm influência na qualidade do ar interior (QAI). Conforto térmico, níveis de dióxido de carbono, agentes microbiológicos e matéria particulada apresentaram níveis inaceitáveis em 20 a 35% dos compartimentos estudados. A maioria dos ERPI tinham taxas de ventilação satisfatórias, sendo que a maioria dos edifícios eram velhos e com janelas que não proporcionam conforto interior.

Foi possível avaliar o impacto dos poluentes do ambiente interior na saúde e qualidade de vida dos indivíduos. A perceção de saúde foi baixa, especialmente para aqueles com doenças respiratórias, mas a maioria dos residentes tinha uma perceção favorável da sua qualidade de vida (QDV), que incluía condições ambientais do ERPI.

Os problemas de saúde foram analisados de acordo com o registo de diseases and medications and report of symptoms. Cardiovascular problems, mainly high blood pressure related, were highly prevalent. Digestive and psychological problems were also very prevalent, in general due to protective medication related to polypharmacy, or to sleep needs. Next, metabolic problems mainly due to diabetes mellitus and degenerative musculoskeletal situations, played a significant expression. Cognitive and affective problems affected about half of the residents, registering considerable number of elderly treated with antidepressants. Neurological disorders, especially disorders of balance, but also sequelae of stroke, affected a third of the individuals. Blood and nonspecific and respiratory problems affected about one-fifth of the elderly.

For those with respiratory diseases, the most reported were allergic rhinitis and asthma, presenting frequent cough and wheezing in the previous 12 months. It was shown a relationship between bedroom

doenças, terapêutica e sintomas. Problemas cardiovasculares, relacionados principalmente com hipertensão, foram altamente prevalentes. Problemas digestivos e psicológicos foram, também, muito prevalentes, em geral devido à toma de medicação de proteção relacionada com a polimedicação, ou à toma de hipnóticos. Em seguida, problemas endocrino-metabólicos, sobretudo devido a *diabetes mellitus* e situações degenerativas do sistema musculo-esquelético, apresentaram uma expressão significativa. Problemas cognitivos e emocionais afetaram cerca de metade dos residentes, verificando-se um número considerável de idosos tratados com antidepressivos. Alterações neurológicas, em particular distúrbios do equilíbrio, mas também sequelas de acidente vascular cerebral, afetaram um terço dos indivíduos. Problemas de sangue, inespecíficos e respiratórios afetaram cerca de um quinto dos idosos.

Nos idosos com doenças respiratórias, as mais relatadas foram rinite alérgica e asma, referindo tosse frequente e ventilation during the night, and the presence of respiratory symptoms, respiratory diseases and lung function defects.

The microbiological characterization of the acute respiratory episodes was positive in two thirds of all cases and detected a great diversity of agents. The genetic characteristics of the influenza strains on samples of the same household indicated a probable common source of infection.

In order to contribute to improve the health of residents living in ECC related to the IAQ, it is very important to revise overcrowding, change inadequate ventilation, identify sources of contamination, control thermal parameters and adjust clothing to environmental characteristics.

pieira nos últimos 12 meses. Demonstrou-se uma relação entre a ventilação do quarto, durante a noite, e a presença de sintomas respiratórios, doenças respiratórias e alterações na função respiratória.

A caracterização microbiológica dos episódios respiratórios agudos reportados foi positiva em dois terços dos casos, detetando-se uma grande diversidade de agentes. As características genéticas das estirpes da gripe em amostras do mesmo ERPI indicando uma provável fonte comum de infeção.

A fim de contribuir para a melhoria da saúde dos residentes de ERPI relacionada com a QAI, é muito importante rever a sobrelotação, mudar ventilação inadequada, identificar fontes de contaminação, controlar parâmetros térmicos e ajustar as roupas às características ambientais.

We suggest the following recommendations:

- Open external windows daily in all rooms, for about one hour, and close the internal doors to prevent air drafts.
  - In days of bad weather, open the windows never less than 15 minutes;
  - During Spring, open the windows in the early afternoon, when pollens are dispersed in the higher layers of the atmosphere and close them around 6 p.m., when pollens go back to the ground.
  - The aeration should be done when there are no occupants in these divisions, preferring the lunchtime period, when residents are in the dining room;
  - So that the renewed air can reach temperature equilibrium while minimizing the impact on the thermal comfort, close the windows some time before the

Sugerimos as seguintes recomendações:

- Abrir as janelas exteriores diariamente, em todas as divisões, durante cerca de uma hora, fechando as portas interiores de forma a evitar correntes de ar.
  - Nos dias de mau tempo, arejar nunca menos de 15 minutos;
  - Durante a primavera, arejar no início da tarde, quando os pólens se encontram dispersos nas camadas mais altas da atmosfera, fechando as janelas pelas 18 horas, quando os pólens voltam ao solo;
  - O arejamento deve ser feito quando não há ocupantes nessas divisões, preferindo o período de almoço, quando os residentes estejam na sala de refeições;
  - Para que o ar renovado possa alcançar o equilíbrio de temperatura, minimizando o impacto sobre o conforto térmico, fechar as janelas algum tempo antes do regresso dos ocupantes.

return of the occupants.

- Keep internal doors open, whenever compatible with the privacy of residents;
- Keep an air temperature of comfort, which should take into account the activity performed by residents:
  - In the absence of physical activity, closer to 25°C;
  - In the presence of physical activity, lower temperature, however higher than 20°C;
- Keep the relative humidity between 25% and 55%;
- Avoid using heating vent because it promotes the suspension of dust in the air preferring to use convector heaters;
- If there is air conditioning do filter maintenance often;
- In case of works in the building, keep the divisions not intervened closed;
- After baths, always close the door

- Manter as portas interiores abertas, sempre que compatível com a privacidade dos residentes;
- Manter uma temperatura ambiente de conforto, que deve ter em conta a atividade desempenhada pelos residentes:
  - Na ausência de atividade física, próxima dos 25°C;
  - Na presença de atividade física, temperatura mais baixa, contudo superior a 20°C;
- Manter a humidade relativa entre 25% e 55%;
- Evitar o uso de termoventilador, pois promove a suspensão do pó no ar, preferindo o uso de termoconvectores;
- Caso exista ar condicionado fazer a manutenção dos filtros frequentemente;
- Em caso de obras no edifício, manter as divisões não intervencionadas fechadas;
- Depois dos banhos, fechar sempre a porta das casas de banho e abrir a

of the bathroom and open the window or turn on the extractor, preventing water vapor from spreading through the building;

- During food preparation, always close the kitchen door and open the windows, preventing fumes and odors from spreading through the building. If there is an exhauster, always turn it on and clean the filters regularly;
- It is recommend placing forced extractors in internal bathrooms, kitchen and in rooms with high pollution sources (e.g. where smoking is allowed, atelier, …), avoiding contamination to other divisions;
- Ironing clothes in a location that has forced extraction or window, always closing the door, preventing water vapor and particulate matter from spreading through the building. Do not iron clothes in the rooms nor sitting rooms.

In the rehabilitation of old buildings and construction of new ones:

janela ou ligar o extrator, evitando que o vapor de água se espalhe pelo edifício;

- Durante a confeção dos alimentos, fechar sempre a porta e abrir as janelas da cozinha, evitando que vapores e odores se espalhem pelo edifício. Caso exista exaustor, ligá-lo sempre e limpar os filtros com regularidade;
- É aconselhável a colocação de extratores forçados nas casas de banho interiores, na cozinha e em salas com fontes de poluição elevada (p.ex. onde seja permitido fumar, oficinas, …), evitando a contaminação para outras divisões;
- Passar a roupa a ferro num local que disponha de extração forçada ou janela, fechando sempre a porta, evitando que o vapor de água e partículas em suspensão se espalhem pelo edifício. Não passar a roupa a ferro nos quartos nem nas salas.

Na reabilitação dos edifícios antigos e na construção de novos edifícios:

- Bedrooms and sitting rooms should be equipped with ventilation system;
- Prefer bottom hung or tilt and turn windows, because the impact of outside air flow in the occupied zone is smaller.

The cleaning should be done when there are no occupants in the divisions, being in other divisions.

- Wash weekly bed clothes at 60°C;
- Wash pillows, duvets and blankets every three months, if possible at 60°C;
- Avoid flannel bed linen, wool blankets and feather duvets, opting for cotton linen and synthetic duvets that can be washed at 60°C;
- Avoid storage underneath beds that make it difficult cleaning;
- Avoid excessive decorative items that make it difficult cleaning;
- Clean the dust with a slightly damp cloth;

- Os quartos e as salas devem ser equipados com sistemas de ventilação;
- Preferir janelas de batente ou oscilobatente, porque o impacto do fluxo de ar exterior na zona ocupada é menor.

A limpeza deve ser feita quando não há ocupantes nas divisões, encontrando-se noutros compartimentos.

- Lavar semanalmente as roupas das camas a 60°C;
- Lavar as almofadas, os edredões e os cobertores trimestralmente, se possível a 60°C;
- Evitar os lençóis de flanela, os cobertores de lã e os edredões de penas, optando por roupa de algodão e edredões sintéticos, que possam ser lavados a 60°C;
- Evitar armazenamento debaixo das camas, pois dificulta a limpeza;
- Evitar o excesso de artigos de decoração que dificultem a limpeza;
- Limpar o pó com um pano ligeiramente húmido;

- Avoiding the use of "sprays", air fresheners and detergents with intense smell, since these products may be irritating to the respiratory tract, and promote aeration after cleaning;
- Clean well the dust on the bookshelves, removing the books regularly. It is preferable to keep the books in closed bookshelves to avoid dust accumulation;
- Avoid excessive carpets, fitted carpeting, plaids on the sofas and draperies;
- Vacuuming often carpets, fitted carpeting and sofas;
- Wash carpets and curtains every three months, if possible at 60°C;
- Wash often carpets, fitted carpeting and sofas, at least 2 times per year, if possible at 60°C;
- Prefer vacuuming instead of sweeping;
- Change vacuum filter regularly and if possible, use a cleaner with high

- Evitar a aplicação de “sprays”, o uso de ambientadores e detergentes com cheiro intenso, uma vez que esses produtos podem ser irritantes para as vias respiratórias, promovendo o arejamento após a limpeza;
- Limpar bem o pó das estantes, retirando os livros regularmente. É preferível guardar os livros em armários fechados para evitar acumulação de pó;
- Evitar o excesso de tapetes, alcatifas, mantas nos sofás e reposteiros;
- Aspirar frequentemente tapetes, alcatifas e sofás;
- Lavar tapetes e cortinados trimestralmente, se possível a 60°C;
- Lavar frequentemente carpetes, alcatifas e sofás, pelo menos 2 vezes por ano, se possível a 60°C;
- Preferir aspirar a varrer;
- Trocar o filtro do aspirador regularmente e, se possível, utilizar um aspirador com filtro de alta eficiência (HEPA – high efficiency

efficiency filter (HEPA - high efficiency particulate air);

- Avoid wallpaper, that is a focus of development of mites and fungus. If there is wallpaper, it should be replaced when becomes damaged.

If there are moisture spots on the walls and ceilings, after detect and solve triggering factors:

- Wash walls and ceilings with dilute bleach in water, at a ratio of 1 of bleach to 10 of water, and then aerate well the division;
- Paint walls and ceilings with antifungal paint and aerate well the division.
- It is not advisable to have plants and aquariums in the interior, particularly near bedrooms, as they are a focus of moisture;
- In elderly with respiratory vulnerability avoid contact of animals with fur or feathers.

particulate air);

- Evitar o papel de parede, pois é um foco de desenvolvimento de ácaros e fungos. Se houver papel de parede, deve ser substituído assim que ficar deteriorado.

Caso existam pontos de humidade nas paredes e tetos, após detetar e resolver os fatores desencadeantes:

- Lavar as paredes e tetos com lixívia diluída em água na proporção de 1 medida de lixívia para 10 de água, e arejar bem a divisão em seguida;
- Pintar as paredes e tetos com tintas antifúngicas e arejar bem a divisão.
- Não é aconselhável a existência de plantas e aquários no interior, principalmente junto aos quartos, uma vez que são foco de humidade;
- Nos idosos com vulnerabilidade respiratória evitar o contacto de animais com pêlo ou penas.

Taking into account the relationship between IAQ and respiratory vulnerability found in GERIA project, the proposed recommendations are guidelines to lead to health and quality of life improvement of elderly residents in ECC.

Tendo em conta a relação entre a QAI e a vulnerabilidade respiratória encontrada no projeto GERIA, as recomendações propostas constituem orientações que pretendem conduzir à melhoria da saúde e qualidade de vida dos idosos residentes em ERPI.

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