ENGENHARIAS, TECNOLOGIA, GESTÃO E TURISMO
ENGINEERING, TECHNOLOGY, MANAGEMENT AND TOURISM
INGENIERÍA, TECNOLOGÍA, ADMINISTRACIÓN Y TURISMO

millenium

Millenium, 2(Edição Especial Nº16)

en

QUALIDADE DO AR INTERIOR NUMA ESTRUTURA RESIDENCIAL PARA PESSOAS IDOSAS E SEUS EFEITOS NA SAÚDE DOS TRABALHADORES E UTENTES

INDOOR AIR QUALITY IN A RESIDENTIAL FACILITY FOR THE ELDERLY AND ITS EFFECTS ON THE HEALTH OF WORKERS AND USERS REVIEW

CALIDAD DEL AIRE INTERIOR EM UMA ESTRUCTURA RESIDENCIAL PARA PERSONAS MAYORES Y SUS EFECTOS EM LA SALUD DE TRABAJADORES Y USUARIOS

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RECEIVED: 27th January, 2024
REVIEWED: 01st January, 2025
ACCEPTED: 23rd January, 2025
PUBLISHED: 13th February, 2025

DOI: https://doi.org/10.29352/mill0216e.34480

RESUMO

Introdução: As avaliações da Qualidade do Ar Interior apresentam um desafio muito significativo, nomeadamente quando as análises são realizadas em edifícios que incluem um ambiente particularmente sensível e vulnerável à população idosa.
Objetivo: Avaliar a qualidade do ar interior de uma Estrutura Residencial para Pessoas Idosas (ERPI) e relacionar com os efeitos adversos na sua saúde dos seus ocupantes
Métodos: O local de estudo decorreu numa ERPI localizada em Portugal. Procedeu-se à avaliação da qualidade do ar, através da medição dos parâmetros ambientais formaldeído (CH_2O), monóxido de carbono, dióxido de carbono, $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0}$, PM_{10}, PM_{Totais}, as partículas ultrafinas e variáveis meteorológicas, temperatura e humidade relativa no interior e no exterior da ERPI.
Resultados: Verificou-se, que a temperatura foi o único parâmetro que apresentou valores mais elevados no exterior em comparação ao interior da instituição. Além disso, foi a temperatura e o CH_2O os únicos parâmetros que registaram valores superiores no período da tarde em comparação com o período da manhã. Neste estudo o sintoma mais prevalente entre os ocupantes foi as dores de cabeça, seguido de prurido, ardor ou irritação nos olhos e crise de espirros.
Conclusão: A qualidade do ar e o conforto térmico da maioria das divisões estudadas eram adequadas, mas a concentração de CH_2O pode indicar a possibilidade de realizar intervenções corretivas, como reduzir as fontes emissoras e aumentar a ventilação.

Palavras-chave: qualidade do ar interior; estrutura residencial para pessoas idosas; trabalhadores; utentes; saúde

ABSTRACT

Introduction: Indoor Air Quality assessments present a very significant challenge, particularly when the analyses are carried out in buildings that include an environment that is particularly sensitive and vulnerable to the elderly population.
Objective: To assess the indoor air quality of a Residential Structure for the Elderly (RSEI) and relate it to the adverse effects on the health of its occupants.
Methods: The study site was an RSE located in Portugal. Air quality was assessed by measuring the environmental parameters formaldehyde (CH_2O), carbon monoxide, carbon dioxide, $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0}$, PM_{10}, PM_{Totals}, ultrafine particles, meteorological variables temperature, and relative humidity inside and outdoor space of the RSE.
Results: Through the analysis of the results, it was observed that the temperature was the only parameter that presented higher values outside compared to inside the institution. This is because the measurements were carried out during spring, with days of intense heat. In addition, temperature and CH_2O were the only parameters that registered higher values in the afternoon compared to the morning. In this study, the most prevalent symptoms among occupants were headaches, followed by itching, burning, irritation in the eyes, and sneezing.
Conclusion: The air quality and thermal comfort of most of the rooms studied were reasonable, but the CH_2O concentration may indicate the possibility of carrying out corrective interventions, such as reducing the emitting sources and increasing ventilation.

Keywords: indoor air quality; nursing home; workers; users; health

RESUMEN

Introducción: Las evaluaciones de la Calidad del Aire Interior presentan un desafío muy importante, particularmente cuando los análisis se realizan en edificios que incluyen un entorno especialmente sensible y vulnerable para la población de edad avanzada.
Objetivo: Evaluar la calidad del aire interior de un Centro Residencial para Ancianos (ERPI) y relacionarla con los efectos adversos sobre la salud de sus ocupantes.
Métodos: El lugar del estudio se llevó a cabo en un ERPI ubicado en Portugal. La calidad del aire se evaluó midiendo los parámetros ambientales formaldehído (CH_2O), monóxido de carbono, dióxido de carbono, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, PM_{10}, $PM_{Totales}$, partículas ultrafinas y meteorológicos variables, temperatura y humedad relativa dentro y fuera del ERAM.
Resultados: Se encontró que la temperatura fue el único parámetro que presentó valores mayores en el exterior respecto al interior de la institución. Además, la temperatura y el CH_2O fueron los únicos parámetros que registraron valores superiores en la tarde respecto a la mañana. En este estudio, el síntoma más frecuente entre los ocupantes fue el dolor de cabeza, seguido de picor, quemazón o irritación en los ojos y estornudos.
Conclusión: La calidad del aire y el confort térmico de la mayoría de los ambientes estudiados fueron adecuados, pero la concentración de CH_2O puede indicar la posibilidad de realizar intervenciones correctivas, como reducir las fuentes de emisión y aumentar la ventilación.

Palabras clave: calidad del aire interior; estructura residencial para personas mayores; trabajadores; usuarios; salud

DOI: https://doi.org/10.29352/mill0216e.34480

INTRODUCTION

Indoor air quality (IAQ) is currently a concern because air pollutants can pose health risks and comfort issues to building occupants. IAQ in healthcare and aged care facilities is particularly important because these facilities receive both workers and the public, including susceptible populations such as the elderly, patients with chronic respiratory diseases, and immunocompromised patients (Ferreira, Loureiro, & Seco, 2021).

In Europe, workers spend more than 30% of their time working indoors (Schweizer, et al., 2007), and the elderly are widely exposed to indoor air because they spend more than 80% of their time at home and/or in Residential Facilities for the Elderly (Matz, et al., 2014). In this sense, respiratory diseases in elderly residents in institutions of this typology have been reported due to exposure to indoor air pollutants (Bentayeb, et al., 2015).

The increasing frequency of people in indoor environments, such as homes, offices, schools, commercial or administrative public places, and vehicles, has caused concern about IAQ. This is particularly important for cities and urban areas, as 80-90% of time is spent indoors. As a result, people are more vulnerable to indoor air pollution than to outdoor air pollution (Ferreira & Cardoso, 2014; Loureiro, et al., 2017). Air quality in nursing homes can affect the health and comfort of all the elderly and workers. In these places, great care needs to be taken with air quality because, in addition to the problems related to occupational health, great care needs to be taken with the elderly, as they belong to a vulnerable age group (Loureiro et al., 2017).

Air pollution is a public health problem, with humans being a major contributor to the emission of the most common pollutants into the atmosphere. These pollutants include particulate matter (such as $PM_{2,5}$ and PM_{10}), carbon monoxide (CO), carbon dioxide (CO_2), CH_2O, and VOC (Palmisani et al., 2021; Ferreira & Barros, 2022).

Older individuals spend approximately 19-20 h/day indoors, and these individuals are particularly at risk of the harmful effects of air pollutants, even at low concentrations, due to their reduced immune defenses and multiple underlying chronic diseases. Exposure to poor IAQ can produce or exacerbate eye irritation, nausea, upper respiratory complications, cognitive impairment, asthma, respiratory infections, cardiovascular disease, chronic obstructive pulmonary disease and cancer (Ferreira, Loureiro, & Seco, 2021). Thus, IAQ is a particular concern for nursing home residents important for both health and quality of life.

In this sense, the term Sick Building Syndrome (SBS) emerges, which is used to describe cases of discomfort and/or acute non-specific symptoms reported by occupants of certain buildings (Abreu, Lanzinha, & Nepomuceno, 2011). IAQ may be the main contributor to SBS, i.e., a medical condition in which some users of a given building report symptoms at the dermatological, respiratory, ENT, ophthalmological, and even neurological and/or nausea levels. This concept emerged in 1983 through the World Health Organization (WHO). This syndrome has the capacity to negatively interfere with productivity and absenteeism in the case of workers, and the fragile health and comfort of the elderly, and results from internal and external elements of the building. It is related to the concentration of CO_2, CH_2O, VOC, ozone, PM_{10}, bacteria, and fungi (Surawattanasaku et al., 2022).

Quality of life is directly linked to the quality levels of the air we breathe. This is because breathing polluted air can be harmful to workers' health, comfort, and productivity (Santos, Almeida, & Oliveira, 2018; Ferreira & Cardoso, 2014). To date, no studies have been found that simultaneously address IAQ and thermal comfort (TC) in older adults. In addition, there is a scarcity of evidence on the impact of indoor pollutants, such as particulate matter (PM), bioaerosols, and VOC, on common diseases in older adults. Therefore, there is a need to investigate IAQ, TC, and the health of older people. Identifying subgroups susceptible to TC and pollutants is especially important to designing appropriate and effective interventions to maintain a healthy and comfortable environment (Carvalho et al., 2020; Ferreira & Barros, 2022).

This can lead to numerous symptoms, most commonly those like the symptoms that affect us when we have the flu or a cold: headaches, fatigue, nasal congestion, coughing, sneezing, and irritation of the mucous membranes (Abreu, Lanzinha, & Nepomuceno, 2011; Santos, Almeida, & Oliveira, 2018). According to the WHO, 20% of building occupants complain of physical problems, acute symptoms, and discomfort when they enter a building and that, after leaving the building, the symptoms gradually disappear or are attenuated. Taking SBS into account, we can see that ventilation is fundamental, as it is the process by which new air is intentionally supplied and stale air is removed (Thach, et al., 2019).

In view of the above, the main objective of this study was to assess the indoor air quality of a Residential Structure for the Elderly and relate it to the adverse effects on the health of its occupants (workers and elderly).

1. METHODS

1.1 Sample

The sample of this study consisted of 3 common rooms, 4 bedrooms, and 1 dining room of a Residential Structure for the Elderly located in Portugal, as well as 21 individuals who participated in the study. Of these, 57.1% were workers, and the rest were users; 85.7% were female, and 14.3% were male. This was a descriptive observational study, analytical in nature, with a cross-sectional timeline and level II knowledge. The sampling method applied was non-probabilistic and the technique was by convenience.

DOI: https://doi.org/10.29352/mill0216e.34480

1.2 Data collection instruments and procedures

The data collection consisted of two distinct stages, firstly the air quality assessment, through the measurement of the environmental parameters CH_2O, CO, CO_2, $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0}$, PM_{10}, PM_{Totals} and ultrafine particles (UFP) and meteorological variables T° and Rh inside 3 common rooms, 3 double rooms, and 1 single room with bedridden user 1 Canteen and in the outdoor space of the RSE under study, the second stage consisted of the application of a questionnaire addressed to the workers and users who were present in the Institution during the period in which the measurements occurred.

Regarding the first stage of the investigation, the measurements were carried out over a period of 30 minutes, with minute-by-minute sampling, before and after occupancy in each room (room 1, room 2, room 3), in the rooms (Bedroom 1, Bedroom 2, Bedroom 3 and bedridden room) and the Canteen in the institution, in the morning and afternoon on different days. For the measurements, the equipment was placed in the most central position possible of each space evaluated and, approximately, at the height of the airways of occupants in the sitting position. The Outdoor Air Quality measurements took place outside the Institution, at the same height as the IAQ measurements, but at least 1.0 m away from the exterior walls.

Portable real-time reading equipments was used to collect the parameters. With regard to the parameters CO, CO_2, T° and Hr, the equipment Q-TrackTM Plus, brand TSI, model 8552/8554, was used to evaluate the concentrations of $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0}$, PM_{10} e PM_{Totals}, the equipment Particles Counters, brand Lighthouse Worldwide Solutions, model 3016 LAQ, for the evaluation of ultrafine particles the equipment P-Track Ultrafine Particle Counter, brand TSI, model 8525 and for the evaluation of CH_2O the equipment Formaldehyde Monitor (model Formalmeder htv, brand PPM) was used.

It was considered as a reference for the maximum concentration of CO, 9 ppm, for CO_2, 1250 ppm, for CH_2O, 0,08 ppm, para as $PM_{2,5}$, 0,025mg/m^3, para as PM_{10}, 0,05 mg/m^3, as referred to in Ordinance No. 138G/2021, of July 1. Given the lack of reference values for the concentration of pollutants $PM_{0,5}$, $PM_{1,0}$ e $PM_{5,0}$ e PM_{Totals}, and for the concentration of UFP in indoor air, the analytical mean values recorded in outdoor air measurements were taken as a reference point. According to Decree-Law no. 243/86 of August 20, the reference comfort environmental conditions for T˚ should oscillate between 18 and 22˚C, while Rh should oscillate between 50 and 70%.

Regarding the second stage of research, the questionnaire was divided into three fundamental parts: the first addressed the personal data of the occupants of the institution; the second part was related to the perception of the indoor air quality of the respondents, the third was intended to obtain data on the health condition of the individuals, that is, if there was a history of chronic disease and symptoms of respiratory and allergic disease.

After receiving a positive opinion from the ethics committee (Written opinion no 33_CEIPC/2023), a request was made to the institution, which authorized the measurements and questionnaires. Prior to this, a prior explanation of the study's objectives was given to the participants (workers and users), guaranteeing their consent. Throughout the study, the confidentiality and anonymity of the data collected were preserved.

1.3 Statistical analysis

The collected data were statistically treated using the statistical program IBM SPSS Statistics 28.0. Descriptive statistics, including frequency tables, measures of dispersion, and measures of central tendency, were used in the study. A prior assessment of the assumptions of the metric variables was performed for statistical inference purposes. The statistical tests used were Pearson's chi-square, one-sample t-Student, ANOVA, Kruskal-Wallis, pairwise comparisons, and the Mann-Whitney test. Data interpretation was based on a 95% confidence level and a significance level of $p<0.05$.

2. RESULTS

After the application of the pre-defined data collection instruments, the estimated analytical values of CO, CH_2O, CO_2, $PM_{2.5,}$ and PM_{10} concentrations in the indoor air of the various divisions of the evaluated Institution were compared globally with the legally established values.

It was observed that there were statistically significant differences between the analytical mean values of CO and the protection threshold in all the spaces evaluated, so the mean values were below the protection threshold in all of them. Divergences in the CO concentration averages were recorded, with Rooms 1 and 2 being the rooms with the highest average values, while the Canteen had the lowest average values. Regarding the analytical mean values of CO_2, it was found that there were statistically significant differences between the estimated mean values and the protection threshold in all spaces under study, and all values were below the established protection threshold. The highest mean value was recorded in the bedridden room and the lowest in Room 2. Looking at the results for CH_2O in all rooms, the values were above the protection threshold, i.e. 0.08 ppm. The highest average values were recorded in the Canteen. Regarding the average concentrations of $PM_{2.5}$, it was found that there were statistically significant differences from the protection threshold in all spaces evaluated. The average values were all below the protection threshold, with Room 1 being the space with the highest average values. Regarding the mean concentrations of PM_{10}, statistically significant differences were observed between the mean values and the protection threshold in all spaces evaluated. All spaces presented averages lower than the protection threshold, with Bedroom 2 presenting the highest average concentrations

DOI: https://doi.org/10.29352/mill0216e.34480

and Room 3 having the lowest average values.

We then set out to evaluate the average concentrations of $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, PM_{10}, PM_{Totals}, and UFP in the indoor air of the various spaces evaluated as a function of the variables "unoccupied" and "occupied."

Table 1 shows that the values differ when the space is occupied and when there is no occupancy, with the mean values in the "occupied" condition being higher than in the "unoccupied" condition, except for the mean concentrations of UFP where the mean values were higher in the "unoccupied" condition.

Table 1 - Average concentrations of $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, PM_{10}, PM_{Totals} and UFP, inside the different spaces evaluated as a function of the variables "unoccupied" and "occupied"

		Occupied	Unoccupied	*p-value*
$PM_{0.5}$	M	3.370	3.170	0.023
(µg/m³)	DP	1.417	1.482	
$PM_{1.0}$	M	5.239	4.784	<0.001
(µg/m ³)	DP	2.164	2.397	
$PM_{2.5}$	M	8.459	7.492	0.933
(µg/m ³)	DP	2.727	2.931	
$PM_{5.0}$	M	18.199	15.920	<0.001
(µg/m ³)	DP	5.802	4.472	
PM_{10}	M	23.593	20.444	<0.001
(µg/m ³)	DP	6.642	3.983	
PM_{Totais}	M	37.570	30.148	<0.001
(µg/m ³)	DP	11.052	5.791	
UFP	M	6070.74	7753.52	<0.001
(part./cm³)	DP	1868.476	6963.329	

M= Mean; SD= Standard Deviation; Test: *t-student* for 1 sample

We then tried to evaluate the behavior of particulate matter between the different spaces that are frequented by users and workers of the institution under study (Table 2).

Table 2 - Average concentrations of $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0,}$ PM_{10}, PM_{Totals} and UFP inside the different spaces evaluated

		Assessed space								
Parameter		Bedroom 1	Bedroom 2	Bedroom 3	Bedridden room	Canteen	Room 1	Room 2	Room 3	K-W;gl;p
$PM_{0.5}$	M	3.112	2.955	3.0237	2.963	3.435	3.816	3.830	3.123	196.026;7
(µg/m³)	DP	1.679	1.572	1.273	1.267	1.476	1.357	1.214	1.378	<0.001
$PM_{1.0}$	M	4.879	4.765	4.651	4.991	4.894	5.649	5.858	4.634	155.848;7
(µg/m ³)	DP	2.658	2.332	1.916	1.990	2.013	2.276	2.064	2.566	<0.001
$PM_{2.5}$	M	8.240	8.047	7.578	8.401	7.808	8.552	8.507	7.152	139.249;7
(µg/m ³)	DP	3.391	2.692	2.635	2.404	2.111	2.673	2.535	3.786	<0.001
$PM_{5.0}$	M	18.272	18.632	17.466	17.149	17.563	16.647	17.125	14.762	89.136; 7
(µg/m ³)	DP	5.4126	4.468	4.641	7.064	4.842	5.216	4.599	5.486	<0.001
PM_{10}	M	23.595	23.851	22.750	21.101	23.334	22.837	20.868	19.385	118.515;7
(µg/m ³)	DP	6.131	4.757	5.795	5.088	6.760	6.500	3.841	5.855	<0.001
PM_{Totais}	M	39.155	35.045	36.868	32.283	35.420	33.387	29.366	33.063	221.940;7
(µg/m ³)	DP	10.172	6.383	8.705	8.243	12.147	10.658	6.534	11.079	<0.001
UFP	M	6099.44	6282.03	6408.19	6303.71	12885.08	5789.14	5089.83	5598.22	274.332;7
(part./cm³)	DP	2637.60	1915.24	2534.00	1783.40	10126.56	1871.37	2078.36	4139.97	<0.001

M= Mean; SD= Standard Deviation; Test: *Kruskal-Wallis*; *Pairwise* comparisons

According to the results shown in Table 2, the different types of material showed different behaviors between the different rooms under study (p<0.05).

Table 3 shows the relationship between the temperature assessed inside the Institution, according to the various spaces monitored during the study.

According to the results obtained, the temperature values differed according to the different spaces studied (p<0.05). Regarding the spaces under study, most of the measurements performed in these places were with "High temperature" levels, although Room 2 presented 29.0% of the evaluations with "Adequate temperature". A similar profile occurred in Bedroom 3 and Room 1, with 24.3% and 24.0%, respectively.

DOI: https://doi.org/10.29352/mill0216e.34480

Table 3 - Meteorological variable temperature inside the various controlled spaces during the study

		Low Temperature <18°C	Temperature Suitable Temperature [18-22] °C	High Temperature >22°C	Total	x^2; gl; p
Bedroom 1	n (%)	9 (3.0%)	33 (11.0%)	258 (86.0%)	300	
Bedroom 2	n (%)	32 (10.7%)	8 (2.7%)	260 (86.7%)	300	
Bedroom 3	n (%)	30 (10.0%)	73 (24.3%)	197 (65.7%)	300	
Bedridden room	n (%)	0 (0%)	42 (14.0%)	258 (86.0%)	300	
Canteen	n (%)	2 (0.7%)	48 (16.0%)	250 (83.3%)	300	300.845;14;<0.001
Room 1	n (%)	30 (10.0%)	72 (24.0%)	198 (66.0%)	300	
Room 2	n (%)	4 (1.3%)	87 (29.0%)	209 (69.7%)	300	
Room 3	n (%)	0 (0%)	0 (0%)	300 (100%)	300	
Total	n (%)	107 (4.5%)	363 (15.1%)	1930 (80.4%)	2400	

Test: *Pearson*'s chi-square

Table 4 attempts to present the relationship between relative humidity as a function of the various sites/spaces monitored during the study.

Table 4 - Meteorological variable Hr inside the various controlled spaces during the study

		Low Humidity <50%	Humidity Adequate Humidity[50-70] %	High Humidity >70%	Total	x^2; gl; p
Bedroom 1	n (%)	0 (0%)	292 (97.3%)	8 (2.7%)	300	
Bedroom 2	n (%)	25 (8.3%)	275 (91.7%)	0 (0%)	300	
Bedroom 3	n (%)	13 (4.3%)	287 (95.7%)	0 (0%)	300	
Bedridden room	n (%)	0 (0%)	299 (99.7%)	1 (0.3%)	300	457.072;14;<0.001
Canteen	n (%)	0 (0%)	299 (99.7%)	1 (0.3%)	300	
Room 1	n (%)	34 (11.3%)	202 (67.3%)	64 (21.3%)	300	
Room 2	n (%)	1 (0.3%)	261 (87.0%)	38 (12.7%)	300	
Room 3	n (%)	0 (0%)	300 (100%)	0 (0%)	300	
Total	n (%)	73 (3.0%)	2215 (92.3%)	112 (4.7%)	2400	

Test: *Pearson*'s chi-square

According to the results obtained, there were statistically significant differences between the rooms under study for the different humidity degrees ($p<0.05$). Regarding the rooms, most of the measurements taken in these locations had "adequate humidity" levels, although Room 1 presented 21.3% of the evaluations with "high humidity". We also found that Bedroom 2 presented 8.3% of the assessments with "low humidity".

We then sought to understand the relationship between the average concentrations of the environmental parameters evaluated by the meteorological variables, T° and Hr, inside the spaces as a function of their occupancy (Table 5).

Analysis of the results obtained, we can affirm that when the sites had the presence of users/workers, the values of CH_2O, CO, CO_2, of the different particulate materials, T° and Hr were significantly higher when compared to the same sites without any occupation ($p<0.05$).

Table 5 - Average concentrations of CH_2O, CO, CO_2, $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0}$, PM_{10}, PM_{Totals}, UFP, T° and Hr inthe interior of the different spaces considering the "Unoccupied" and "Occupied" condition

Parameter	Inside the Institution Occupied N=1350 (Med. Ord.)	Unoccupied N=1050 (Med. Ord.)	M-W; p
CH_2O (ppm)	1283.83	1093.36	596250.000; <0.001
CO (ppm)	1283.00	1094.42	597368.500; <0.001
CO_2 (ppm)	1531.47	774.97	261939.000; <0.001
$PM_{0.5}$ (µg/m³)	1261.31	1122.32	626657.500; <0.001
$PM_{1.0}$(µg/m³)	1290.46	1084.84	587309.500; <0.001
$PM_{2.5}$(µg/m³)	1328.69	1035.68	535693.500; <0.001
$PM_{5.0}$(µg/m³)	1336.79	1025.28	524765.000; <0.001
PM_{10} (µg/m³)	1352.92	1004.53	502986.000; <0.001
PM_{Totals} (µg/m³)	1424.41	912.62	406478.000; <0.001
UFP (part./cm3)	1254.64	1130.90	635667.500; <0.001
T° (°C)	1265.65	1116.73	620792.500; <0.001
Hr (%)	1360.18	995.20	493184.000; <0.001

Med. Ord.= Median of the ordinations. Test: *Mann-Whitney* test

DOI: https://doi.org/10.29352/mill0216e.34480

Next, we tried to understand whether the time of day could express differences in CH_2O, CO, CO_2, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, PM_{10}, PM_{Totals}, UFP, T° and Hr (Table 6).

Table 6 – Average concentrations of CH_2O, CO, CO_2, $PM_{0,5}$, $PM_{1,0}$, $PM_{2,5}$, $PM_{5,0}$, PM_{10}, PM_{Totals}, UFP, T° and Hr inside the different spaces considering the different measurement periods

Parameter	Period		
	Morning N=1380 (Med. Ord.)	Afternoon N=1170 (Med. Ord.)	M-W; p
CH_2O (ppm)	1232.46	1326.27	747900.000; <0.001
CO (ppm)	1435.34	1086.97	586717.000; <0.001
CO_2(ppm)	1462.82	1054.55	548792.000; <0.001
$PM_{0.5}$(µg/m³)	1529.55	975.85	456710.000; <0.001
$PM_{1.0}$(µg/m³)	1549.27	952.60	429503.000; <0.001
$PM_{2.5}$(µg/m³)	1559.72	940.27	415078.000; <0.001
$PM_{5.0}$(µg/m³)	1491.54	1020.69	509171.500; <0.001
PM_{10} (µg/m³)	1488.93	1023.76	512760.000; <0.001
PM_{Totals} (µg/m³)	1441.06	1080.23	578830.000; <0.001
UFP (part./cm³)	1351.46	1185.90	702469.000; <0.001
T° (°C)	1049.75	1086.97	495759.000; <0.001
Hr (%)	1639.34	846.35	305197.500; <0.001

Med. Ord.= Median of the ordinations. Test: *Mann-Whitney*

As we can see from the results presented above, there were statistically significant differences between the parameters evaluated and the measurement period. It was found that the "morning period" in the sites under study presented significantly higher values of particulate matter, CO, and CO_2 compared to the "afternoon period" ($p<0.05$). Regarding CH_2O and temperature, the values were higher in the afternoon period than in the morning period. It was also observed that in the meteorological condition "Cloudy Weather," the environmental parameters evaluated presented, in general, significantly higher values compared to the "Sun" condition ($p <0.05$), except for CO, UFP, and temperature that presented higher values on "Sun" days.

In relation to the spaces evaluated indoors and in the outside air, the results show statistically significant differences between the indoor and outdoor spaces and the parameters CO_2, UFP, and T° ($p<0.05$). It should be noted that the average values were higher inside the evaluated institution, except for the temperature that registered higher average values outside (spring).

Next, we sought to analyze the presence or absence of symptoms/diseases reported by the occupants who participated in the study. Of the 21 individuals surveyed, 18 reported having symptoms/diseases, of which 11.1% were male and 88.9% female. 55.6% of the participants who indicated having symptoms/diseases were workers.

The 21 occupants who participated in the study, 4.8% indicated bronchitis, 42.9% dizziness, 61.9% headaches, 4.8% asthma, 19% dry cough, 47.6% itching, burning or irritation in the eyes, 4.8% wheezing/ wheezing, 28.6% sneezing, runny or stuffy nose, 19% breathing difficulties and finally 28.6% allergies.

It should be noted that of the 18 individuals who took part in the study and indicated that they had symptoms/illnesses, 11 reported that their symptoms/illnesses worsened with the seasons. Of these, 29.7% reported that their symptoms/illnesses worsened in spring, 22.8% in winter, 24.8% in fall, and 22.7% in summer.

Regarding the prevalence of symptoms/diseases reported by the study participants with the season, the results showed that there was a pattern of association between the season in which the symptoms tend to manifest and the presence or absence of allergies, headaches, dizziness, and dry cough ($p\leq0.05$). In relation to the symptom/disease allergies, of the 10 respondents who reported having it and that it worsened with the season, 60% suffered from this condition in spring. Regarding headaches, of the 15 respondents who indicated that they had it and that it worsened with the season, 46.7% suffered from this condition in the spring. As for dizziness, of the 10 respondents who indicated that they had it and that it worsened with the season, 60% suffered from this condition in spring. Regarding the symptoms of dry cough, of the 6 respondents who indicated that they had it and that it worsened with the season, 66.7% suffered from this condition in the spring. However, there was no pattern of association between the presence of asthma, chronic bronchitis, wheezing, sneezing, itching, burning or irritation of the eyes, breathing difficulties, and other relevant symptoms and the season in which they tend to worsen ($p>0.05$). Of the 18 respondents who reported feeling sickness/symptoms, only 27.8% stopped showing symptoms/illnesses when they went outside the institution under study.

DOI: https://doi.org/10.29352/mill0216e.34480

3. DISCUSSION

After analyzing the results obtained, we could see that, on average, the concentrations of the pollutant CO inside the RSE were below the protection threshold value. However, when checking the average concentrations of the air pollutant CO per space evaluated, it appears that the spaces with the highest levels of CO were Rooms 1 and 2, which reached an average value of 2 ppm, with the maximum value being 2.2 ppm, which did not exceed the protection threshold value of 9.0 ppm. Some studies indicate that exposure to CO is one of the main causes of unintentional poisoning, giving rise to a high number of deaths per year in Europe and the USA, and that the health effects resulting from exposure to toxic pollutants, such as CO, are more acute for sensitive groups of the population, such as the elderly (Madureira, et al., 2016).

Carbon dioxide is a colorless and odorless gas and can act as an irritant to the respiratory system. Its concentration in indoor air can give a good indication of the ventilation rate. High concentrations of CO_2 show the lack of air renewal in the premises and a possible accumulation of other toxic gases and odors since the lack of ventilation does not allow their dilution to acceptable concentrations (Azedo, 2019). The space where higher average values were found was in the Bedridden Room, with 728 ppm reaching a maximum of 1140 but did not exceed the protection threshold of 1250 ppm at any time. These high values may be due to the fact that the room is constantly occupied, has a smaller area than the rooms we evaluated, and is not ventilated as well as possible. The main source of CO_2 in indoor air results from the biological metabolism of its occupants, so the values of this air pollutant are generally higher in areas of buildings in which occupants stay longer, being directly related to the number of occupants per square meter (Azuma, et al., 2018; Fan, et al., 2023). Hence the Bedded Room is the space evaluated with higher average values.

Formaldehyde is also a volatile organic compound. However, it is usually referred to separately, as its collection and analysis method differs from other VOCs. It is a colorless gas but can be easily detected by humans due to its strong odor. Its main sources are treated wood, combustion, and resins. Symptoms associated with its exposure include eye and upper respiratory irritation, headaches, nausea, and feelings of fatigue. It is the most frequently occurring pollutant in indoor atmospheres at concentrations capable of causing sensory irritation to the eyes and respiratory system (Ferreira, Loureiro, & Seco, 2021; Monteiro, 2021). From the analysis of the average CH_2O concentration values, it was found that all the spaces evaluated had values higher than the legally established protection threshold value, i.e., higher than 0.08 ppm. This fact can be explained by the presence of emitting sources of this pollutant, such as disinfectants, wood products, pressed wood, unsealed plywood, urea-formaldehyde foam pipe insulation, fabrics, glue, paints, carpets, furniture, and carbon paper. This fact should not be ignored since there are studies that indicate that exposure to CH_2O is one of the main causes of oral and ocular mucosal irritations, nausea, skin irritations, as well as burns (Monteiro, 2021).

Regarding $PM_{2.5}$ concentrations, it was found that they reached significantly higher average concentration values in the morning compared to the afternoon, in the condition with occupation and in the "cloudy weather" condition, never exceeding the protection threshold value (25µg/m³). It was found that Rooms 1 and 2 were those with the highest average concentration values, but the maximum value recorded was in Room 3 with 20.8 µg/m³.

As for concentrations of PM_{10}, it was found that in no space was the protection threshold exceeded (50µg/m^3). We found that significantly higher average concentration values were reached in the morning compared to the afternoon, with higher values in the "cloudy weather" condition, and in the "occupied" condition. Bedrooms 1 and 2 recorded the highest average values, although the maximum value of 47.5µg/m^3 was recorded in Room 1, which is very close to the protection threshold. Normally, indoor air quality levels are worse in the morning because the building has been closed all night, compared to the afternoon, in this case, there has already been the possibility of natural ventilation of the spaces, which leads to dilution and consequently a decrease in the concentrations of air pollutants inside the spaces assessed, namely CO2 and particulates. These results highlight the importance of continuous monitoring to control $PM_{2.5}$ and PM_{10} concentrations inside the RSE, since they can potentiate the worsening or onset of chronic respiratory diseases, as mentioned in a study carried out in nursing homes in our country (Loureiro, et al., 2017).

Temperature and humidity are also important factors for indoor air comfort levels as they can facilitate the proliferation of microbiological contaminants. These contaminants can affect the health of workers and the elderly. We found that most of the measurements taken had high-temperature values, that is, values above 22 °C, perhaps since the measurements were taken on days of heat, with the highest values recorded outside, as expected, and inside the space with the maximum temperature recorded was the Canteen. Some studies indicate that the elderly prefer environments about 2˚C warmer than the rest of the population and that the comfort temperature for the sedentary elderly population is above 25˚C (Loureiro et al., 2017; Ferreira, Loureiro, & Seco, 2021). Thus, we can say that workers must be subjected to slightly higher temperatures for the elderly to be comfortable inside the RSE. Institutions must also comply with the temperature ranges legally established for the summer and winter seasons.

In this study, the most prevalent symptom/disease among occupants was headache, with 61.9 percent, followed by itching, burning or irritation in the eyes, and sneezing. These results can be compared with those found in other studies, which show that humid indoor environments can cause bouts of sneezing, headaches, and allergies (Madureira et al., 2016). In this study, workers and users reported that these symptoms/illnesses tend to worsen, especially in spring, and may be related to the quality of the indoor air in the institution.

DOI: https://doi.org/10.29352/mill0216e.34480

CONCLUSION

After conducting this study, we can draw several conclusions. The values of particulate matter, except for UFP, as well as CH_2O, CO_2, and Rh, showed significantly higher mean values in the meteorological condition "Cloudy weather," and CO, T˚, and UFP showed higher mean values in the condition "Sun." We also found that all the parameters evaluated had higher values when the spaces were occupied. Regarding the evaluations by period, it was observed that temperature and CH_2O were the only parameters that showed higher values in the afternoon compared to the morning.

CH_2O was the only atmospheric parameter that exceeded the protection threshold in all spaces evaluated. Therefore, it is necessary to take measures to reduce its concentration, such as regular cleaning, using cleaning products that do not include CH_2O in their constitution, and using air purifiers to reduce the exposure of workers and users to this pollutant.

Based on the results, we can conclude that the most common ailments reported by occupants were headaches, followed by symptoms of itching, burning, or irritation in the eyes. These symptoms may be related to poor indoor air quality, highlighting the importance of addressing and improving environmental conditions to promote a healthier environment.

Indoor air quality in nursing homes is crucial for the health and well-being of the occupants of these types of institutions. Older people are more vulnerable to the harmful effects of air pollution due to pre-existing health conditions and weakened immune systems. Good indoor air quality is important to preserve respiratory health, prevent allergies and sensitivities, reduce the risk of cardiovascular diseases, and promote general well-being. Measures such as adequate ventilation, use of air filters, humidity control, regular cleaning, use of products with low VOC emissions to reduce chemical pollution, maintenance of ventilation systems, and use of efficient and certified equipment can help ensure a healthy indoor environment for older people.

Several limitations were identified throughout the study. One was the lack of specific legislation on reference values for concentrations of atmospheric pollutants in outdoor air; another was the lack of legislation on indoor air quality for the pollutants $PM_{0.5}$, $PM_{1.0,}$ $PM_{5.0}$, and ultrafine particles. Another limitation was the low number of questionnaire responses, both from employees and users of the institution under study.

Clean, fresh air makes for a healthier and more comfortable environment. On the other hand, polluted and poor-quality air can cause discomfort, irritation, fatigue, and even sleep problems. This can affect the quality of life of the elderly, as well as their ability to engage in daily and social activities.

In the future, it would be interesting to conduct studies of pollutant concentrations for the fall/winter season, comparing them with the results obtained for the spring/summer season.

Finally, a similar study should be carried out in other nursing homes in different geographical locations in the country, as well as assessing other pollutants that were not possible to assess in this study, to make the assessment of indoor air quality in this type of building more meaningful.

AUTHOR CONTRIBUTIONS

Conceptualization, A.F., F.P., A.L. and J.P.F.; data curation, F.P., A.L. and J.P.F.; formal analysis, F.P., A.L. and J.P.F.; investigation, A.F., F.P., A.L. and J.P.F.; methodology, F.P., A.L. and J.P.F.; resources, A.F., F.P., A.L. and J.P.F.; programs, A.L. and J.P.F.; supervision, A.F., A.L. and J.P.F.; validation, A.F., A.L. and J.P.F.; writing-original draft, F.P.; writing-review and editing, A.F. and J.P.F

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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