Indoor Air Quality in Elderly Centers

Subjects: Public, Environmental & Occupational Health

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The elderly segment of the population is more vulnerable to adverse environmental conditions. Indoor air quality is one of the most relevant health determinant, especially for elders resident in Care Centers because elders spend most time indoors. The recent COVID-19 pandemic contributed greately to raise awareness on the importance of breathing safe air without biological and physical-chemical contaminants. The heath effects on elders of the main pollutants are discussed in this topic.

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1. Introduction

Indoor air quality (IAQ) and its negative health effects is a main public health issue. Substances found in the indoor environment are among the main determinants of an individual's health, whether they are [1]:

- chemicals:
- volatile organic compounds (VOCs): esters, alcohols (e.g., ethanol, isopropanol), ketones (e.g., acetone), aldehydes (e.g., hexanal) and terpenes (e.g., limonene)
- formaldehyde (CH₂O)
- ozone (O₃)
- nitrogen dioxide (NO₂)
- carbon monoxide (CO)
- sulfur dioxide (SO₂)
- particulate matter (PM) of aerodiameter <10, <2.5, and <0.1 µm (PM₁₀, PM_{2.5}, PM_{0.1}, respectively)
- asbestos
- radon
- tobacco smoke
- biocontaminants (e.g., bacteria, fungi, viruses, molds, allergens) ^[1].

IAQ and thermal comfort, which are key factors affecting occupants' health and well-being, are influenced by ambient parameters, such as outdoor temperature, atmospheric pressure, buildings surrounding surfaces temperature, air movement, ventilation, relative humidity, and carbon dioxide (CO₂) concentration $\frac{[2][3][4]}{2}$.

The world population is increasingly ageing and, in 2019,1 out of 11 people was above 65 years old ^[5]. This global growing trend ^[6] urgently calls for effective actions, to ensure the protection of this demographic group that is more vulnerable to adverse environmental conditions. Elders spend comparatively more time indoors than younger generations; therefore, the quality of indoor air is a very important health determinant and wellbeing factor, especially for those that are enduring their final years with limiting disease. The vulnerability of elders is a natural consequence of inherent deterioration of biological functions, including immune defenses, but it is often aggravated by poor health conditions such as respiratory or circulatory illness; therefore, elders have a greater predisposition to respiratory infections 2. In addition to natural ageing, elders have an accumulated lifelong exposure to pollution and other environmental conditions ^[8]. Due to their reduced mobility, they tend to spend most of their time indoors (95% in average) $^{(9)}$, usually in bedrooms and living-dining rooms, corresponding to about 19 to 20 h/day $^{(10)}$. This is particularly critical to residents in geriatric facilities who are potentially at higher risk of exposure to indoor air pollution [11]. Therefore, the indoors environment is likely to influence the health of elderly people, who are a vulnerable group to air pollutants exposure. Indoor air accumulates several types of pollutants normally associated with specific compounds originating from the various household products used, such as in cleaning, disinfection, hygiene, and healthcare activities, and also emitted from building materials and furnishings ^[12]. Cleaning solutions and detergents frequently used in nursing homes and healthcare institutions, reduce the risk of infections but increase the levels of total volatile organic compounds (TVOC) in the air ^[9]. Therefore, keeping elderly people healthy is a challenge that requires better understanding of health consequences exposure to air pollutants ^[8].

So far, the respiratory health effects of indoor air pollution have been well documented in the general population but less analyzed in elderly people living in elderly centers, nursing homes, and other care facilities ^{[13][14]}. There are few data on exposure to indoor air pollutants and related effects on respiratory health in the elderly population. Few studies relate exposure to internal air pollutants with effects on the respiratory function, such as wheezing, breathlessness, cough, asthma, or lung cancer ^[15]. Data on the effects of indoor allergens on respiratory health in the elderly in the elderly are scarce ^[16].

Studies have shown that the elderly, particularly those over 80 years, are more likely to have health impairments, even with moderate levels of indoor air pollutants [7][17]. One of the most effective methods to reduce the concentration of pollutants is the dilution effect by simply increasing the rate of air exchange (ventilation) of the indoor spaces [18][19]. Almeida-Silva et al. [9] characterized the indoor air quality in 10 elderly care centers (ECCs) in Portugal to assess the elders' daily exposure to air pollutants, showing that due to insufficient room ventilation, the concentration of some substances (CO₂, VOCs, O₃, and PM₁₀) exceeded the legal limit values.

Concerning the emerging compounds, Arnold et al. ^[20] carried out a study at ECCs in the United States and in Portugal to determine the concentrations of organophosphate esters (OPEs), brominated flame retardants (BFRs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs) in dust samples collected indoors from fourteen facilities. This study results revealed that OPEs, PAHs, and BFRs were the most abundant and OCPs and PCBs were the least abundant semi-volatile organic compounds (SVOCs) groups in the collected dust. Concerning biological contaminants, airborne microorganisms, such as bacteria and fungi, are often present in the indoor air. In particular, the indoor habitat harbors microorganisms that are not commonly found outdoors, which is also influenced by the air temperature, relative humidity, architectural design, and the source of air ventilation ^[21]. In this case, the ventilation of spaces and the density of occupants can influence the abundance of these microorganisms and also the transmission of some pathogenic microbes ^[22]. A study ^[23] of indoor air in a large hospital building revealed that the most common bacterial strains belonged to genera *Staphylococcus*, *Micrococcus*, *Kocuria*, *Aerococcus*, *Kytococcus*, *Bacillus*, *Pseudomonas*, *Corynebacterium*, and *Streptococcus*, while the most abundant fungal genera included *Cladosporium*, *Aspergillus*, *Penicillium*, *Alterneria*, *Geotrichium*, and *Ulocladium*. Frequent cleaning is an important factor for maintaining a low microbial load in the air.

The European Union (EU) has established legislation on air quality specifications for both atmospheric and indoor air. In the scope of the European Green Deal implementation and the EU Climate and Energy policies ^[24], alongside the economic crisis brought by the COVID-19 pandemic and the present energy crisis, it is rather obvious that energy consumption and supply security are top and urgent priorities in the EU. Presently, energy efficiency and security policies are receiving public attention, and the EU legal framework for energy consumption in the buildings sector is being recast with a strong focus on energy efficiency as the main goal. The principle that "energy efficiency comes first" is a precious one that should always be implemented; however, energy savings in Heating, Ventilating and Air Conditioning (HVAC) systems cannot be achieved by reducing the ambition to continuously raise the quality of indoor air standards.

2. Characteristics of Elderly Centers as Built Environments

Some characteristics of the built environment may significantly affect IAQ of elderly centers. The likelihood of exposure to different indoor air pollutants is influenced by factors such as:

- building design
- · construction and furniture components and materials
- management and maintenance of operational systems (e.g., HVAC, mechanical ventilation)
- · density of occupants
- occupants' activities.

Insufficient ventilation may result in poor air quality with high concentration of indoor air pollutants, since these are not able to be diluted or dissipated by air convenction. Assuring an adequate ventilation in space is fundamental, especially in buildings where users spend most of their time indoors, such as elders and people with physical or mobility disabilities, who end up being exposed to indoor air conditions for prolonged periods of time (**Figure 1**).



Figure 1. Factors influencing IAQ in elderly centers (authors' own creation).

Building design can affect users' life quality. Window sizing, orientation, openings, and vents determine not only the natural sunlight but also the natural fresh-air availability that the different interior spaces may have, which are critical for interior pollutants removal by natural ventilation. A few studies have analyzed how the presence of nearby green spaces (i.e., gardens, lawns, trees, flower bushes, shrubs, green walls and roofs) may improve not only aesthetics but also air quality of elderly centers ^[24]. A few studies have shown that green spaces may partially filter and remove air pollutants in urban areas ^[25], being especially useful to reduce PM at pedestrian level in buildings close to main roads ^[26].

Mendes et al. ^[2] monitored IAQ and thermal comfort parameters (CO, CO₂, PM₁₀, PM_{2.5}, TVOC, formaldehyde, bacteria, fungi, room air temperature, humidity) of 22 elderly centers located in Porto (Portugal) during summer and winter. This study results enabled the comparison of reference values from existing standards (national and international) and the variability among spaces (i.e., bedroom, living room, medical office) within the same building and between different buildings. The authors also tried to find correlations between the building characteristics and IAQ parameters. For that purpose, an inventory of building properties was collected for each building monitored, such as type of construction components (brick or stone masonry), the presence or absence of envelope thermal insulation, the windows type (single or double glazing) and sealants, ventilation type (natural, mechanical, or both), heating system (central or local heaters), and the presence of observable building pathologies (condensations). The building characteristics that mostly influenced the IAQ and thermal comfort were the window frame type, heating, ventilation, and thermal insulation. The indoor air quality parameters most affected were the presence of microorganisms (bacteria and fungi), relative humidity, and indoor temperature. It is important to note that many buildings were not originally projected to be elderly centers; instead, they were adapted for such function.

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