



Short Communication

Adequate indoor air quality in nursing homes: An unmet medical need

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HIGHLIGHTS

- IAQ in nursing homes is not regulated by legislation and is seldom monitored.
- Many nursing home residents are susceptible to the effects of air pollutants.
- We propose an action plan for assessing and addressing IAQ in nursing homes.
- A proactive approach may promote health, well-being, and quality of life.

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ABSTRACT

A small but growing body of literature indicates that concentrations of indoor particulate and gaseous pollutants in long-term care facilities (i.e., skilled nursing facilities) for older adults, hereafter referred to nursing homes, often exceed those recorded in nearby, comparable outdoor environments. Unlike the outdoors, indoor air quality (IAQ) in nursing homes is not regulated by legislation and is seldom monitored. To that end, residents of nursing homes commonly spend the vast majority of their time indoors where they are exposed to indoor air pollutants for long periods of time. Given that many nursing home residents, especially those of advanced age, are more susceptible to the effects of air pollutants, even at low concentrations, this prolonged exposure may adversely affect their health, well-being, quality of life and increase medical expenditures due to frequent, unscheduled acute care visits and hospitalizations. We propose an action plan for assessing IAQ in nursing homes, understanding the impacts of IAQ on adverse health outcomes of nursing home residents, and addressing vulnerabilities in these facilities to safeguard health, well-being, and quality of life of nursing home residents and minimizing unscheduled acute care visits and hospitalizations. We propose that IAQ should be regularly monitored in nursing homes to proactively identify and address vulnerabilities in these facilities and that resources should be provided for remedial interventions to improve IAQ in nursing homes, including but not limited to source control, improving ventilation and filtration, and deploying air cleaners where appropriate. This proactive approach may pave the way for establishing enforceable standards for indoor air quality in nursing homes that will promote health, well-being, and quality of life of nursing home residents and reduce medical expenditures.

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1. Main text

A small but growing body of literature indicates that concentrations of indoor particulate and gaseous air pollutants in nursing homes (i.e., long-term care or skilled nursing facilities for older adults) often exceed those recorded in nearby outdoor environment (United States Environmental Protection Agency, n.d.; Almeida-Silva et al., 2014; Bentayeb et al., 2015; Wang et al., 2018; Almeida-Silva et al., 2016; Tebbe, 2017). Unlike the outdoors, however, indoor air quality (IAQ)

in nursing homes is not regulated by legislation and is seldom monitored (United States Environmental Protection Agency, n.d.; Sandsröm et al., 2003). Nursing home residents commonly spend the vast majority of their time indoors and are thus exposed to indoor air pollutants for long periods of time (Almeida-Silva et al., 2014). Given that the majority of nursing home residents are 65 years and older (CDC, 2004) and commonly have underlying chronic medical conditions and reduced immune defenses that may make them more susceptible to the effects of air pollutants (Moore et al., 2012), prolonged exposure to indoor air pollutants, even at low concentrations, may adversely affect their health, well-being, and quality of life and increase medical expenditures due to their frequent, unscheduled acute care visits and hospitalizations (Centers for Medicare & Medicaid Service, 2019; Belo et al., 2019;

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Morishita et al., 2018; Levinson, n.d.). Additionally, the rapid spread of COVID-19 in nursing homes has led to tragic consequences for residents and has highlighted numerous shortcomings in monitoring, preparedness, and resources for interventions to mitigate the transmission of infectious diseases (Inzitari et al., 2020; Ouslander and Grabowski, 2020), including those with airborne transmission potential, such as improved ventilation or air filtration.

The mechanism(s) underlying the adverse health outcomes associated with prolonged exposure to indoor particulate and gaseous pollutants in human subjects has not been fully elucidated. It is postulated that these pollutants promote chronic inflammation and oxidative stress in target organs of susceptible individuals with underlying chronic medical conditions, such as pulmonary and cardiovascular diseases. These aggravate pre-existing organ dysfunction and clinical condition of these patients leading to unscheduled acute care visits and hospitalizations (Bentayeb et al., 2015; Sandsröm et al., 2003; Centers for Medicare & Medicaid Service, 2019; Belo et al., 2019; Morishita et al., 2018; Levinson, n.d.).

It is estimated that approximately 1.3 million individuals currently reside in almost 15,600 nursing homes across the U.S., with the majority aged 75 and older (Centers for Disease Control and Prevention, 2016). With life expectancy on the rise, it is projected that by 2034 the number of Americans aged 65 and older will increase by approximately 30 million individuals (Census Bureau, 2017). It is anticipated, that the demand for nursing homes will continue to grow despite increasing trends in assisted living and in-home care options and continued improvements in healthcare to improve quality of life (Joint Center for Housing Studies of Harvard University, 2015).

To date, only a few studies have investigated the effects of IAQ on the health of nursing home residents (Almeida-Silva et al., 2014; Bentayeb et al., 2015; Belo et al., 2019; Mendes et al., 2012). Bentayeb and colleagues conducted the comprehensive Geriatric study on health effects of air quality in nursing homes in Europe (GERIE; www.geriestudy.eu) in 600 individuals 65 years of age and older who resided in 50 nursing homes in 7 European countries (Bentayeb et al., 2015). They found that exposure to elevated concentrations of indoor particulate matter with aerodynamic diameter less than 10 μm (PM_{10}) and nitrogen dioxide (NO_2) in the main common rooms of these facilities was associated with breathlessness and cough. In addition, elevated indoor concentrations of ultrafine particles with aerodynamic diameter less than 0.1 μm ($\text{PM}_{0.1}$) were associated with wheeze during the last year. Elevated indoor NO_2 , formaldehyde, and $\text{PM}_{0.1}$ concentrations were associated with decreased lung function and chronic obstructive pulmonary disease (COPD). Notably, these associations were observed with concentrations of indoor air pollutants that did not exceed existing international guidelines and were amplified in nursing homes with poor ventilation and in residents over the age of 80. Only 19% of nursing homes had adequate indoor air circulation and proper ventilation as determined by indoor carbon dioxide (CO_2) concentrations. Of note, indoor ozone concentrations were low in these nursing homes, a finding that corroborates earlier observations in 10 Portuguese nursing homes (Almeida-Silva et al., 2014). Conducting the study in 7 European countries makes the results more generalizable to nursing homes across Europe. Collectively, these data suggest that residents of nursing homes in Europe are susceptible to the health effects of indoor air pollution.

Mendes et al. (2012) conducted a similar study in 84 nursing homes in Lisbon and Oporto, Portugal, a country with the 8th oldest population in the world (GERIA; <http://geria.webnode.com>). The investigators found a relatively high prevalence of respiratory symptoms among geriatric residents of nursing homes in both cities. Distinctively, allergic rhinitis was reported by participants exposed to high indoor concentrations of PM_{10} . A relationship between increased indoor concentrations of volatile organic compounds (VOC) and $\text{PM}_{2.5}$ and pulmonary infection and inflammation, respectively, was also noted (Belo et al., 2019). However, the possible relationship between indoor air pollutant

concentrations and dysregulation of cardiovascular and/or metabolic function in nursing home residents was not investigated in either study. It is also unlikely that the results of these studies can be transferred to nursing homes in the U.S. because of the variation in nursing home structure, business models, mission, vision, and values, and resident characteristics.

To the best of our knowledge, only one published study in the U.S. reported IAQ in nursing homes. Tebbe (2017) evaluated IAQ in four nursing homes in Northwest Ohio. She found that indoor PM concentrations exceeded ambient concentrations at all four facilities. The highest concentrations were recorded in the kitchen, satellite kitchen, and hair salon in mid-morning and mid-afternoon, which coincided with peak times of resident activities. Despite the inherent limitations of this pilot study, these data suggest that indoor air sampling should be performed concomitantly in several 'hot spots' of nursing homes. Given that exposure to indoor air pollutants is influenced by local conditions, further studies to monitor indoor air pollution during different seasons of the year, and to determine air pollutant concentrations throughout the day using personal sampling are indicated.

Possible sources of indoor air pollutants in nursing homes in Europe and the U.S. were not elucidated in these studies. Conceivably, they could be related to inadequate ventilation and air exchange in these facilities, cooking on gas rather than electric stoves and recurring use of personal care products, pesticides, insecticides, and household cleaners (United States Environmental Protection Agency, n.d.). In addition, the proximity of some nursing homes to major congested roadways, railroads, and busy airports may be an important contributing factor (Wang et al., 2018; Almeida-Silva et al., 2016). These studies did not investigate the role of inadequate IAQ as a modifiable risk factor for unscheduled acute care visits and hospital admissions of susceptible nursing home residents due to acute decompensation of pre-existing cardiopulmonary and metabolic diseases. However, it is well established that hospital admissions are costly and impact patient's care transition by interrupting care plan, escalating discomfort of both patients and family members and increasing the risk of hospital-acquired adverse events, such as serious, drug-resistant infections (Centers for Medicare & Medicaid Service, 2019; Levinson, n.d.). Notably, the Inspector General of US Department of Health and Human Services reported that in fiscal year 2011 Medicare spent \$14.3 billion on transfer of Medicare beneficiaries from nursing homes to hospitals for inpatient admissions (Centers for Disease Control and Prevention, 2016). A significant proportion of these residents returned to the hospital within 30 days of their discharge.

Given the low awareness of inadequate IAQ risks in nursing homes and that no national IAQ standards exist (United States Environmental Protection Agency, n.d.), current technological and professional resources are not properly equipped to effectively monitor and report IAQ data in nursing homes, nor to implement appropriate remedial actions as indicated. Accordingly, we propose that IAQ should be monitored in nursing homes to proactively identify and address vulnerabilities in these facilities thereby safeguarding health, well-being and quality of life of its residents and minimizing their unscheduled acute care visits and hospitalizations.

Remedial interventions to improve IAQ in nursing homes include source control, improving ventilation and deploying air cleaners where appropriate (United States Environmental Protection Agency, n.d.). The most effective way to improve IAQ is to eliminate individual sources of pollution or to reduce their emissions, such as cooking and combustion activities. Another approach is to increase the amount of outdoor air coming indoors with mechanical ventilation to dilute the concentrations of indoor air pollutants which can also be coupled with improved central filtration or air cleaning. Lastly, commercial, stand-alone, portable air cleaners that remove both particulate and gaseous pollutants can be deployed. To that end, Morishita et al. (2018) showed that 72-hour use of commercial, inexpensive, stand-alone, portable air cleaners placed in a low-income senior facility in Detroit,

MI was associated with significant reductions in indoor PM_{2.5} concentrations and systolic blood pressure.

Given these challenges, we propose the following action plan for assessing IAQ in nursing homes, understanding relationships between IAQ and adverse health outcomes of nursing home residents, and addressing vulnerabilities in these facilities to safeguard health, well-being, and quality of life of nursing home residents and minimizing unscheduled acute care visits and hospitalizations:

- IAQ, including contaminant concentrations and parameters such as ventilation rates, should be regularly monitored in nursing homes to proactively identify and address vulnerabilities in these facilities.
- Epidemiological investigations should explore associations between IAQ and adverse health outcomes in nursing home populations.
- Results from IAQ monitoring and epidemiology investigations should inform the development of national or international guidelines and standards for nursing home facilities.
- Resources should be provided for remedial interventions to improve IAQ in nursing homes, including but not limited to source control, improving ventilation and filtration, and deploying air cleaners where appropriate.

COVID-19 has further demonstrated the need for rapidly developing and deploying IAQ solutions in nursing homes. We envision that increased systemic attention to these under-studied facilities with vulnerable populations will ultimately improve the health, well-being, and quality of life of nursing home residents and reduce medical expenditures.

CRediT authorship contribution statement

All authors contributed writing and editing to this work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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