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# Air quality of nursing homes and its effect on the lung health of elderly residents

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In industrialized countries the elderly spend most of their time indoors. The elderly may be at a higher risk of suffering from indoor air pollution-related diseases compared to the rest of the population, because of their increased exposure to potential indoor risk factors. This editorial aims to critically analyze the recent literature regarding this important topic. Results of studies performed on the elderly living in nursing homes clearly highlight that they are at risk of respiratory health impairment, even at moderate air pollutant concentrations, particularly if they are over 80 years of age and living in poorly ventilated nursing homes. The future epidemiological research on ageing and respiratory diseases should investigate the underlying biological and physiological mechanisms, in addition to the adverse health effects of potential indoor risk factors, in order to help defining effective strategies for healthy ageing.

## Introduction

The main challenge for the future is the ageing of population, particularly the increasing number of very old people (aged >80 years). It is expected that 34.7 million citizens will be over 80 years in the European Union by 2030.[1] The old-age dependency ratio (those ≥65 years/those 15–64 years) is projected to increase from 25.4 to 53.5% in the period 2008–2060.[2] Increasing longevity can determine a rise in medical costs and an increase in demands for health services, since older people are typically more susceptible to chronic diseases. The elderly are also at higher risk of the effects of outdoor and indoor air pollution because of increased susceptibility and vulnerability. Outdoor air pollution is responsible of short-term and chronic adverse effects on cardiopulmonary morbidity and mortality in the elderly.[3] However, in industrialized countries the elderly spend most of their time indoors [4]: ~5% of those >65 years

and 20% of those >85 years are nursing home residents ([www.uscare.com](http://www.uscare.com)). Due to reduced outdoor activities the elderly people are potentially more exposed to indoor air pollutants than the rest of the population.[5,6]

Therefore, keeping the elderly healthy by preventing chronic diseases is a major challenge for many countries requiring a better understanding of the health consequences of the exposure to environmental factors, including air pollution.[7]

So far, respiratory health effects of indoor air pollution have been well documented in the general population; on the other hand, this important item was only seldom analyzed in the elderly living in nursing homes and by few researchers' groups.

## Indoor air pollution

Elderly likely spend most time within their place of residence where they are exposed to air Total Suspended Particles, including PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>0.1</sub>

**KEYWORDS:** Elderly • indoor air pollution • nursing home • susceptibility • respiratory effects

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(particulate matter of aerodiameter <10, <2.5 and <0.1  $\mu\text{m}$ , respectively), ozone ( $\text{O}_3$ ), nitrogen dioxide ( $\text{NO}_2$ ), carbon monoxide (CO), sulfur dioxide ( $\text{SO}_2$ ), volatile organic compounds (VOCs) (aldehydes, ketones, esters, ...), allergens and micro-organisms.[8]

Organic matter/fossil fuel combustion for heating/cooking, environmental tobacco smoke (ETS) and woodstoves are a source of PM and CO; unvented gas/kerosene appliances are major sources of  $\text{NO}_2$  and CO; furthermore, building materials and new furniture, solvents, paints, adhesives, insulation, cleaning activities and office supplies emit large quantities of VOCs and formaldehyde.[9,10] Indoor biological allergens mainly originate from house dust mite, furred pets, cockroaches, molds and, to a lesser extent, plants and rodents.[4]

Outdoor-generated pollutants penetrate the indoor environment increasing the level of indoor air pollution exposure.[10]

Nursing homes are a custodial care environment mainly attended by the elderly. Only a recent European study (the Geriatric study on health effects of air quality in nursing homes in Europe – GERIE study), performed on 600 elderly living in 50 nursing homes, measured the air pollution concentration in the main common rooms (used for recreation, watching TV, meetings or dining) where the participants spent most of their time. Concentrations of air pollutants did not exceed the existing international and national standards. The indoor mean level of  $\text{PM}_{10}$  was  $>50 \mu\text{g}/\text{m}^3$  in 12% of the nursing homes (mean value  $29.8 \mu\text{g}/\text{m}^3$ ) and  $\text{NO}_2$  levels exceeded  $40 \mu\text{g}/\text{m}^3$  in 4% of the nursing homes (mean value  $20.1 \mu\text{g}/\text{m}^3$ ), while the indoor level of ozone was very low (mean value  $21.1 \mu\text{g}/\text{m}^3$ ). The formaldehyde levels were low and the maximum indoor level (weekly average) was  $21 \mu\text{g}/\text{m}^3$  (mean value  $7.21 \mu\text{g}/\text{m}^3$ ). Only 19% of the nursing homes were well ventilated.[7]

Recently, the exposure of Portuguese institutionalized elders to  $\text{PM}_{10}$  and to nanoparticles (NP) was determined. In particular, an equipment able to calculate the deposited surface area of NP into lungs was used. Mean  $\text{PM}_{10}$  concentration in bedrooms and living rooms was  $11 \mu\text{g}/\text{m}^3$  and  $19 \mu\text{g}/\text{m}^3$ , respectively, and the NP-deposited surface area ranged from 10 to  $46 \mu\text{m}^2/\text{cm}^3$  with higher peaks detected in living rooms with respect to the bedrooms.[11]

Regardless of the low levels of indoor air pollution, some relationships between air pollution exposure and respiratory health status were found,[7] as reported below.

### Health effects

It is well known that indoor air pollution may adversely affect both cardiovascular system and respiratory system. In particular, the elderly are at higher risk of suffering from various respiratory diseases, such as chronic obstructive pulmonary disease (COPD), asthma, pneumonia and tuberculosis, as well as from cardiovascular diseases, than other age groups. It could be argued that in the elderly the burden of respiratory diseases would depend on higher intensity and longer duration of exposure to environmental risk factors. Epidemiological researches to

identify whether frailty enhances air pollution susceptibility in the elderly are still at an early stage.[8]

One of the most important indoor pollutant is ETS, the main source of air-suspended particles. In Europe, 20–60% of adults are exposed to ETS.[12] A past comprehensive review reported a significant relationship between indoor ETS exposure (at home) and asthma, COPD and chronic respiratory symptoms with odds-ratio (OR) (in exposed vs. unexposed elderly) ranging from 1.45 to 1.97, from 1.68 to 5.63 and from 1.35 to 4.50, respectively.[6] The EU smoke-free laws determined a reduction of ETS exposure in public spaces, in particular in health-care facilities. But, this kind of exposure remains an important source of indoor pollution in the event of lack of observance for the smoking ban, in private settings or in the event of penetration of smoke from outdoor (i.e. people smoking outside the nursing home, but near a window or a door).

In the GERIE study, a significant relationship between exposure to chemical indoor air pollutants and respiratory outcomes in the elderly was shown, even at moderate concentrations.[7] Exposure to high levels of  $\text{NO}_2$  (concentrations higher than the mean value of  $\text{NO}_2$   $20.1 \mu\text{g}/\text{m}^3$ ) resulted related to higher risk of having COPD (defined according to spirometric values) (OR: 3.74; 95% CI: 1.06–13.1) and usual breathlessness and cough (OR: 1.58; 95% CI: 1.15–2.20 and OR: 1.56; 95% CI: 1.03–2.41, respectively). High levels of  $\text{PM}_{10}$  (higher than  $29.8 \mu\text{g}/\text{m}^3$ ) were associated with an excess risk for usual breathlessness and cough (OR: 1.53; 95% CI: 1.15–2.07 and OR: 1.73; 95% CI: 1.20–2.50, respectively); high levels of  $\text{PM}_{0.1}$  (higher than  $12907 \text{pt}/\text{cm}^3$ ) were related to COPD (OR: 8.16; 95% CI: 2.24–29.3) and to wheeze in the past year (OR: 2.82; 95% CI: 1.15–7.02). Formaldehyde high levels (higher than  $7.21 \mu\text{g}/\text{m}^3$ ) were related to reported COPD (OR: 3.49; 95% CI: 1.17–10.3).[7]

In a recent French study, 20 VOCs were objectively measured in 490 dwellings. Associations between breathlessness and living in dwellings with elevated concentrations of toluene and o-xylene were statistically significant in elderly but not in the rest of the population.[13]

The GERIE study analyzed  $\text{CO}_2$  as an indicator of poor ventilation, showing that only 19% of the population had adequate ventilation in nursing homes. A more pronounced effect of indoor air pollution on respiratory outcomes was observed in the elderly permanently living in poorly ventilated nursing homes.[7]

At last, the GERIE study showed that elderly subjects aged  $\geq 80$  years were at higher risk with respect to those  $< 80$  years.[7] This result supports the hypothesis of a link between ageing and frailty and indicates the susceptibility of older adults to the health effects of air pollution.

### Susceptibility

Changes in lung structure and function, as a consequence of normal ageing, may significantly contribute to predisposition for respiratory diseases among healthy elderly and may influence their response to air pollution. In particular, the immune system

undergoes age-associated alterations, weakening the physiological defense mechanisms and accruing biological damages (the *immunosenescence*). Besides natural ageing, the immune system can be made less effective in protecting the elderly, especially if already ill or frail, by other factors like the past infections, comorbidities and medications,[14,15] which is called pathological ageing.

Moreover, it was shown that the gerontologic frailty (syndrome characterized by multisystem decline) may modify the association between ambient level of ozone, PM<sub>10</sub> and lung function, with larger decrease of lung function parameters in frail elderly with respect to robust ones.[15]

The susceptibility with ageing to air pollution can be enhanced by other factors: smoking, occupational and past environmental exposure history can weaken the cardiovascular and respiratory systems; an imbalanced dietary habit can lead to deficits of key dietary factors such as antioxidants, which are part of the first line of defense to oxidative air pollutants.[14]

## Conclusions

Whether elderly are at higher risk of developing air pollution-related diseases than the rest of the population is under debate.[13] Indoor air pollution may play a special role in the elderly, since they are likely to spend most of their time

indoors due to reduced outdoor activities. Under the hypothesis that the severity of respiratory diseases may depend on intensity and duration of exposure to air pollution, the elderly might be at higher risk of suffering from air pollution-related diseases than the rest of the population because of their longer exposure to air pollution.

The results of the GERIE study clearly highlight that the elderly are at risk of respiratory health impairment, even at moderate air pollutant concentrations, particularly if over 80 years and living in poorly ventilated nursing homes.

The future epidemiological research on ageing and respiratory diseases should investigate the underlying biological and physiological mechanisms, in addition to the adverse health effects of potential indoor risk factors, in order to help defining effective strategies for healthy ageing.

## Financial & competing interests disclosure

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