

## 21036 Elderly Exposure to Fungi: A Review Study

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### Introduction

Indoor air quality is an increasing concern since people spend 90% of their time indoors. The majority of exposure to air pollution happens indoors rather than outdoors, despite the focus being on the latter. Indoor air quality in elderly care centers (ECC) is an emerging important issue arising in the last decade because of the increase of (1) life expectancy, (2) number of individuals residing in ECC, and (3) population aging, which is correlated with the inversion of the age pyramid (United Nations UN, 2012; GEP/MSSS, 2010). However, given the magnitude of the ECC population that is ageing, and the considerable amount of time spent by elders within ECC, information linking contamination of ECC by particles, micro-organisms and exposure of elders continues to be sparse (Almeida-Silva *et al.* 2014a,b). Thus, societies must provide environments that guaranty the wellbeing of vulnerable groups like the elderly.

The older population is growing faster than the total population in practically all regions of the world – and the difference in growth rates is increasing (United Nations UN, 2012). Since 1996 until 2008 the number of adults aged >65 years increased 31% (from 380 million to 500 million). According to the United Nations UN (2013) the percentage of total population aged 60 years or over in the world was 11% for the year 2010 and is estimated to be 18% for 2050. Although indoor concentration and number of carcinogenic air pollutants has been decreasing since the 1950s (Weschler, 2009), all of the previously evidences, plus the changes on life-style and the fact that people spend a large part of their life inside indoor environments have promoted an increase on exposure to indoor air pollutants (Byčenkienė *et al.*, 2009; Zhao *et al.*, 2009; Dales *et al.*, 2008; Leech *et al.*, 2002; Klepeis *et al.*, 2001). Consequently, we are witnessing an intensification of studies developed by the scientific community concerning Indoor Air Quality (IAQ) and its effects upon health (Canha *et al.*, 2012a,b; Franck *et al.*, 2011; World Health Organization WHO, 2010; Saliba *et al.*, 2009; Fraga *et al.*, 2008; Fromme *et al.*, 2007; Kosonen and Tan, 2004; Lee *et al.*, 2002; Wilson, 1996; Allen and Miguel, 1995). Indoor air pollution is caused by a combination of several factors: hazardous substances that are emitted from the outdoors, buildings, construction materials, furnishings, equipment, inadequate ventilation, indoor human activities, etc. (Almeida-Silva *et al.*, 2015; Canha *et al.*, 2013; Viegas *et al.*, 2010; Weschler, 2009). Physical factors such as air temperature, air velocity and relative humidity are usually used as indicators of thermal comfort, in IAQ studies. The main chemical and biological parameters used to characterize the IAQ are carbon monoxide (CO) and dioxide (CO<sub>2</sub>), the volatile organic compounds (VOC), the formaldehyde (H<sub>2</sub>CO), the ozone (O<sub>3</sub>), the particulate matter (PM), fungi and bacteria. Several studies positively correlated indoor exposure to microorganisms and microbial components with adverse health effects including headache and respiratory symptoms (Douwes *et al.*, 2003). Considering specifically fungi, their spores are complex agents that may contain multiple hazardous components. Health hazards may differ across species because fungi may produce different allergens and mycotoxins. Moreover, some species also infect humans (Eduard and Halstensen, 2009). Most infections occur in immunocompromised hosts or as a secondary infection, following inhalation of fungal spores or the toxins produced by them (Srikanth *et al.*, 2008). It is known that some people are sensitive to molds and exhibit symptoms such as dry nose, wheezing, and red or itchy eyes or skin when exposed to molds. Severe reactions have also been observed among workers exposed to large amounts of molds in occupational settings including fever and shortness of breath. Exposure to mold or dampness may also lead to development of asthma in some individuals (Centers for Disease Control and Prevention CDC, 2017).

### Methodology

In order to identify the scientific publications to be included in this review and analysis, three search engines were used: Web of Science (WoS), Scopus, and Online Knowledge Library (b-on). This strategy allowed to access to the largest number of existing publications under this topic. These search engines were selected due to its interdisciplinary nature, in order to cover several disciplines – from mycology to environmental science.

The search methodology was developed under three steps.

#### First Step

The follow keywords were selected and search in all selected search engines:

- A. “elderly” + “indoor” + “fung\*”.
- B. “old\*” + “indoor” + “fung\*”.
- C. “old\*” + “indoor air” + “fung\*”.

## Second Step

After the first approach a list of inclusion and exclusion criteria was created, in order to do a deep and refined selection of the retrieved publications. Inclusive criteria: publications that studied indoor environments related to elderly people; publications in English and Portuguese. Exclusive criteria: publications before the year 2000; publications in duplicate; the follow keywords – “child\*”, “infant\*” and “work”. **Table 1** presents the number of publications under the study in first and second methodological steps.

## Third Step

A database with all selected articles was elaborated. During this process all duplicate publications were erased, as well as publications that didn't present any quantitative or qualitative data regarding fungi concentrations in elderly homes. The studies included in this integrative review were selected based on their content. In terms of content, each publication selected for this literature review included results based on empirical data on the relation between fungi concentrations assessed indoors and elderly or old people. Considering the purpose of this study, the possible influence of sociodemographic variables was not considered in this article, since it was considered irrelevant.

At the end, 11 publications (**Table 2**) were compiled to be discussed in the next sub-chapter.

## Results and Discussion

**Table 2** summarizes the selected publications after the application of the three methodological steps described previously.

The temporal distribution of the 11 publications identified according to the stated criteria was not uniformed. A total of 9% covered the period between 2005 and 2010; 27% represented the period between 2010 and 2015; 64% were from the period between 2015 and 2019. The largest proportion of studies identified in recent years, or in other words since 2015, may be due to the fact that scientific

**Table 1** Number of publications identified according to each keywords' group, search engine and inclusion and exclusion criteria

| Keywords            | A  |    | B                |    | C   |    |
|---------------------|----|----|------------------|----|-----|----|
| Methodological Step | 1  | 2  | 1                | 2  | 1   | 2  |
| WoS                 | 46 | 17 | 313 <sup>a</sup> | –  | 212 | 19 |
| Scopus              | 15 | 9  | 111              | 14 | 57  | 9  |
| b-On                | 22 | 11 | 96               | 15 | 47  | 10 |

<sup>a</sup>Due to the big amount of generated data and the heterogeneity of the results this keywords' group for WoS was rejected.

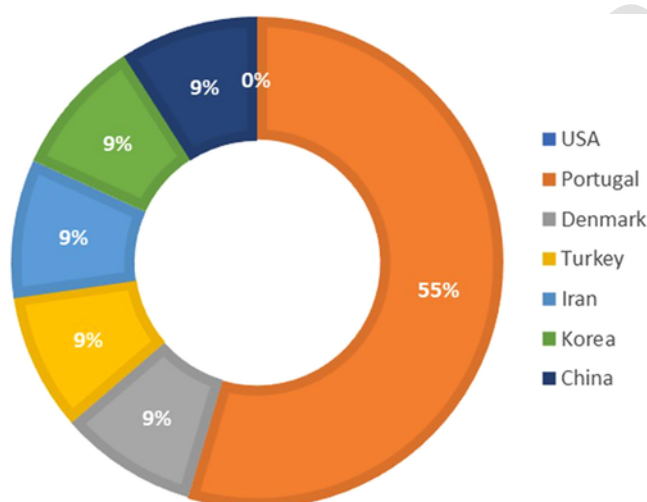
**Table 2** Selected publications after the three methodological steps

| Title  | Year | Ref.                                 |
|--|------|--------------------------------------|
| Airborne microbiological characteristics in public buildings of Korea  | 2007 | (Kim and Kim, 2007)                  |
| Biological air contamination in elderly care centers   | 2014 | (Aguiar <i>et al.</i> , 2014)        |
| Fungal Contamination Assessment in Portuguese Elderly Care Centers   | 2014 | (Viegas <i>et al.</i> , 2014)        |
| Indoor air quality and thermal comfort in elderly care centers   | 2015 | (Mendes <i>et al.</i> , 2015)        |
| Indoor and outdoor exposure to ultrafine, fine and microbiologically derived particulate matter related to cardiovascular and respiratory effects in a panel of elderly urban citizens | 2015 | (Karottki <i>et al.</i> , 2015)      |
| “Avaliação da qualidade do ar interior em lares de idosos, 2013–2014: projeto GERIA” (Portuguese)  | 2016 | (Cano <i>et al.</i> , 2016)          |
| The impact of indoor air quality and contaminants on respiratory health of older people living in long-term care residences in Porto   | 2016 | (Mendes <i>et al.</i> , 2016)        |
| Airborne fungal diversity inside a nursing home in Edirne, Turkey  | 2017 | (Yilmaz <i>et al.</i> , 2017)        |
| Bioaerosol exposure and circulating biomarkers in a panel of elderly subjects and healthy young adults   | 2017 | (Faridi <i>et al.</i> , 2017)        |
| Indoor environmental conditions in urban and rural homes with older people during heating season: a case in cold region, China   | 2018 | (Fan <i>et al.</i> , 2018)           |
| “Qualidade do ar interior em ambiente geriátrico no Nordeste de Portugal” (Portuguese)   | 2018 | (Madacussengua <i>et al.</i> , 2018) |

studies about indoor air pollutants in elderly care centers only effectively began in the second half of the 20th century, with scientific production on this theme intensifying from this period onwards.

The selected publications are from Europe (73%) and Asia (27%). **Fig. 1** represents the general characterization of the selected publications according to the country in study. It is possible to observe that Portugal shows the highest percentage (55%) of developed works on the studied field, followed by Asiatic Continent (Iran, Korea and China). This shows a Portuguese great concern about this topic and goes in line with the European society' evolution: (1) in 2014 the Portuguese ageing rate was higher than the European average, with 21% of the population aged 65 or over (**Eurostat, 2014**); (2) according to Eurostat, Portugal will have the oldest European population in 2050, with almost 50% of the population with more than 55 years old. The justification is given by a historical drop in fertility rates, increased average life expectancy and, in some cases, migration patterns (**Eurostat, 2019**) (see **Figure SI 1**).

Regarding the methodology of each study it was possible to observe (**Table 3**) that 63% (n = 7) of the selected works used impaction as sampling method, either using the Merck Air Sampler MAS-100 (n = 4), the Six-stage cascade impactor (Andersen, Model 10–800) (n = 1), the Merck Millipore M Air T (n = 1), or the Surface Air System air sampler (n = 1) (**Table 2**). Of those, 5 used malt extract agar



**Fig. 1** Publications distributed according to its localization.

**Table 3** Detailed information regarding the applied methodology

| Ref.                         | Indoor | Outdoor | Equipment   | Agar                     | Incubation conditions (duration (days); temperature (°C)) |
|------------------------------|--------|---------|---|--------------------------|---|
| (Kim and Kim, 2007)          | x      | x       | Six-stage cascade impactor (Andersen, Model 10–800) | MEA with chloramphenicol | 3–5d; 20–25°C   |
| (Aguiar et al., 2014)        | x      | x       | Merck Air Sampler MAS-100                           | MEA                      | 3d; 25°C  |
| (Viegas et al., 2014)        | x      | x       | Merck Air Sampler MAS-100                           | MEA with chloramphenicol | 5–7d; 27°C ± 2°C  |
| (Mendes et al., 2015)        | x      | x       | Merck Air Sampler MAS-100                           | MEA                      | 25°C  |
| (Karottki et al., 2015)      | x      | –       | Electrostatic Dust Cloths (for 15 days)             | DG-18                    | 3–7d; 25°C  |
| (Cano et al., 2016)          | x      | x       | Merck Air Sampler MAS-100                           | MEA                      | 4–5d; 25°C  |
| (Mendes et al., 2016)        | x      | x       | n/d   | n/d                      | n/d   |
| (Yilmaz et al., 2017)        | x      | x       | Merck Millipore M Air T                             | RBCA                     | 7d; 25°C  |
| (Faridi et al., 2017)        | x      | x       | QuickTake® 30                                       | SDA with chloramphenicol | 3–7d; 20–28°C   |
| (Fan et al., 2018)           | x      | -       | Adherent material applied in floor surfaces         | DG-18                    | 5d; 25°C  |
| (Madacussengua et al., 2018) | x      | x       | Surface Air System                                  | RBCA                     | 3–5d; 25°C  |

Note: n/d: Not described.

(MEA) (two with chloramphenicol added) and 2 Rose-Bengal Chloramphenicol Agar (RBCA). **Faridi et al. (2017)** used the QuickTake® 30 as air sampling device, with a spore trap cassette system, and Sabouraud Dextrose Agar (SDA) supplemented with chloramphenicol as culture medium. Other two studies used a different methodology, based on passive methods: adherent material applied in floor surfaces (Fan et al., 2017); and Electrostatic Dust Cloths (**Karottki et al., 2015**) using Dichloran Glycerol Agar (DG-18) as culture medium. The applied methodologies regarding temperature and incubation time are not equal through the selected works. For the impaction-based sampling studies, three (Madacussengua et al., 2019; Kim and Kim, 2007; Aguiar et al., 2014) describe similar conditions, with incubation periods from 3 to 5 days in a temperature between 20–25°C. A slight difference could be observed in **Cano et al. (2016)** and **Fan et al. (2018)** with a duration and temperature of incubation around 4–5 days and 25°C, respectively. The other studies, **Yilmaz et al. (2017)**, **Faridi et al. (2017)**, **Karottki et al. (2015)** and **Viegas et al. (2014)**, applied more incubation time for its samples: 5–7 days, and incubation temperatures between 25°C and 29°C. **Mendes et al. (2015)** only presented the temperature of incubation, 25°C.

Although the number of publications is scarce, it is interesting to notice the small divergence of reported results across Europe and Asia: median concentrations (considering all studies) were 350 CFU m<sup>-3</sup> and 406 CFU m<sup>-3</sup> respectively, and the most frequently found genera were *Cladosporium* sp., *Penicillium* sp. and *Aspergillus* sp. regardless the region. Knowing that weather conditions and geography-related vegetation (Jędrzycka, 2014; Núñez et al., 2016) are the most accountable factors contributing to airborne fungi diversity, a wider heterogeneity in the results was expected.

Overall, the main findings reported in these publications were:

- (1) Fungi species found in indoor air were similar to the ones found outdoor;
- (2) *Penicillium* sp., *Aspergillus* sp. and *Cladosporium* sp. were the dominant genera of fungi both indoor and outdoor;
- (3) Levels of fungi indoor were weakly but significantly correlated with the levels of PM<sub>2.5</sub>;
- (4) Median concentration levels of indoor fungi exceed the median outdoor levels during winter season;
- (5) Fungi median indoor concentrations were slightly above references in winter season, and peak values in both seasons (winter and summer) were concerning;
- (6) Significant positive correlations were found between temperature and *Aspergillus* sp., *Cladosporium* sp. and *Alternaria* sp. levels;
- (7) Correlation between circulating biomarkers, especially IL-6 and white blood cells counts, and fungal aerosols exposure among elderly subjects was found;
- (8) Fungi levels in rural houses were higher than in urban houses.

No Health Authority or equivalent organization has already set specific limits for indoor air pollutants' levels regarding environments harboring particular groups of individuals, as children, the elderly, patients, and other immunologically vulnerable individuals. In addition, for fungi, the only existing regulation for indoor levels is specifically set for indoor environments as a measure of good indoor air quality, yet the values vary greatly between countries/entities. For instance: the European Confederation Commission recommends levels of fungi under 2000 CFU m<sup>-3</sup>; the World Health Organization (**World Health Organization WHO, 2009**), under 500 CFU m<sup>-3</sup>; the American Industrial Hygiene Association (AIHA) under 1000 CFU m<sup>-3</sup> (**EL-Morsy, 2006**); the Turkish Standards Institute under 1000 CFU m<sup>-3</sup> [TS 12281/Nisan 1997] (**EL-Morsy, 2006**); the Portuguese government sets the limit of indoor air fungi level at the level of concomitant outdoor air fungi level (**Ordinance no 353-A/2013**).

The levels of fungi found for elderly care centers varied between 5 CFU m<sup>-3</sup> and 1343 CFU m<sup>-3</sup> among the studies in review. Depending on the location, these levels could or not be acceptable. If the indoor concentrations of airborne fungi are higher than the outdoor concentration, the presence of indoor generative sources may be suspected. Nevertheless, from a health perspective the risk that fungi exposure poses is much more related to the susceptibility of the individuals rather than to general limits. As observed in one of the publications a correlation between circulating biomarkers of inflammation – IL-6 and white blood cells count – and fungi exposure could be established for a population of older people. Among older adults, asthma-related hospitalizations have already been associated with the presence of mold in the home environment. (**Hsu et al., 2018**). These data are suggestive that much more studies are needed to assess the influence of fungi in indoor air and older-people's health.

## Conclusion

The growing number of aged populations is a consequence, among others, of the better health conditions that medical progress has enabled. These populations, despite their longevity, may present new challenges as their immune system, resistance, past diseases, and overall frailty may predispose them differently to otherwise non-threatening substances and contaminants. This still growing new reality coupled with changes in lifestyles and environment makes it a priority to fully assess the risk that indoor air contaminants exposure poses to these populations. Establishing safe exposure limits specifically considering these populations needs would result in improved health and quality of life, and a significant reduction in costs with healthcare.

## Appendix A Supplementary Material

Supplementary data associated with this article can be found in the online version at doi:10.1016/B978-0-12-819990-9.21036-6.

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