

Identification of saprophytic and allergenic fungi in indoor and outdoor environments

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Received: 28 February 2018 / Accepted: 27 August 2018
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Abstract The airborne spores of some saprophytic and allergenic fungi such as *Aspergillus*, *Alternaria*, and *Cladosporium* are found throughout the world and exposure to these agents may result in various types of allergic diseases. The aim of this study, therefore, was to investigate the frequency of different saprophytic, allergenic, and pathogenic fungi in indoor and outdoor environments. During a 6-month period, 780 samples were obtained from a number of houses, mosques, parks, public restrooms, grocery stores, laboratories, and hospitals. An open-plate method was applied for air sampling by exposing 90-mm plates containing chloramphenicol/potato dextrose agar and malt extract agar were exposed to air for 30 min. Alternatively, the sampling from surfaces was performed using sterile wet swab and tape-stripe method. All samples were then inoculated in media and incubated at 28 °C for 2–3 weeks. The isolated fungi were purified in order to detect the genus, and if possible, species level of the targeted fungi based on

morphological and microscopic features using standard methods. The findings revealed that the dominant indoor and outdoor fungal species were *Aspergillus*, *Penicillium*, and *Cladosporium* whose frequency values were 16.42%, 16.17%, and 14.92% respectively. The lowest frequency was related to *Acrophialophora* and *Madurella* (0.25%). More notably, the results for air and surface were similar. It was also found out that the three dominant genera were *Aspergillus* (16.53%), *Penicillium* (15.50%), and *Cladosporium* (11.93%), with *Basidiobolus* and *Acrophialophora* having the lowest frequency. It was observed that different environmental spaces have a great bearing on the spreading of such allergic agents, especially in subtropical humid climates.

Keywords Allergenic fungi · Airborne fungi · Indoor and outdoor air · Saprophytic fungi

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Introduction

Molds are found in both outdoor and indoor environments (Dassonville et al. 2008) and are widely distributed in air, soil, water, decaying vegetation (Hageskal et al. 2009; Shams-Ghahfarokhi et al. 2014), and all building materials with enough moisture (Dassonville et al. 2008). They can live under extreme conditions in almost all regions and all climates (Kalyoncu 2010).

Atmospheric air—both indoor and outdoor—contains certain varieties of fungal elements and some fungal spores, but the concentration of fungal

elements differs according to location, altitude, time of day, season, and climate conditions (Chadeganipour et al. 2010).

The abundance of fungi in different environments, combined with the small size and easy dispersion of their propagules, favors high concentrations of fungal spores in the air in both indoor and outdoor environments (Sen and Asan 2009). Indoor and outdoor fungal exposure levels are associated with the development of allergic respiratory diseases (Arikoglu et al. 2016).

Airborne fungi are emanated from biological and non-biological sources and can transfer to the respiratory tract of humans directly or indirectly (Picco and Rodolfi 2000; Kuhn et al. 2005; Basilico et al. 2007). The effect of fungal particles on human health is associated with their size and physical properties (Kim et al. 2009). Microbial contaminants in indoor environments are most often present in suspended dust and may cause immunological reactions in susceptible individuals (Sousa et al. 2014).

Many fungal species have been described as the cause of allergic disease and their concentration is species-specific (Fukutomi and Taniguchi 2015). *Aspergillus*, *Alternaria*, and *Cladosporium* are among the most common allergens; in susceptible people or those exposed to extremely high inocula, invasive mycoses may follow exposure to fungi (Hedayati et al. 2011; Foladi et al. 2013).

Allergenic fungi secrete certain allergen enzymes into their surroundings (Levetin et al. 2016) and can cause some effects such as IgE-mediated allergy, non-IgE-mediated hypersensitivity, allergic rhinitis, and asthma (Wu et al. 2000; Soeria-Atmadja et al. 2010; Meheust et al. 2014; Fukutomi and Taniguchi 2015; Arikoglu et al. 2016).

Although susceptible people may be infected at different places, it should be noted that different environmental spaces have their importance roles in contributing to the spread of these agents, especially in subtropical humid climates (Rafiei and Amirrajab 2010).

Further, it has long been recognized that the qualitative determination of the fungi recovered from environmental samples is more useful than determining the concentrations of fungi (Horner et al. 2004).

For this reason, concerns about health effects of airborne fungi in different environments have been increasing for some years. This study aims to evaluate the distribution of airborne fungi in different indoor and outdoor environments in Isfahan, Iran.

Materials and methods

This study was carried out for a 6-month period from 21 March to 22 September 2014. A total of 780 samples were collected from the indoor and outdoor air ($n = 316$) and the surfaces ($n = 464$) of different sites including ten houses, ten mosques, ten greengroceries and butcheries, six parks, ten public restrooms, six laboratories, and two hospitals (Table 1). The interval between sampling of each site was about 2–3 weeks.

Air sampling

Air samples were collected from the indoor and outdoor air of each site. The sampling time was always the same: between 08:00 and 10:00 AM.

Airborne fungi were sampled using an open-plate method; 90-mm diameter Petri dishes containing potato dextrose agar (PDA) and malt extract agar (MEA) (Merck, Germany) supplemented with chloramphenicol were placed with lids open in sampling locations at a height of about 1.5 m above the floor (Chadeganipour et al. 2010; Kalyoncu 2010; Rostami et al. 2017) for 30 min, and after which, the plates were transferred to the laboratory as soon as possible. The total number of air samples and consequently the number of Petri dishes were given in Table 1. Of the 316 air samples, half belonged to the indoor samples and other half belonged to the outdoor samples.

Surface sampling

Surface sampling was done after the completion of air sampling to mitigate the possibility of artificial spore aerosolization. Surface samples were obtained from wall surfaces with or without visible fungal growth. The surface samples were collected using a combination of the swab sampling and tape-lift sampling methods (Kuhn et al. 2005).

Sterile wet swabs were used to remove the visible or invisible fungal particles from surfaces. For the tape-strip technique, a 3-cm piece of adhesive tape was placed on the surface and then removed. The tape was then cut into 1-cm pieces. Each piece was placed on the medium with the adhesive side facing down. Ten samples were taken from moldy fruits which was done using a sterile teasing needle. The samples were then immediately cultured on media under sterile conditions. All samples were cultured on PDA and MEA supplemented with chloramphenicol.

Table 1 The sites, locations, and number of samples

Sites	Locations of sampling	Number of samples		Total
		Air	Surface	
Houses	Living room, bed room, kitchen, bath room, balcony, and warehouse.	120	240	360
Mosques	Washstand and praying room	40	40	80
Hospitals	Operation room, recovery room, reception, and emergency ward	16	16	32
Food stores	Indoor and outdoor	40	60	100
Public restrooms	Indoor and outdoor	40	60	100
Parks	Three separate locations of park	36	–	36
Laboratories	Two separate locations of laboratory	24	48	72
Total		316	464	780

Identification of fungi

All cultured samples were incubated at 28 °C and were checked daily in terms of fungal colony growth. The identification of fungi was carried out based on the morphological features of colonies and microscopic examination. Definite identification of fungi was done using various mycological references (Fisher and Cook 1998; Ellis et al. 2007). Fungi were identified at the genus and, if possible, species levels.

Results

Air samples

A total of 402 colonies were isolated on 316 Petri dishes from indoor and outdoor air samples, which represented 16 genera (Table 2). The distribution of fungi varied in indoor and outdoor environments.

The frequency rate of isolated fungi in indoor samples was higher than that in outdoor samples. The four most predominant indoor and outdoor fungal species were found to be *Aspergillus* spp. (16.42%), *Penicillium* sp. (16.17%), *Cladosporium* sp. (14.92%), and *Mucor* spp. (12.69%).

The lowest frequency rate was observed for *Acrophialophora* (0.25%) and *Madurella* (0.25%).

Aspergillus (22.10%) and *Alternaria* (18.95%) were the most frequent genera in outdoor air, while *Penicillium* (21.23%) and *Cladosporium* (15.09%) were the dominant isolated species in indoor air (Table 2).

Aspergillus niger was the most prevalent isolate among all species of *Aspergillus*. The frequency rates of *Aspergillus* species were *A. niger* (42.42%), *A. flavus* (24.24%), *A. fumigatus* (12.12%), *A. clavatus* (3.03%), *A. glaucus* (3.03%), *A. terreus* (1.52%), and unidentified species (13.64%) (Table 3).

Madurella grisea was isolated from a hospital recovery room and was distinguished from *M. mycetomatis* by its inability to growth at 37 °C and its ability to assimilate sucrose (Ellis et al. 2007).

Total concentration of indoor and outdoor fungi was found to be significantly higher in greengroceries and butcheries, while the lowest rate was found in samples from hospital operation and recovery rooms (Table 4).

Surface samples

A total of 587 pure colonies were isolated in the culture media. The most prevalent fungal isolates were obtained from greengroceries and butcheries, houses, public restrooms, and laboratories with the frequency rates of 28.11%, 24.87%, 21.29% and 15.33% respectively. *Aspergillus* was the most common isolate, with a frequency of 16.53%, followed by *Penicillium* 15.50% and *Cladosporium* 11.93% (Table 5).

In conclusion, 989 fungal colonies were isolated and purified from indoor, outdoor, and surface samples. A total of 20 fungal genera were identified, of which *Aspergillus* sp. (16.48%), *Penicillium* sp. (15.77%), and *Cladosporium* (13.14%) were the dominant genera (Table 6). Figures 1 and 2 show the distribution status of fungi in different environments.

Table 2 Distribution of isolated airborne fungi genera according to indoor and outdoor environments

Genus	Number of colonies			%	χ^2	Sig.
	Indoor	Outdoor	Total			
<i>Absidia</i>	4	—	4	1	—	—
<i>Acrophialophora</i>	1	—	1	0.25	—	—
<i>Alternaria</i>	10	36	46	11.44	14.696	< 0.001*
<i>Aspergillus</i>	24	42	66	16.42	4.909	0.027*
<i>Aureobasidium</i>	9	—	9	2.24	—	—
<i>Cladosporium</i>	32	28	60	14.92	0.267	0.606
<i>Epicoccum</i>	—	2	2	0.5	—	—
<i>Fusarium</i>	15	3	18	4.48	8.000	0.005*
<i>Madurella</i>	1	—	1	0.25	—	—
<i>Mucor</i>	30	21	51	12.69	1.588	0.208
<i>Paecilomyces</i>	5	6	11	2.73	0.091	0.763
<i>Penicillium</i>	45	20	65	16.17	9.615	0.002*
<i>Rhizopus</i>	20	16	36	8.95	0.444	0.505
<i>Scopulariopsis</i>	12	7	19	4.73	1.316	0.251
<i>Stemphylium</i>	2	3	5	1.24	—	1.000 ^a
<i>Ulocladium</i>	2	6	8	1.99	—	0.289 ^a
Total (%)	212 (52.74)	190 (47.26)	402 (100)	100	1.204	0.273

^a Exact sig. *Significant at 0.05 level

Discussion

Airborne fungal spores are among the most common organisms in nature (Soeria-Atmadja et al. 2010). Fungal spores can be dispersed through atmospheric air and can exist as saprophytes or as parasites of animals and plants. Fungi are ubiquitous airborne allergens and are the leading cause of various human diseases (Menezes et al. 2004).

Table 3 Distribution of identified *Aspergillus* species in air samples

<i>Aspergillus</i> species	Number of isolates	Percent
<i>A. niger</i>	28	42.42
<i>A. flavous</i>	16	24.24
<i>A. fumigatus</i>	8	12.12
<i>A. clavatus</i>	2	3.03
<i>A. glaucus</i>	2	3.03
<i>A. terreus</i>	1	1.52
Unidentified species	9	13.64
Total	66	100

Monitoring of the spore distribution of fungi in different places would provide valuable data to evaluate human health risk; therefore, identification and detection of airborne fungi in densely populated areas are necessary.

In the present study, the distribution of airborne fungi was investigated in different indoor and outdoor environments; it was found that the dispersion rate of fungal spores in indoor environments was higher than that in outdoor environments.

According to available reports, *Aspergillus* and *Penicillium* species are present in outdoor and indoor air throughout the year (Knutsen et al. 2012). In our study, outdoor and indoor air samples analysis show that *Penicillium* and *Aspergillus* were respectively the most dominant isolated genera (Table 2). According to the obtained results given in Table 2 and based on the data by chi-square, while the number of *Aspergillus* and *Alternaria* was significantly higher in outdoor samples, the number of *Penicillin* and *Fusarium* was meaningfully higher in indoor samples ($p < 0.05$). However, no significant difference was observed among the isolated fungi in indoor or outdoor samples ($\chi^2(1) = 1.204$, $p = 0.273$).

Table 4 Distribution of isolated airborne fungi according to the site and location of isolation

Isolated genera	House					Mosque		Greengrocery and butcheries	Public restroom
	Bed room	Living room	Bath room	Ware room	Kitchen	Balcony			
<i>Absidia</i>	—	—	—	—	—	—	—	—	—
<i>Acrophialophora</i>	—	—	—	—	—	—	—	—	—
<i>Alternaria</i>	—	—	—	3	2	2	—	12	11
<i>Aspergillus</i>	1	2	6	6	4	3	3	7	9
<i>Aureobasidium</i>	—	—	—	2	1	—	—	1	3
<i>Cladosporium</i>	1	1	4	3	3	1	2	13	14
<i>Epicoccum</i>	—	—	—	—	—	—	—	—	1
<i>Fusarium</i>	—	—	—	—	1	—	—	12	2
<i>Madurella</i>	—	—	—	—	—	—	—	—	—
<i>Mucor</i>	—	1	2	4	2	—	1	16	9
<i>Paecilomyces</i>	—	—	1	3	—	—	1	1	2
<i>Penicillium</i>	1	1	4	6	5	3	3	14	13
<i>Rhizopus</i>	—	—	1	1	1	—	1	8	8
<i>Scopulariopsis</i>	—	—	—	1	—	1	1	4	6
<i>Stemphylium</i>	—	—	—	—	—	—	—	2	—
<i>Ulocladium</i>	—	—	—	—	—	—	—	2	1
Total (%)	3 (0.75)	5 (1.24)	18 (4.48)	29 (7.21)	19 (4.73)	11 (2.74)	12 (2.98)	92 (22.88)	79 (19.65)

Isolated genera	Park	Laboratory	Hospital			Total	
			Operation room	Recovery room	Reception	Emergency	%
<i>Absidia</i>	—	4	—	—	—	—	1
<i>Acrophialophora</i>	—	1	—	—	—	—	0.25
<i>Alternaria</i>	8	7	—	—	—	1	11.44
<i>Aspergillus</i>	12	8	—	1	1	3	16.42
<i>Aureobasidium</i>	—	2	—	—	—	—	2.24
<i>Cladosporium</i>	5	9	1	—	1	2	14.92
<i>Epicoccum</i>	1	—	—	—	—	—	0.50
<i>Fusarium</i>	1	1	—	—	—	1	4.48
<i>Madurella</i>	—	—	—	1	—	—	0.25
<i>Mucor</i>	3	12	—	—	1	—	12.69
<i>Paecilomyces</i>	1	1	—	—	—	—	2.74
<i>Penicillium</i>	4	6	—	2	1	2	16.17
<i>Rhizopus</i>	2	13	—	—	1	—	8.95
<i>Scopulariopsis</i>	5	1	—	—	—	—	4.72
<i>Stemphylium</i>	2	1	—	—	—	—	1.24
<i>Ulocladium</i>	4	1	—	—	—	—	1.99
Total (%)	48 (11.94)	67 (16.67)	1 (0.25)	4 (1)	5 (1.24)	9 (2.24)	402 (100)

Table 5 Distribution of isolated fungi from surfaces according to site and location of their isolation

Isolated genera	House				Mosque				Greengrocery and butcheries				Public Restroom		Laboratory		Hospital		Total	%
	House				Mosque				Greengrocery and butcheries				Public Restroom		Laboratory		Hospital			
	Bed room	Living room	Bath room	Ware room	Kitchen	Balcony									Operation room	Recovery room	Reception	Emergency		
<i>Absidia</i>	1	1	–	–	1	2	–	1	1	1	4	–	–	1	–	–	12	2.04		
<i>Acrophialophora</i>	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	0.17		
<i>Alternaria</i>	–	–	–	–	2	2	5	24	20	20	7	–	–	–	–	–	60	10.22		
<i>Aspergillus</i>	6	3	11	15	5	8	3	15	11	11	8	1	–	5	6	97	16.53			
<i>Aureobasidium</i>	–	–	–	–	1	–	1	3	7	7	2	–	–	–	1	15	2.56			
<i>Basidiobolus</i>	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	0.17			
<i>Chrysosporium</i>	–	–	–	1	–	1	1	1	–	–	1	–	–	–	–	5	0.85			
<i>Cladosporium</i>	1	–	4	10	3	1	2	15	20	20	9	1	1	1	2	70	11.93			
<i>Curvularia</i>	–	–	–	1	–	2	–	–	3	3	2	–	–	–	–	8	1.37			
<i>Drechslera</i>	–	–	–	–	–	–	–	4	–	–	8	–	–	–	–	12	2.04			
<i>Epicoccum</i>	–	–	–	2	–	–	–	–	4	4	1	–	–	–	–	7	1.19			
<i>Fusarium</i>	–	–	–	3	1	–	5	20	4	4	3	–	–	1	1	38	6.47			
<i>Mucor</i>	–	2	2	–	2	2	–	26	16	16	12	–	–	–	–	62	10.56			
<i>Paecilomyces</i>	–	2	1	5	–	1	2	5	5	5	1	–	–	–	–	22	3.75			
<i>Penicillium</i>	6	–	8	2	5	3	7	30	13	13	6	2	3	2	4	91	15.50			
<i>Rhizopus</i>	–	1	5	2	1	–	–	8	13	13	8	–	–	1	–	39	6.64			
<i>Scopulariopsis</i>	–	–	2	–	–	1	–	6	6	6	6	–	–	1	–	22	3.75			
<i>Stemphylium</i>	–	–	–	–	–	3	1	3	–	–	7	–	–	–	–	14	2.39			
<i>Ulocladium</i>	–	–	–	2	–	–	–	4	1	1	4	–	–	–	–	11	1.87			
Total (%)	14 (2.39)	9 (1.53)	33 (5.62)	43 (7.33)	21 (3.58)	26 (4.43)	27 (4.60)	165 (28.11)	125 (21.29)	90 (15.33)	4 (0.68)	4 (0.68)	12 (2.04)	14 (2.39)	587 (100)	100				

Table 6 Distribution of isolated fungi genera from air and surface

Genus	Number of colonies			%	χ^2	Sig.
	Air	Surface	Total			
<i>Absidia</i>	4	12	16	1.62	4.000	0.046*
<i>Acrophialophora</i>	1	1	2	0.20	—	1.000
<i>Alternaria</i>	46	60	106	10.72	1.849	0.174
<i>Aspergillus</i>	66	97	163	16.48	5.896	0.015*
<i>Aureobasidium</i>	9	15	24	2.43	1.500	0.221
<i>Basidibolus</i>	—	1	1	0.10	—	—
<i>Chrysosporium</i>	—	5	5	0.50	—	—
<i>Cladosporium</i>	60	70	130	13.14	0.769	0.380
<i>Curvularia</i>	—	8	8	0.80	—	—
<i>Drechslera</i>	—	12	12	1.21	—	—
<i>Epicoccum</i>	2	7	9	0.91	—	0.180
<i>Fusarium</i>	18	38	56	5.66	7.143	0.008*
<i>Madurella</i>	1	—	1	0.10	—	—
<i>Mucor</i>	51	62	113	11.42	1.071	0.301
<i>Paecilomyces</i>	11	22	33	3.33	3.667	0.056
<i>Penicillium</i>	65	91	156	15.77	4.333	0.037*
<i>Rhizopus</i>	36	39	75	7.58	0.120	0.729
<i>Scopulariopsis</i>	19	22	41	4.14	0.220	0.639
<i>Stemphylium</i>	5	14	19	1.92	4.263	0.039*
<i>Ulocladium</i>	8	11	19	1.92	0.474	0.491
Total (%)	402 (40.65)	587 (59.35)	989 (100)	100	34.606	< 0.001

^a Exact sig. *Significant at 0.05 level

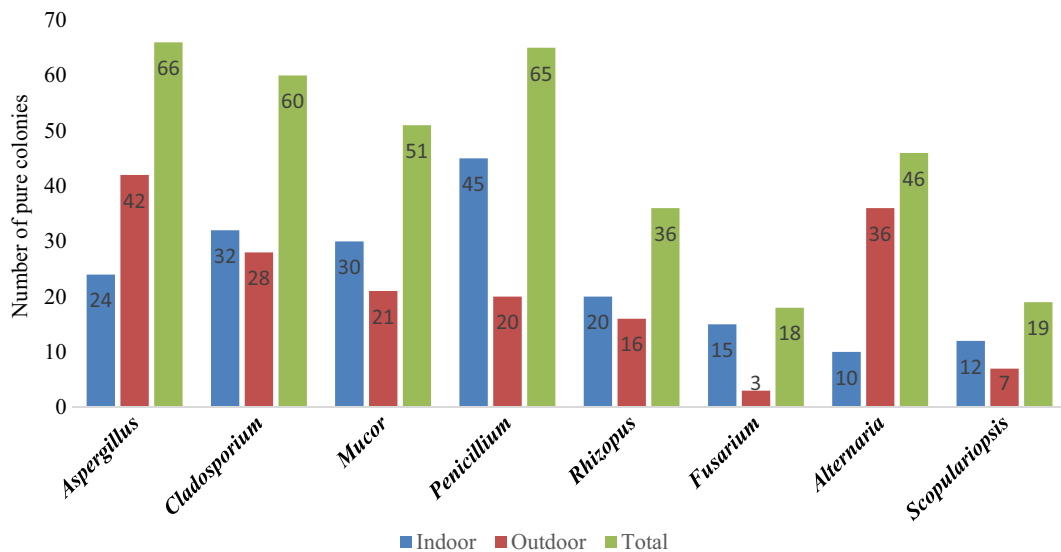


Fig. 1 Distribution of isolated fungi in indoor and outdoor air. ■ indoor. ■ outdoor. ■ total

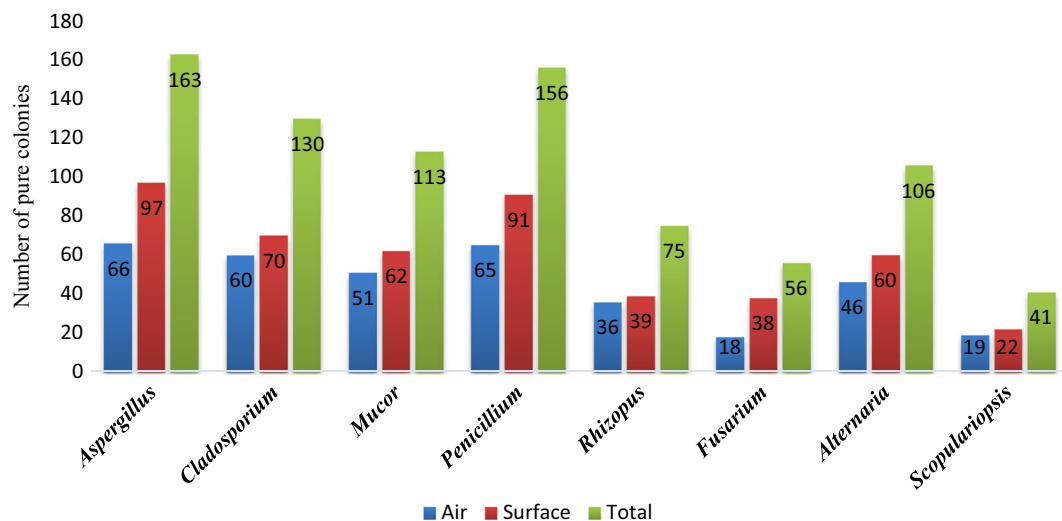


Fig. 2 Distribution of isolated fungi in air and surface samples. ■ air. ■ surface. ■ total

A relatively strong correlation was detected between indoor and outdoor fungal levels of *Cladosporium*. In a study done in the homes of asthmatic participants, *Cladosporium*, *Alternaria*, *Aspergillus*, and *Penicillium* were predominant indoor fungal species (Sharpe et al. 2015), while *Cladosporium*, *Penicillium*, *Aspergillus*, and *Alternaria* were found to be predominant in another such study (Arikoglu et al. 2016). Although *Aspergillus*, *Cladosporium*, and *Penicillium* were encountered in most previous studies, various species of fungi have been reported as the dominant species by different researchers (Basílico et al. 2007; Sen and Asan 2009; Chadeganipour et al. 2010; Hedayati et al. 2011). The distribution of airborne fungi in subway stations was investigated and it turned out that *Penicillium* and *Alternaria* were the two dominants genera (Hossieni et al. 2013). The distribution of fungal elements in indoor and outdoor environments depends on numerous physical and biological factors (Mirhoseini et al. 2016; Rostami et al. 2017). Indoor fungi originate from outdoor environments or moist surfaces (Knutsen et al. 2012).

Our study was done in two seasons, spring and summer. The seasonal variation can affect the fungi population in the environment. There may be a direct relationship between the fungal population and the incidence of allergic diseases. Common allergenic molds have dry spores and can disperse easily in dry and windy weather (Soeria-Atmadja et al. 2010). Isfahan is a dry city with low rainfall, which probably affects the distribution status of fungal spores.

Various reports have shown that *Alternaria*, *Cladosporium*, *Aspergillus*, and *Penicillium* are among the most common fungi that cause asthma (Zubairi et al. 2014).

Some studies have shown that the majority of fungi in outdoor air belonged to the phyla Ascomycota and Basidiomycota (Knutsen et al. 2012), but in our study, the most common fungal species belonged to Ascomycota and Zygomycota. In our study, members of *Mucor* were among the most common fungi isolated from indoor and outdoor samples. However, these were not found to be predominant species in other studies.

Aspergillus spp. are widely distributed in different environments and can cause various respiratory infections in immunocompromised patients (Ajodanifar et al. 2011). Specifically, four species of *Aspergillus* *fumigatus*, *A. terreus*, *A. nidulans*, and *A. niger* are common agents of human and animal diseases (Levetin et al. 2016). In our study, the genus *Aspergillus* was the most frequently isolated genus from outdoor samples, mostly represented by *A. niger*, *A. flavus*, *A. fumigatus*, *A. clavatus*, *A. glaucus*, and *A. terreus* (Table 3).

The second and third most predominant genera isolated from outdoor samples were *Alternaria* and *Cladosporium* (Table 2). *Cladosporium* and *Alternaria* spores are dispersed by wind and are found abundantly in indoor and outdoor environments. Some species are known to be the major agents of allergic diseases in sensitized people (Levetin et al. 2016; Skjoth et al. 2016).

In our study, *Penicillium* was the most commonly isolated species in indoor samples. *Penicillium* species are common wherever organic material is available and some can even grow under conditions with very little water. *Penicillium* is one of the most common airborne allergenic fungi, along with *Cladosporium* and *Alternaria*. In addition, *Penicillium* exposure in damp homes is a risk factor for asthma (Levetin et al. 2016).

The results of the present study are not consistent with some related research works. For instance, in a study, *Epicoccum* was found to be one of the three predominant genera (Basilico et al. 2007); however, in our study, *Epicoccum* was isolated from outdoor samples at a frequency rate of 1%. These differences may indicate diverse geographical and climate conditions.

The highest frequency rate of fungus isolation from air samples was found in greengroceries and butcheries, followed by houses, public restrooms, laboratories, parks, hospitals, and mosques. The distribution pattern of airborne fungi is given in Table 4. In all, 22.88% of isolated airborne fungi were found in greengroceries and butcheries, possibly due to the presence of humidity, organic matter, and nutrients in these places. According to some reports, moisture or high relative humidity is a predisposing factor for the growth of fungal spores (Basilico et al. 2007). The genus *Mucor* was the fungus most frequently isolated from grocery stores, with a frequency of 17% of all fungi isolated from there. Most species in the Mucoromycotina are saprobes, commonly found in soil, compost, stored grain, fruit, vegetables, and dung (Levetin et al. 2016).

The second and third most frequently isolated fungi are *Penicillium* and *Cladosporium*, with frequency rates of 15% and 14% respectively.

In all, 21% of airborne fungi were isolated from houses. The frequency of isolated fungi from wall surfaces is summarized in Table 4. The presence of fungi on different surfaces in homes can increase the risk of exposure to fungal elements (Sharpe et al. 2016) and can subsequently cause some adverse respiratory symptoms (Zock et al. 2002). Human occupants are an important source of microbes in indoor environments. Occupied rooms have a higher level of fungal spores than unoccupied rooms. Floor dust is the main source of fungi and the

amount of isolated fungi in outdoor and indoor samples is usually the same (Adams et al. 2015). Outdoor fungal spores mainly originate from fungi growing on trees, plants, and grass, whereas fungal indoor spores originate from the persistent damp in household structures and may also be outdoor spores that have entered through doors and windows (Tham et al. 2017).

The microbiology laboratories of the university were selected for sampling. The isolation rate of fungi from laboratories was 16.67% of all isolated fungi. However, fungal conidia were found to be present in indoor environment of the laboratory or surfaces and may have contaminated the cultures media, thus increasing the risk of dispersion of conidia in the laboratory (Sautour et al. 2012).

In one case, *Madurella grisea* was isolated from a hospital's recovery room. *Aspergillus* and *Penicillium*, with a frequency of 26.32% ($n=5$), were the most frequently isolated species from different sections of hospitals, followed by *Cladosporium* {21.06% ($n=4$)}, *Fusarium*, *Alternaria*, *Mucor*, *Rhizopus*, and *Madurella* {5.26% ($n=1$)} (Table 4).

Some hospital infections are caused by fungi, such as some species of *Aspergillus*, *Fusarium*, or Mucorales. Indeed, fungi present in hospital rooms may grow on the organic matter of building materials and develop microcolonies. The spores emanating from these colonies could be inhaled by immunosuppressed patients and cause local infections prior to possible dissemination (Sautour et al. 2009). Hospitalized patients particularly those who are immunocompromised are at a high risk of morbidity due to fungal opportunistic infections (Hedayati et al. 2011).

Based on the results given in Table 5 and by doing a chi-square test, a significant difference was observed between air and surface samples in case of *Absidia*, *Aspergillus*, *Fusarium*, *Penicillium*, and *Stemphylium* ($p<0.05$), and the number of these fungi at the surface samples was significantly higher than air samples ($\chi^2(1)=34.606, p<0.001$).

In general, 989 fungal colonies were studied. The most commonly isolated colony was related to the genus *Aspergillus* (16.48%), followed by *Penicillium* (15.77%) and *Cladosporium* (13.14%).

In conclusion, considering that people spend most of their time in indoor environments, and distribution of

indoor fungi are largely affected by the outdoor environment, the distribution of fungal spores needs to be assessed. Increasing the awareness of patients with respiratory and skin allergies is necessary for preventing their exposure to fungi.

Acknowledgements Special thanks to all the people involved in this research.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

- Adams, R. I., Bhangar, S., Pasut, W., Arens, E. A., Taylor, J. W., Lindow, S. E., Nazaroff, W. W., & Bruns, T. D. (2015). Chamber bioaerosol study: outdoor air and human occupants as sources of indoor airborne microbes. *PLoS One*, 10(5), e0128022. <https://doi.org/10.1371/journal.pone.0128022>.
- Ajodanifar, H., Hedayati, M. T., Mayahi, S., Khosravi, A., & Mousavi, B. (2011). Airborne fungi in poultry and cattle house from Iran. *Archives of Industrial Hygiene and Toxicology*, 62, 243–248. <https://doi.org/10.2478/10004-1254-62-2011-2099>.
- Arikoglu, T., Batmaz, S. B., Coşkun, T., Otag, F., Yildirim, D. D., & Kuyucu, S. (2016). The characteristics of indoor and outdoor fungi and their relation with allergic respiratory diseases in the southern region of Turkey. *Environmental Monitoring and Assessment*, 188, 380. <https://doi.org/10.1007/s106661-016-5371-7>.
- Basilico, M. D. L. Z., Chiericatti, C., Aringoli, E. E., Althaus, R. L., & Basilico, J. C. (2007). Influence of environmental factors on airborne fungi in houses of Santa Fe City, Argentina. *The Science of the Total Environment*, 376(1–3), 143–150. <https://doi.org/10.1016/j.scitotenv.2007.01.001>.
- Chadeganipour, M., Shadzi, S., Nilipour, S., & Ahmadi, G. (2010). Airborne fungi in Isfahan and evaluation of allergenic responses of their extracts in animal model. *Jundishapur Journal of Microbiology*, 3(4), 155–160.
- Dassonville, C., Demattei, C., Detaint, B., Barral, S., Bex-Capelle, V., & Mmas, I. (2008). Assessment and predictors determination of indoor airborne fungal concentration in Paris newborn babies' homes. *Environmental Research*, 108, 80–85. <https://doi.org/10.1016/j.envres.2008.04.006>.
- Ellis, E., Davis, S., Alexiou, H., Handke, R., & Bartley, R. (2007). *Descriptions of medical fungi* (2nd ed.). Adelaide: University of Adelaide. Mycology Unit, Women's and Children's Hospital, North Adelaide 5006 Australia.
- Fisher, F., & Cook, N. B. (1998). *Fundamental of diagnostic mycology* (First ed.p. 19106). Independence Square West Philadelphia: W.B. Saunders Company.
- Foladi, S., Hedayati, M. T., Shokohi, T., & Mayahi, S. (2013). Study on fungi in archives of offices, with a particular focus on *Stachybotrys chartarum*. *Journal de Mycologie Medicale*, 23(4), 242–246. <https://doi.org/10.1016/j.mycmed.2013.09.003>.
- Fukutomi, Y., & Taniguchi, M. (2015). Sensitization to fungal allergens: resolved and unresolved issues. *Allergology International*, 64, 321–331.
- Hageskal, G., Lima, N., & Skaar, I. (2009). The study of fungi in drinking water. *Mycological Research*, 113(Pt 2), 165–172. <https://doi.org/10.1016/j.mycres.2008.10.002>.
- Hedayati, M. T., Mayahi, S., Movahedi, M., & Shokohi, T. (2011). Study on fungal flora of tap water as a potential reservoir of fungi in hospitals in Sari city, Iran. *Journal de Mycologie Medicale*, 21(1), 10–14. <https://doi.org/10.1016/j.mycmed.2010.12.001>.
- Horner, W. E., Worthan, A. G., & Morey, P. R. (2004). Air- and dustborne mycoflora in houses free of water damage and fungal growth. *Applied and Environmental Microbiology*, 70(11), 6394–6400. <https://doi.org/10.1128/AEM.70.11.6394-6400.2004>.
- Hossieni, M., Jabbari, H., Naddafi, K., Nabizadeh, R., Rahbar, M., Yunesian, M., et al. (2013). Concentration and distribution characteristics of airborne fungi in indoor and outdoor air of Tehran subway stations. *Aerobiologia*, 29(3), 355–363. <https://doi.org/10.1007/s10453-012-9285-8>.
- Kalyoncu, F. (2010). Relationship between airborne fungal allergens and meteorological factors in Manisa city, Turkey. *Environmental Monitoring and Assessment*, 165(1–4), 553–558. <https://doi.org/10.1007/s10661-009-0966-x>.
- Kim, K. Y., Kim, H. T., Kim, D., Nakajima, J., & Higuchi, T. (2009). Distribution characteristics of airborne bacteria and fungi in the feedstuff-manufacturing factories. *Journal of Hazardous Materials*, 169(1–3), 1054–1060. <https://doi.org/10.1016/j.jhazmat.2009.04.059>.
- Knutsen, A. P., Bush, R. K., Demain, J. G., Denning, D. W., Dixit, A., Fairs, A., Greenberger, P. A., Kariuki, B., Kita, H., Kurup, V. P., Moss, R. B., Niven, R. M., Pashley, C. H., Slavin, R. G., Vijay, H. M., & Wardlaw, A. J. (2012). Fungi and allergic lower respiratory tract diseases. *Journal of Allergy and Clinical Immunology*, 129(2), 280–291.
- Kuhn, R. C., Trimble, M. W., Hofer, V., Lee, M., & Nassof, R. S. (2005). Prevalence and airborne spore levels of *Stachybotrys* spp. in 200 houses with water incursions in Houston, Texas. *Canadian Journal of Microbiology*, 51(1), 25–28. <https://doi.org/10.1139/w04-110>.
- Levetin, E., Horner, W. E., & Scott, J. A. (2016). Taxonomy of allergenic fungi. *The Journal of Allergy and Clinical Immunology: In Practice*, 4(3), 375–385.e1. <https://doi.org/10.1016/j.jaip.2015.10.012>.
- Meheust, D., Le Cann, P., Reboux, G., Millon, L., & Gangneux, J. P. (2014). Indoor fungal contamination: health risks and measurement methods in hospitals, homes and workplaces. *Critical Reviews in Microbiology*, 40(3), 248–260. <https://doi.org/10.3109/1040841X.2013.777687>.
- Menezes, E. A., Carvalho, P. G., Trindade, E. C. P. M., Sobrinho, G. M., Cunha, F. A., & Morato Casrto, F. F. (2004). Airborne fungi causing respiratory allergy in patients from Fortaleza, Ceara, Brazil. *Journal Brasileiro de Patologia e Medicina Laboratoria*, 40(2), 79–84.
- Mirhoseini, S. Y., Nikaeen, M., Satoh, K., & Makimura, K. (2016). Assessment of airborne particles in indoor environments: applicability of particle counting for prediction of bioaerosol

- concentrations. *Aerosol and Air Quality Research*, 16, 1903–1910. <https://doi.org/10.4209/aaqr.2015.08.0528>.
- Picco, A. M., & Rodolfi, M. (2000). Airborne fungi as biocontaminants at two Milan underground stations. *International Biodeterioration and Biodegradation*, 45(1), 43–47.
- Rafiei, A., & Amirrajab, N. (2010). Fungal contamination of indoor public swimming pools, Ahwaz, south-west of Iran. *Iranian Journal of Public Health*, 39(3), 124–128.
- Rostami, N., Alidadi, H., Zarrinfar, H., & Salehi, P. (2017). Assessment of indoor and outdoor airborne Fungi in an educational, research and treatment center. *Italian Journal of Medicine*, 11, 52–56.
- Sautour, M., Sixt, N., Dalle, F. L., Ollivier, C., Fourquenot, V., Calinon, C., et al. (2009). Profiles and seasonal distribution of airborne fungi in indoor and outdoor environments at a French hospital. *Science of the Total Environment*, 407, 3766–3771. <https://doi.org/10.1016/j.scitotenv.2009.02.024>.
- Sautour, M., Fournel, I., Dalle, F., Calinon, C. L., Ollivier, C., Goyer, M., et al. (2012). Dynamics of fungal colonization in a new medical mycology laboratory. *Journal de Mycologie Medicale*, 22, 14–20. <https://doi.org/10.1016/j.mycmed.2011.11.001>.
- Sen, B., & Asan, A. (2009). Fungal flora in indoor and outdoor air of different residential houses in Tekirdag City (Turkey): seasonal distribution and relationship with climatic factors. *Environmental Monitoring and Assessment*, 151(1–4), 209–219. <https://doi.org/10.1007/s10661-008-0262-1>.
- Shams-Ghahfarokhi, M., Aghaei-Gharehbolagh, S., Aslani, N., & Razzaghi-Abyaneh, M. (2014). Investigation on distribution of airborne fungi in outdoor environment in Tehran, Iran. *Journal of Environmental Health Science & Engineering*, 12, 54–60.
- Sharpe, R. A., Bearman, N., Thornton, C., Husk, K., & Osborne, N. (2015). Indoor fungal diversity and asthma: a meta-analysis and systematic review of risk factors. *Journal of Allergy and Clinical Immunology*, 135(1), 111–122.
- Sharpe, R. A., Cocq, K. L., Nikolaou, V., Osborne, N. J., & Thornton, C. R. (2016). Identifying risk factors for exposure to culturable allergenic moulds in energy efficient homes by using highly specific monoclonal antibodies. *Environmental Research*, 144, 32–42.
- Skjoth, C. A., Damialis, A., Belmonte, J., De Linares, C., Fernandez-Rodriguez, S., Grinn-Gofron, A., et al. (2016). *Alternaria* spores in the air across Europe: abundance, seasonality and relationships with climate, meteorology and local environment. *Aerobiologia*, 32, 3–32. <https://doi.org/10.1007/s10453-016-9426-6>.
- Soeria-Atmadja, D., Onell, A., & Borga, A. (2010). IgE sensitization to fungi mirrors fungal hylogenetic systematic. *Journal of Allergy and Clinical Immunology*, 125(6), 1379–1386. e1. <https://doi.org/10.1016/j.jaci.2010.02.028>.
- Sousa, A. C. A., Almeida, J. R. S. L., Pereira, C. C., Pastorinho, M. R., Pereira, A. M. C., Nogueira, A. J. A., et al. (2014). Characterization of fungal communities in house dust samples collected from central Portugal, a preliminary survey. *Journal of Toxicology and Environmental Health*, 77(14–16), 972–982. <https://doi.org/10.1080/15287394.2014.911137>.
- Tham, R., Katelaris, C. H., Vicendese, D., Dharmage, S. C., Lowe, A. J., Bowatte, G., Taylor, P., Burton, P., Abramson, M. J., & Erbas, B. (2017). The role of outdoor fungi on asthma hospital admission in children and adolescents: A 5-year time stratified case-crossover analysis. *Environmental Research*, 154, 42–49.
- Wu, P. C., Su, H. J. J., & Ho, H. M. (2000). A comparison of sampling media for environmental viable fungi collected in a hospital environment. *Environmental Research*, 82(3), 253–257. <https://doi.org/10.1006/enrs.1999.4017>.
- Zock, J. P., Jarvis, D., Luczynska, C., Sunyer, J., & Burney, P. (2002). Housing characteristics, reported mold exposure, and asthma in the European community respiratory health survey. *Journal of Allergy and Clinical Immunology*, 110(2), 285–292. <https://doi.org/10.1067/mai.2002.126383>.
- Zubairi, A. B. S., Azam, I., Awan, S., Zafar, A., & Imam, A. A. (2014). Association of airborne *Aspergillus* with asthma exacerbation in southern Pakistan. *Asia Pacific Allergy*, 4(2), 91–98. <https://doi.org/10.5415/apallergy.2014.4.2.91>.