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PROFILE OF INDOOR AIRBORNE FUNGI IN RESIDENTIAL HOUSES OF DELHI AND NATIONAL CAPITAL REGION, INDIA

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Abstract – Indoor fungi are important biocontaminants which have adverse affects on human health. The great abundance of fungi combined with small size and ease of dispersion of their propagules favors high concentration of fungal spores in indoor environments. Indoor airborne fungi are known to induce numerous human diseases such as chronic bronchitis, asthma, fungal allergies and hypersensitivity reactions. The present study was envisaged to identify and quantify prevalent airborne fungi in 26 residential homes in Delhi, India. Samples were collected from four different locations in each house (kitchen, bathroom, living room and outdoor) on Czapek Dox Agar medium plates by settle plate technique. A written questionnaire was prepared to collect the respiratory health status of residents and building related parameters. A*lternaria* species were the most dominant components of indoor aeromycota in homes followed by *Cladosporium, Aspergillus* and *Penicillium*. Other fungi isolated from homes were *Epicoccum, Trichoderma, Curvularia, Helminthosporium, Trichothecium* and *Mucor.* Fungal I/O ratio for each residential home (n=26) was calculated from average indoor and outdoor fungal counts. Of these, 31% homes had I/O ratio >1 indicating that there is a strong indoor source for fungal contamination. Besides, highest fungal counts were observed in living rooms followed by bathrooms and kitchens. Indoor fungal exposure may be a significant predisposing factor for development of fungal mediated respiratory diseases in our study population.

INTRODUCTION

Fungi are ubiquitous, causing respiratory allergy in 20% to 30% of atopic individuals (Kurup *et al.*, 2000). Fungi have a great capacity to colonize on different variety of substrata and develop in extreme conditions, from where they become airborne. Spores of most fungi do not survive for significant periods in air but those that survive have quite specific mechanisms to prevent damage from desiccation and irradiation. Fungi colonize and produce numerous aerially dispersed spores, which easily spread them throughout the living space. They may originate out of doors, but are well able to propagate and produce spores on indoor surfaces and materials. The significance of fungi in causing diseases of plants, animals and human beings has been extensively studied. The most important airborne fungi include *Aspergillus, Cladosporium*, *Penicillium*, *Alternaria*, *Epicoccum*, *Curvularia*, etc (Agarwal *et al.*, 1974).

It has been estimated that people in modern society spend approximately 90% of their time in indoor environments (Leech *et al.*, 2002). Therefore, indoor air quality has become an important health concern. The great abundance of fungi combined with small size and ease of dispersion of their propagules favors high concentration fungal spores in the indoor environments. People are continuously in contact with airborne fungi via inhalation which cause numerous human diseases.

The exposure may also lead to a wide variety of generalized symptoms ranging from headache, fatigue, nausea to serious effects on human health through three processes: allergy, toxicity, and infection. Many allergic diseases such as asthma, hypersensitivity pneumonia, rhinitis, eczema and urticaria may occur in association with exposure to indoor molds (Hardin *et al.*, 2003). Most fungi produce mycotoxins, secondary metabolites and volatile organic compounds which could contribute to ill health. â(1-3)-D glucan has been suggested as a

potential contributor for indoor air related health effects primarily associated with airway inflammation (Douwes, 2005). The increased health risks and economic impact from mold growth resulting from indoor dampness are recognized as significant public health problems requiring attention and remediation (Pasanen, 2001). Thus, the present study was envisaged to identify and quantify prevalent airborne fungi in 26 residential homes in Delhi NCR, India.

MATERIALS AND METHODS

Air sampling was undertaken to identify and quantify colony forming various units of airborne fungi in residential homes of Delhi, India (March-May 2016). The latitudinal and longitudinal locations of National Capital Region of Delhi, India are 23.38 degree north and 77.13 degree east.

Isolation of culturable fungi: Air samples were collected on Czapek Dox Agar (CDA) medium plates (supplemented with streptomycin sulphate-0.06 g/L) by settle plate technique. The sample size was taken as 26 residential homes. Samples were collected from four different locations (kitchen, bathroom, living room, outdoor) of each home during morning hours (7 am- 11 am). Eight CDA plates were taken to the sites in sterilized containers. At each location, two petriplates were exposed in air at 1 m height for 10 minutes. After exposure, petriplates were brought back to the laboratory in pre-sterilized bags and kept in the incubator for 5 days at 25 ± 2°C. The fungal colonies observed after incubation were counted (Vermani *et al.*, 2014; Chauhan *et al.*, 2017).

The fungal isolates were sub-cultured on CDA slants and subsequently identified by preparing lactophenol cotton blue mounts. The identification was based on colony morphology and microscopic characteristics (Ainsworth *et al.*, 1972). The data was reported as percent abundance of each fungi calculated as per the formula:

$$\text{Percent abundance} = \frac{\text{Total number of colonies of any genus or species in all replicates}}{\text{Total number of colonies in all replicates}}$$

RESULTS

A total number of 78 samples were collected from indoor air of residential homes. The quantitative and qualitative analysis revealed that the investigation sites (residential homes) were contaminated with a variety of conidial fungi. Thirteen different genera of fungi were isolated from both indoor and outdoor samples of residential homes. A*lternaria* species were the most dominant components of indoor and outdoor aeromycota followed by *Cladosporium, Aspergillus* and *Penicillium* as presented in Fig. 1. Other fungi isolated from homes were *Epicoccum Trichoderma, Curvularia, Helmenthosporium, Trichothecium* and *Mucor.* Sterile mycelia also formed a major component of isolated fungi in the residential homes. *Nigrospora* and *Curvualaria* were isolated only from indoors. *Mucor* was isolated only from outdoors. The concentrations of these fungi were variable in each home. The variations in percent abundance of *Alternaria, Cladosprium, Aspergillus* and *Penicillium* in 26 sampled homes are presented in Fig. 2.

Fungal I/O ratios for 26 residential homes were

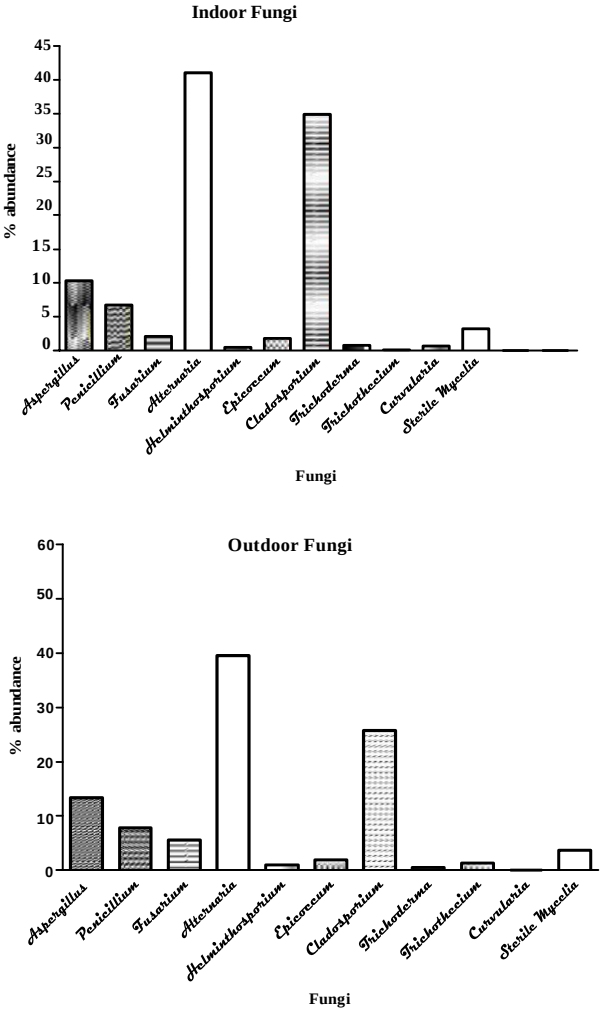

Fig. 1. Percent abundance of fungi isolated in indoor and outdoor environments

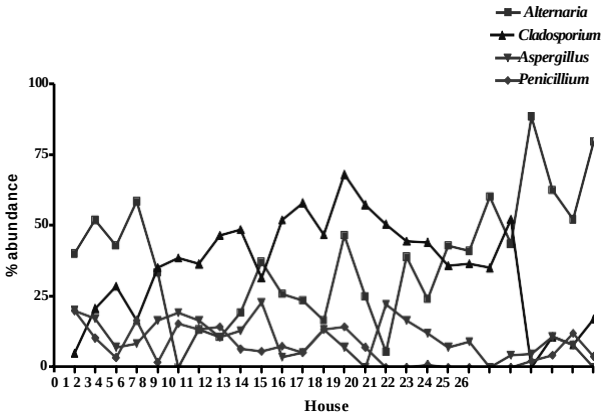

Fig. 2. Variations in percent abundance of four abundant fungi (*Alternaria, Cladosprium, Aspergillus* and *Penicillium*) in 26 residential homes

calculated from average indoor and outdoor fungal counts. Of these, 31% homes had I/O ratio >1 indicating that there is a strong indoor source for fungal contamination (Table 1). I/O ratio<1 suggested that the indoor inhalation exposure to airborne fungi is largely influenced by outdoor airborne fungal concentrations (Table 1). Fungal counts at different locations in indoor environment varied with highest fungal counts in living room (257 cfu) than bathroom (220 cfu) and kitchen (219 cfu) indicating higher levels of fungal contamination in living rooms (Table 2).

Table 1. I/O ratio of fungal counts isolated from indoor and outdoor environments in 26 residential homes

Sample	Total Indoor	Average	Outdoor	I/O Ratio
1	26	8.6	16	0.54
2	38	12.6	9	1.41
3	32	10.6	20	0.53
4	27	9.0	14	0.64
5	78	26.0	5	5.20
6	26	8.6	16	0.54
7	35	11.6	22	0.53
8	34	11.3	21	0.54
9	41	13.6	29	0.47
10	47	15.6	22	0.71
11	35	11.6	16	0.73
12	42	14.0	14	1.00
13	41	13.6	16	0.85
14	52	17.3	16	1.08
15	31	10.3	17	0.61
16	22	7.3	9	0.81
17	30	10.0	10	1.00
18	35	11.6	24	0.49
19	20	6.6	19	0.35
20	32	10.6	23	0.46
21	38	12.6	15	0.84
22	65	21.6	24	0.90
23	49	16.3	19	0.86
24	55	18.3	13	1.41
25	54	18.3	13	1.41
26	63	21	14	1.50

Table 2. Fungal counts at different locations in indoor environment.

Fungus	Living Room	Bathroom	Kitchen
Aspergillus	33	25	22
Penicillium	17	13	22
Alternaria	100	89	63
Cladosporium	82	70	89
Curvularia	3	0	1
Fusarium	5	4	5
Epicoccum	6	3	6
Sterile mycelium	7	9	7
Trichoderma	0	3	1
Trichothecium	3	0	0
Nigrospora	0	2	1
Helmenthosporium	1	2	2
Total	257	220	219

DISCUSSION

People spend 90% of their time indoors, 50–70% at home, and 30% in the bedroom, almost one third of their life (Leech *et al.*, 2002); therefore, indoor air quality has become an important health concern. Airborne fungal contaminants are increasingly gaining importance due to the health hazards caused by their spores or microbial metabolites. In addition to the infection risks they carry, bioaerosols have other properties giving them allergic, toxic and inflammatory effects. It has also been suggested that indoor mold exposure may contribute to childhood asthma. The epitopes of some mold types such as *Alternaria, Cladosporium, Aspergillus,* and *Penicillium* may be the cause of allergic symptoms of varying severity in genetically predisposed persons (Bush and Portnoy, 2001).

A large proportion of aerobiological studies have been devoted to study air borne spores in the residential homes of different cities and towns by employing viable plate counts or gravity slides. Irrespective of place, duration and technique of sampling deuteromycetes have been found as most predominant component of aeromycota by all the investigators (Burge 2002; Green *et al.*, 2006; Dassonville *et al.*, 2008; Lee *et al.*, 2006; Sen and Asan, 2009; Hedayati *et al.*, 2010; Wang *et al.*, 2016). Our

results also confirmed this observation. In our survey, both A*lternaria* and *Cladosporium* were the most common fungal genera. Similar results have been reported from turkey in an indoor home survey reported by Sen and Asan, 2009. A wide variety of fungi have been reported as the main constituents in the air of Kuwait and Iran, including *Alternaria*, *Cladosporium* spp., *Aspergillus* spp. and *Penicillium* spp. (Yassin and Almouqtea, 2010; Hedayati *et al.,* 2010). Thus, the prevalence rate of fungal aerospora differs in various countries depending on geographical conditions, indoor environmental conditions, housing characteristics as well as the application of different sampling strategies (Vermani *et al*., 2010).

A significant observation of our study was that all houses showed the presence of *Aspergillus*. Exposure to *Aspergillus* has been reported to cause several types of human health problems, primarily irritations, infections, allergies, and toxic effects, and it has been suggested that toxigenic *Aspergillus* are the cause of additional adverse health effects (Hedayati *et al.*, 2010). In the present study, exposures to high concentrations of *Aspergillus* might act as potential sensitizer in children and adults.

The differences between the number of indoors spores isolated at homes are affected by numerous factors including hygienic standards, ventilation, indoor humidity from the house heating system, furniture that provided substrates for indoor fungal growth. It was observed in the present study that outdoor fungal spores in addition to the physical and hygienic conditions of the indoor environment were extremely important for determining indoor fungal growth (Sen and Asan, 2009). The I/O ratio is another indicator for evaluating the difference between indoor and outdoor fungal levels as well as house-to-house variation of dominant fungi because indoor and outdoor distribution of fungi was not similar in all of the homes (Table 1).

The pilot data from this study will help in understanding human exposure to airborne fungi in relatively clean residential homes. Increased culturability of fungi in indoor homes is significant because it may lead to the increased allergen release from spores causing severe allergies in susceptible individuals (Lee *et al.* , 2006). Besides, some culturable fungi may cause serious infections in immunocompromised individuals (Chapman, 2006).

CONCLUSION

The results of our study showed that the indoor air of residential houses of Delhi-NCR contained high concentrations of airborne fungi viz. *Alternaria*, *Cladosporium*, *Aspergillus* and *Penicillium*, which may cause important health problems such as allergies, rhinitis and chronic fatigue.

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