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Original Research Paper

Analysis of Atmospheric Fungal Biopollutants in the Intramural Air Environment of a Library and its Relevance to Book Deterioration and Allergic Diseases

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ABSTRACT

The fungal spore incidence inside a working library was recorded by operating Rotorod Air Sampler for a period of three months. Apart from dust particles, altogether 47 type of biopollutants were identified of which 42 belonged to fungal spore types and remaining 5 types belonged to group 'other types'. Out of the total 42 fungal spores, 29 belonged to Deuteromycotina, 8 to Ascomycotina, 3 to Basidiomycotina and 2 to Zygomycotina. The spore types of *Cladosporium* (26.21%), Aspergilli + Penicilli (22.32%), *Mucor* + *Rhizopus* (4.92%), *Alternaria* (4.42%), *Curvularia* (3.22%), *Nigrospora* (2.84%), hyaline threads (2.57%), *Leptosphaeria* (2.24%), rust spores (2.04%) and *Torula* (2.02%) were found to occur in a relatively higher concentration. Biopollutants obtained peak in the month of September (34070/m3 of air) with 43.8 spore percentage, when there was a record of 46.7 mm rainfall, average mean temperature of 24.5°C and relative humidity of 86.2%. The significance of fungal spore types recorded as biodeteriogens and aeroallergens was considered. The daily temperature, relative humidity and rainfall was recorded and the effect of prevailing weather on the incidence of fungal airspora is reported in this paper.

INTRODUCTION

A great variety of fungal spores can be collected from indoor environment of library and many of them are involved in the biodeterioration of books, newspapers and binding materials like leather, rexins and cloth. In the recent years, the deterioration of library materials by microorganisms has attracted the attention of many investigators. The biodeterioration includes mildewing or rotting, foxing and browning of papers in library. The role of fungi associated with books or paper materials in library in bringing about their deterioration has been a subject of great interest. Some fungi destroy cellulose decomposing binding material (Verma & Chile 1991). Fungal spores are always present in the atmosphere of library (Plumbe 1964) and getting favourable conditions, they proliferate on the books and cause deterioration.

Human exposure to airborne microorganisms may result in a variety of adverse health effects including infectious diseases (Brachman 1974), allergic and irritant responses (Agarwal & Shivpuri 1974), respiratory problems (Al Doory 1984, Tilak 1989) and hypersensitivity reaction (Solley & Hyatt 1980). The biological agents in relation to deterioration of books inside the library have not been studied thoroughly, hence an attempt was made to study the incidence of fungal biopollutants in this region. The obtained data of aerobiodeteriogens, aeroallergens and biopollutants is presented in this paper.

MATERIALS AND METHODS

An analysis of atmospheric fungal biopollutants was carried out by operating Rotorod Air Sampler (Perkins 1957 modified by Harrington 1959) for one hour in the morning daily between 10 am to 11 am in the Municipal library at Karad, Maharashtra. The sampler was installed at a height of 2 meters above ground level. The studies were conducted for 3 months from July 1, 2009 to September 30, 2009. The daily meteorological data of temperature, relative humidity and rainfall was maintained throughout the study period (Table 2).

The Rotorod Air Sampler has trapping efficiency of 85% and the spores trapped on cellotape were scanned regularly using microscope. The number of spores per unit volume of air was calculated with the conversion factor of Sampler 5 and expressed as number of spores per cubic meter of air. For estimating the spore types, their number, concentration and percentage contribution, slides were scanned. The identification of different spore types was based mainly on comparative spore morphology, spore description and subsequently confirmed by consulting relevant literature (Ellis & Ellis 1985, Barnett & Hunter 1972, Tilak 1989). The spores which could not be identified due to their obscure nature or even otherwise were placed under unidentified type. The identification of spore types was based on microscopic characters.

The study area is situated between 17°43'N latitude and 74°11'E longitude at 1874 feet above mean sea level. Library is located near the Bus stand and surrounded by many large trees in a big garden. About 2 lakh books are present in the Library and it has reading section, computer section, periodical section and book section.

RESULTS AND DISCUSSION

During the period of present investigation, apart from inorganic dust particles, 47 types of biopollutants were trapped in the sampler of which 42 belonged to the fungal spore type origin, while remaining 5 types belonged to 'other types' (8.19%) comprising of hyaline threads (2.57%), hyphal fragments (1.76%), insect scales/parts (0.87%), pollen grains (1.65%) and unidentified spores (1.34%). Out of the 42 fungal spore types, 2 belonged to Zygomycotina (5.30%), 8 to Ascomycotina (9.01%), 3 to Basidiomycotina (4.95%) and 29 to Deuteromycotina (72.55%) (Table 1).

A total of 77855 spores per meter cube of air were recorded during the study period. Biopollutants obtained peak in the month of September with 34070/m^3 of air with 43.8 % of total air spora when there was a record of 24.5°C mean temperature, 86.2% relative humidity and 46.7 mm rainfall (Table 2). It was followed by the month of August (29640/m^3 of air and 38%) when there was a record of 21.6°C mean temperature, 91.7% relative humidity and 95.8 mm rainfall. Minimum spore count was recorded in the month of July (14145/m^3 of air and 18.2%) when there was 21.8°C temperature, 80.8% relative humidity and 38.5 mm rainfall. The average monthwise percentage contribution of each spore group to the total airspora is presented in Table 3.

Maximum spore count of Deuteromycotina was in the month of September (68.6%). Dominance of Ascomycotina was in the month of July (68.6%). Dominance of Ascomycotina was in the month of July (11%) followed by August (9.5%) and September (7.8%). Similarly, dominance of Zygomycotina was in the month of July (7%), Basidiomycotina in the month of September (5.3%) and other types in the month of July (8.9%).

From the group Zygomycotina, 2 spore types were trapped in the sampler. *Cunninghamella* (0.38%) with maximum monthly mean concentration in the month of August (143/m^3) and *Mucor* + *Rhizopus* (4.92%) with maximum concentration in August (1550/m^3) and minimum during month of July (925/m^3). Spore type of *Mucor* + *Rhizopus* cause damage to paper materials and may cause allergenic rhinitis and asthma when inhaled by sensitive individuals (Citron 1962). They may also cause respiratory symptoms and airway diseases (Singh & Singh 1994).

Among 12 ascospore types from group Ascomycotina, spores of *Leptosphaeria* (2.24%), *Pleospora* (1.28%), *Chaetomium* (1.24%), *Hysterium* (1.21%), *Pringsheimia* (1.01%), *Otthia* (0.83) and *Sporormia* (0.80%) were recorded during the study period. Maximum incidence of Ascomycotina spore types was recorded in the month of August (2820/m^3) followed by September (2645/m^3) and minimum during month of July (1550/m^3). Spore types of *Chaetomium* produce green black spots on paper material of books and damage in libraries (Frankland & Gregory 1953, Husanian 1985). **Role of *Chaetomium, Leptosphaeria* and *Pleospora* in causing allergy and acute asthma, similar results were recorded by Karne (2006).**

As has been recorded in India and elsewhere, Basidiospores (0.96%), rust spores (2.04%) and smut spores (1.95%) were common in the air of libraries. Allergenic nature of rust spores and smut spores has been recorded by Cadham (1974), Agarwal & Shivpuri (1974) and Karne & Pande (2006).

Deuteromycotina contributed maximum 29 spore types to the airspora. Among the biopollutants from this group *Cladosporium* (26.21%), Aspergilli and Penicilli (22.32%), *Alternaria* (4.42%), *Curvularia* (3.22%), *Nigrospora* (2.84%), *Torula* (2.02%), *Pithomyces* (1.62%), *Helminthosporium* (1.55%), *Drechslera* (1.32%) and *Periconia* (1.28%) contributed significantly to the total airspora during the months of September (25430/m^3) and August (21340/m^3). Spore types of *Cladosporium, Nigrospora, Alternaria, Aspergillus, Curvularia, Periconia, Trichothecium, Sporidesmium, Epicoccum, Torula, Cercospora* and *Stachybotrys* have been recorded on papers and books (Tilak 1991) and exhibited paper deteriorating activity.

As regards clinical implication of spores, *Alternaria* spores cause allergy (Feinberg 1935, Chaloof et. al. 1940, Karne & Pande 2006) and spores of *Cladosporium* cause respiratory allergic disorders (Agarwal & Shivpuri 1974). *Curvularia, Periconia, Helminthosporium* and *Nigrospora* are known to be potentially allergenic (Tilak 1989). Allergenic diseases due to *Aspergillus* and *Penicillium* are well known (Singh & Singh 1974). *Epicoccum* and *Pithomyces* may cause allergenic reaction (Shenoi & Ramalingam 1976). Allergenic spore types like *Heterosporium* (0.92%), *Stemphylium* (0.52%) and *Fusarium* (0.43%) were recorded in low concentration which correlates with the reports of Karne (2008).

From the group 'other types' hyaline threads (2.57%) hyphal fragments (1.76%), insect scales/parts (0. 87%), pollen grains (1.65%) and unidentified spores (1.34%) were recorded. Pollen grains are well known allergens responsible for nasobronchial allergy in human beings (Nair 1978). Hyphal fragments are also getting importance as potential

Table 1: Monthwise total airspora (Spores/m^3 air) and percent contribution of different spore types in the library environment.

Sr.No.	Spore type	July	August	September	Total	% Contribution
A.	**Zygomycotina**					
1	*Cunninghamella*	60	145	90	295	0.38
2	*Mucor + Rhizopus*	925	1550	1355	3830	4.92
	Total	**985**	**1695**	**1445**	**4125**	**5.30**
B.	**Ascomycotina**					
1	*Chaetomium*	220	310	435	965	1.24
2	*Cucurbitaria*	65	95	155	315	0.40
3	*Hysterium*	170	490	285	945	1.21
4	*Leptosphaeria*	450	705	585	1740	2.24
5	*Otthia*	110	225	310	645	0.83
6	*Pleospora*	190	475	330	995	1.28
7	*Pringsheimia*	155	245	385	785	1.01
8	*Sporormia*	190	275	160	625	0.80
	Total	**1550**	**2820**	**2645**	**7015**	**9.01**
C.	**Basidiomycotina**					
1	Basidiospores	170	240	340	750	0.96
2	Rust spores	295	570	725	1590	2.04
3	Smut spores	180	610	725	1515	1.95
	Total	**645**	**1420**	**1790**	**3855**	**4.95**
D.	**Deuteromycotina**					
1	*Alternaria*	555	1170	1715	3440	4.42
2	Aspergilli + Penicilli	2085	63	8900	17380	22.32
3	*Beltrania*	-	25	45	70	0.09
4	*Bispora*	30	65	105	200	0.26
5	*Cladosporium*	4600	8105	7700	20405	26.21
6	*Cercospora*	20	30	45	95	0.12
7	*Cordana*	-	10	20	30	0.04
8	*Corynespora*	45	80	95	220	0.28
9	*Curvularia*	425	830	1250	2505	3.22
10	*Deightoniella*	-	25	40	65	0.08
11	*Dictyoarthrinium*	15	30	-	45	0.06
12	*Diplodia*	55	105	170	330	0.42
13	*Drechslera*	125	530	370	1025	1.55
14	*Epicoccum*	40	95	145	280	0.36
15	*Fusarium*	65	110	160	335	0.43
16	*Helminthosporium*	205	425	575	1205	1.55
17	*Heterosporium*	130	205	385	720	0.92
18	*Nigrospora*	310	870	1030	2210	2.84
19	*Paecilomyces*	50	185	105	340	0.44
20	*Periconia*	105	410	480	995	1.28
21	*Pestalotia*	-	15	30	45	0.06
22	*Pithomyces*	135	465	660	1260	1.62
23	*Spegazzinia*	60	75	115	250	0.32
24	*Sporidesmium*	65	120	80	265	0.34
25	*Stachybotrys*	-	25	15	40	0.05
26	*Stemphylium*	35	215	155	405	0.52
27	*Torula*	340	490	740	1570	2.02
28	*Trichocladium*	30	75	160	265	0.34
29	*Trichothecium*	185	160	140	485	0.62
	Total	**9710**	**21340**	**25430**	**56480**	**72.55**
E.	**Other type**					
1	Hyaline threads	420	725	855	2000	2.57
2	Hyphal fragments	240	650	480	1370	1.76
3	Insect scales (parts)	120	260	300	680	0.87
4	Pollen grains	220	390	675	1285	1.65
5	Unidentified spores	255	340	450	1045	1.34
	Total	**1255**	**2365**	**2760**	**6380**	**8.19**
	Grand total	**14145**	**29640**	**34070**	**77855**	**100**

Table 2: Comparative data of temperature, relative humidity, rainfall and spore percentage.

Moth	Temperature Mean (°C)	Relative humidity (%)	Rainfall (mm)	Spore percentage
July	21.8	80.8	38.5	18.2
August	21.6	91.7	95.8	38.0
September	24.5	86.2	46.7	43.8

Table 3: Average monthwise percent contribution of each spore group to the total airspora in the library environment.

Spore group	July	August	September
Zygomycotina	7.0	5.7	4.2
Ascomycotina	11.0	9.5	7.8
Basidiomycotina	4.5	4.8	5.3
Deuteromycotina	68.6	72.0	74.6
Other types	8.9	8.0	8.1
Total	**100**	**100**	**100**

allergens (Kulkarni 1981). Insect scales/parts may lead to either occasional, seasonal or perennial allergenic disorders (Shivpuri 1980). The occurrence of hyaline threads in the air of library is suggestive of deteriorated material of the books as they were recorded throughout the study period. The insects (scales or parts) may be coming from the outside or from offered books which may be probably helpful in colonization of fungi (Verma & Chile 1991).

The biopollutants in indoor air may come from the outdoor by ventilation or they may originate within the library building depending on the number and kinds of organisms present and mechanical movements within the intramural environment. The spore concentration was found to be more with enhanced rainfall, relative humidity and low temperature (Table 2). The fungal biopollutants recorded during present study were deteriorating glossy papers, books, newspapers and old papers. However, it was in the form of pigmentation i.e., brown-gray spots, white creamy spots, olive green stain, yellow green to brown spots, green black spots, purple red spots and black spots. Fungal biopollutants may be due to available glue and paste used for book binding and humid inner surface of the library wall that might have served as the suitable substrates for growth of fungi (Pande et al. 1996). In Indian cellulose the paper also contains lignin, hemicelluloses, pectin, waxes, tannins and minerals useful for fungal growth (Vital & Glory 1985). These fungi are associated with foxing and browning of papers in library.

The allergenic fungal spore types, hyphal fragments and insect scales (parts) may be responsible for inducing allergenic reactions to sensitive individuals visiting the library and to the library staff. The fungal biopollutants may be significant potential source of allergens and inhalation of these may be main causative factors for respiratory allergenic ailments like repeated cold, breathlessness, sneezing, bronchial allergy, asthma, decreased lung efficiency, chronic obstructive pulmonary disorders, rhinitis and skin diseases (Agarwal & Shivpuri 1974, Shivpuri 1980, Dhawan & Nigam 2005). Incidence of such diseases has drawn considerable attention in recent days. This collected information may provide basic data for the clinicians for the treatment of sensitive patients suffering from allergy. It also helps on avoidance and management of allergens. The present investigation clearly points out the prevalence of large percentage of allergens inside the library environment, which may be responsible for inducing allergenic reaction to sensitive individuals (Tilak 1989, Shivpuri 1980, Singh & Singh 1994).

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