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Monitoring of Airborne Fungi in Indoor Environments of Reading and Stock Sections of College Library

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Abstract: ***Mold sensitivity, particularly to Alternaria alternata, Cladosporium herbarum, Aspergillus fumigatus and other fungi including Candida, Penicillium and Curvularia species are mainly cause allergic bronchopulmonary mycosis and severe asthma.The studywas conducted from December-2013 to April-2015by using Hi-Air sampler (Hi-Media Ltd. LA-002), with the help of two different media strips PS-640 and PS-290 simultaneously. In both the sections of library, total 34fungal species excluding yeasts and non-sporulated fungi were isolated and identified (Reading & Stock section). The dominant fungal species isolated were Curvularia lunatarecorded 706 CFU/m^3, followed by Curvularia geniculata 612.5CFU/m^3,Curvularia tetramera 537.5CFU/m^3, Aspergillus niger 468.75 CFU/m^3, Aspergillus flavus431.25CFU/m^3, Aspergillus fumigatus475CFU/m^3,Alternaria alternata 350CFU/m^3,Cladosporium herbarum 287.5CFU/m^3, Alternaria soloni 281.25CFU/m^3, Alternaria tenussima262.5CFU/m^3, Cladosporium spp. 245.75CFU/m^3, Penicillium chrysogenum 450CFU/m^3, P. citrinum 456.25CFU/m^3, P. glaucus 556.25CFU/m^3, Penicillium spp. 331.25 CFU/m^3, and Non-sporulating fungi 737.5 CFU/m^3 in reading and stock sections of library. The total mean concentrations of airborne fungi in reading section of library was 7618.75 CFU/m^3, which is minimum as compare to the stock section of library 10306.25 CFU/m^3. Fungi are ubiquitous in the atmosphere, and often constitute the main biological component of the air. They are closely related with indoor and outdoor air pollution and human health. The prevalence of airborne fungi in the environments of library of college was meagerly studied. The present study was conducted to monitor the airborne fungi and their concentrations in two sections of library environments; to find out the fungi which are mainly responsible for the adverse health effects and deteriorating the book materials.***

Keywords: Monitoring, AirborneFungi, Indoor Environments, College Library, *Curvularia spp*.

1. Introduction

Molds in indoor niches are largely linked with the aetiology of asthma and respiratory allergy. Asthma is common in the developed and developing countries and increasing in frequency, despite better living conditions. *Aspergillus fumigatus, Alternaria alternata, Cladosporium cladosporoides, Curvularia tetramera, Mucor, Rhizopus, Penicillium citrinum, Penicillium chrysogenum, Aspergillus flavus, Aspergillus niger* and *Candida spp*. are the major respiratory allergens, which causes most known cases of allergic bronchopulmonary mycosis [10]. The deterioration of the library material by microorganism has attracted the attention of many in recent years. The efforts are directed towards reduction of these losses by finding out the conditions, the causes and the environmental factors which contribute in the biodeterioration of books and the binding material like leather, resins and cloth.The role of biological agents and the deterioration with reference to libraries and museums had been reviewed by [5].For recording the progress of mankind books have been in use for centuries and will probably continue as a medium for recording and exchanging information in future also. Depending upon the nature and the environmental conditions, paper is subjected to the attack from several sources which can be broadly classified as physical, chemical and biological. Heat, sunlight, moisture, dust and dirt are physical sources, which are known to damage paper and cause deterioration. Similarly, acidic and other gases present in the atmosphere and deleterious chemicals added during manufacture of paper are responsible for affecting storage life of paper.

Estimation of allergenic bioparticles in the indoor environment is of great significance. The role of fungi as a causative agent of allergenic rhinitis and bronchial asthma from library dust and book collection is well documented [1]. Fungi on papers and books belong to the species of *Alternaria, Monilia, Fusarium, Chaetomium, Myrothecium, Torula, Stachybotrys, Cladosporium, Sporedesmium, Rhizopus, Epicoccum* and *Paecilomyces*. Most of these are active cellulose decomposing, many are also pigment forming and stain paper usually with yellow, brown and black spots. Some however form colorless colonies. But the action of fungi is very slow, requiring several months for damage to be detected by ordinary means [25]. The airborne fungi in library environment was the species of *Cladosporium, Curvularia, Alternaria, Penicillium, Aspergillus, Mucor, Rhizopus, Trichoderma, Fusarium* and numerous non-sporulated fungiat Bhopal [17].The study of aeromycoflora of libraries are few and sketchy [16, 20, 24].However, problems of students' health in schools, colleges and in universities were not concerned enough in Nagpur city. Aeromycological studies in intramural environmentsof Hospital ward and Library of Nagpur city were previously studied [21]. The aim of the present study was to monitor the airborne allergenic and book deteriorating fungi in indoor environments of reading and stock sections of college library.

2. Materials and Methods

Sampling site& Method of Sampling

Library of Shri Mathuradas Mohota College of Science, Nagpurwas selected for the study of airborne fungi (Plate 1). The indoor area of college library is measure about 1300

Sq/ft reading section and 1050 Sq/ft stock section. Air sampling was conducted in two sections of library in between the working hours of college (10 am to 3.30 pm). Sampling was done with the help of Hi-Air sampler (Hi-Media Ltd. LA-002)intermittently from December-2013 to April-2015by using two media strips:PS-640and PS-290 for total CFU counts (Plate 2).Nagpur has tropical climate, in winter, there is much less rainfall than in summer. The temperature averages maximum of 48^0C in May, while it may come down to 6^0C in winter. Similarly, the relative humidity ranges from 11% to 98%. The minimum and maximum temperatures and relative humidity were recorded during the sampling period in two sections of library by using temperature-hygrometer (Table 1).

Colony Forming Units (CFUs) and Fungal Identification: Sampled media strips were brought back in the laboratory and were incubated in an inverted position at room temperature. After 4-6 days of incubation, the colony forming units (CFUs) were counted and noted and then the total fungal count was expressed as colony forming units per cubic meter of air (CFU/m^3). The CFUs calculated based on this equation.

$$\text{CFUs/m}^3 = \frac{\text{Colonies on agar strip} \times 25}{\text{Sampling time in minutes (4)}}$$

The isolated fungal species were identified by hyphal characteristics, colony morphology, and microscopic studies with the help of standard published literature [4, 14, 20, 21]; (Plate 2).

Plate 1: Air sampling in reading and stock sections of library

3. Results and Discussion

From both the sections of college library, total 34fungal species were isolated and identified excluding yeasts and non-sporulated fungi (reading and stock section). The dominant fungal species isolated were *Curvularia lunata*recorded 706 CFU/m^3, *followed by Curvularia geniculata* 612.5CFU/m^3,*Curvularia tetramera* 537.5CFU/m^3, *Aspergillus niger* 468.75 CFU/m^3, *Aspergillus flavus*431.25CFU/m^3, *Aspergillus fumigates* 475CFU/m^3, *Alternaria alternata* 350CFU/m^3, *Cladosporium herbarum*287.5CFU/m^3, *Alternaria soloni* 281.25CFU/m^3, *Alternaria tenussima*262.5CFU/m^3, *Cladosporium spp.*245.75CFU/m^3, *Penicillium chrysogenum* 450CFU/m^3, *P. citrinum* 456.25CFU/m^3, *P. glaucus* 556.25CFU/m^3, *Penicillium spp*. 331.25 CFU/m^3, and Non-sporulating fungi 737.5 CFU/m^3 in reading and stock sections of library. The total mean concentrations of airborne fungi in reading section of library was 7618.75 CFU/m^3, which is minimum as compare to the stock section of library 10306.25 CFU/m^3(Table 2 & Figure 1&2). Some of the fungal species recorded in reading section of library which counts are below the 100 CFU/m^3, these are *Mucor, Drechslera, Trichoderma, Nigrospora, Candida albicans*, and *Torula*. While in stock section of library they counted more than 100 CFU/m^3(Table 2 & Figure 1 &2). The predominance of *Aspergillus* spp. in libraries has been reported, who made on aerometric survey of fungi in eleven libraries at the University of Michigan to ascertain the role of fungi as allergic contaminants in book collections [3].

The dominant fungal forms like *Curvularia, Aspergillus, Alternaria, Nigrospora, Periconia, Helminthosporium, Bispora, Fusarium, Torula, Cladosporium* and *Pithomyces* were of common occurrence in the air of library as well as found associated with the deteriorated samples of books [25]. A majority of these have been recorded in the present investigation including the cellulose degrading fungi such as *Chaetomium, Rhizopus, Torula,Fusarium, Cladosporium, Curvularia* and *Trichoderma* which were reported to be common on books. Total 43 species representing 23 genera from exposed Petri dishes were reported are *Aspergillus* spp. which was found to be predominant in the library atmosphere, followed by *Cladosporium, Nigrospora, Penicillium, Drechslera* and *Alternaria* [20].The significant concentration of fungal allergens, the species of *Rhizopus, Aspergillus, Lacilliomyces, Penicillium, Alternaria, Curvularia, Cladosporium* and *Helminthosporium* were also reported, but species of *Helminthosporium* and *Lacilliomyces* were not found in present investigation [17]. Nineteen fungal forms isolated by using rotorod sampler and exposure culture plate methods, the spores of *Aspergillus* were found to occur in highest frequency in library environment followed by *Helminthosporium, Alternaria, Curvularia, Penicillium, Rhizopus*, and *Cladosporium* [26].The fungal concentration in Library environment before and after agitation of books was studied and 39 fungal forms were isolated, of which *Aspergillus niger, Penicillium* spp. and *Cladosporium spp*. were found to be dominant before disturbance of books [24].

In the previous study 64 species of fungi were isolated from the library of Govt. Institute of Science, Nagpur by exposed petri-plate method (2-year survey). The species of *Aspergillus* were found predominant and contributed 34.99%, followed by *Cladosporium spp*. 14.77%, *Penicillium spp*. 11.82%, *Curvularia spp*. 9.73%, *Alternaria spp*. 7.03%, *Mucor spp.* 1.99%, *Chaetomium spp*. 1.72%,

Rhizopus spp. 1.9%, and *Trichoderma spp*. 1.7% [21].*Penicillium* species are prevalent indoor fungi and inhalation of *Penicillium* spores or exposure to them can induce both immediate and late asthma in sensitive persons. Among more than 100 known *Penicillium* species, *Penicillium citrinum, Penicillium chrysogenum (Penicillium notatum), Penicillium oxalicum, Penicillium brevicompactum*, and *Penicillium spinulosum*, are considered the most common [8]. The prevalence of *Penicillium* species in indoor environments correlated with peak expiratory flow rate variability in asthmatic persons. There is growing evidence of the effect of climate change on other aeroallergens, including mold sporulation. Aerobiological studies have shown most fungal spores in outdoor air to be from phyla Ascomycota and Basidiomycota. The most commonly studied allergenic fungi are conidia-producing anamorphs of ascomycetes, such as *Alternaria, Aspergillus, Botrytis, Cladosporium, Epicoccum, Fusarium,* and *Penicillium* species. Most of the fungi associated with lower airway allergy and are usually found indoors originate from fungi present outdoors and from fungi might have grown inside the buildings on moist surfaces [22].

The possible cause of allergy for the librarians due to fungal spores present in the library environment was well studied [3]. The airborne viable spore concentrations and identify the fungal species in all indoor spaces from the lending library at the Technical University, Romania. They reported airborne fungal spore deposition rates were within the range of 419-1,677 CFU/m^2 and 296 fungal colonies from over 78 samples were identified and enumerated the predominance of genera being *Aspergillus spp., Penicillium spp., Cladosporium spp., Alternaria spp., and Chaetomium spp.* The species *Alternaria alternata* is independently associated with asthma, and the fungal sensitivity of *Aspergillus* and *Cladosporium* species are reported [10]. Aeromycological survey in intramural environment of a college laboratory was conducted in 2012 and recorded 36 fungal types of which the species of *Aspergillus* was most dominant and followed by the species of *Penicillium, Curvularia, Cladosporium, Alternaria, Chaetomium, Trichoderma, Mucor,* and *Rhizopus* [6].

Efficient air sampling methods are required to determine the fungal presence in indoor environment of college library and their qualitative and quantitative prevalence for effective diagnosis and treatment of allergic diseases and book deteriorating factors. Regarding the cellulose destroying activity and the damage of books caused by the common air-borne fungi like *Alternaria, Aspergillus, Penicillium, Bispora, Chaetomium, Cunninghamella* and *Trichoderma* their activity does not occur unless their requirements were fulfilled. It seems that weather conditions like humidity and temperature play an important role in the development of these saprophytes on the books[12].In the previous study of airborne fungi in the homes of asthmatic patient's author reported altogether 12 fungal species of which the species of *Cladosporium* were found to be dominant followed by the species of *Aspergillus, Curvularia, Trichoderma, Rhizopus, Fusarium, Alternaria, Mucor* and non-sporulating fungi [7].

Twenty-five fungal species from the library environmentwere recorded of which *Aspergillus, Alternaria, Cladosporium, Chaetomium, Rhizopus, Mucor, Torula, Epicoccum, Penicillium, Curvularia, Fusarium* and the species of *Aspergillus niger* followed by *A, fumigatus* and *A. flavus* [15]. The effect of book disinfection to the airborne microbiological community in a library environment well studied and reported the dominant species of *Aspergillus, Cladosporium, Penicillium, Alternaria, Chaetomium, Rhodotorula, Sporodiobolus, Aspergillus penicilliodes* and *Penicillium chrysogenum*[13]. In present investigation also the species of *Aspergillus* found predominant and followed the species of *Cladosporium,Penicillium chrysogenum*, but *Rhodotorula* and *Sporodiobolus* were not detected in present study.In present investigation, the reading section of library found that total 34 fungal species excluding yeasts and non-sporulated fungi. The dominant fungal species isolated were *Curvularia lunata, followed by Curvularia geniculata,Curvularia tetramera, Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus, Alternaria alternata,Cladosporium herbarum, Alternaria soloni, Alternaria tenussima, Cladosporium spp., Penicillium chrysogenum, P. citrinum, P. glaucus, Penicillium spp*., and Non-sporulating fungi in varying concentrations in reading and stock sections of library. The total mean concentrations of airborne fungi in reading section of library was 7618.75 CFU/m^3, which is minimum as compare to the stock section of library 10306.25 CFU/m^3 (Table 2 & Figure 1 & 2). The species *Cladosporium herbarum* frequently dominates indoor and outdoor air and is a major source of inhalant allergens. Most fungi possess multiple and diverse allergens. Some are metabolic products secreted outside the organism; other are cytoplasmic and structural components released on lysis or autolysis of the fungal cell [23].

The fungal allergens approved by the Allergen Nomenclature Sub-committee of the International Union of Immunological Societies (IUIS-2011) www.allergen.org [9]. The most commonly encountered species associated with allergy are *Aspergillus fumigatus, Aspergillus niger, Aspergillus oryzae, Aspergillus flavus,* and*Aspergillus terreus.*Several of these enzymes have been attributed to the pathogenesis of *Aspergillus*species induced diseases. ABPA is the most common form of allergic bronchopulmonary mycosis (ABPM) which is mainly caused by *Aspergillus fumigatus.* Other fungi, including *Candida, Penicillium, Rhizopus, Mucor,*and *Curvularia* species, are occasionally responsible for a similar syndrome. Sensitization to *Aspergillus fumigatus* is common, particularly in patients with more severe airway disease– SAFS [11].

Table 1: Maximum, minimum temperatures in indoor environments of library sections & relative humidity, sampling duration, and dates of sampling

Sampling sites	dates of sampling	duration of sampling in minutes	temperatures ^{0}c in indoor		Relative humidity in indoor (%)
			Maximum	Minimum	
Reading section	12.12.2013	4	26.6	25.4	45
	17.12.2013	4	25.9	24.3	45
	24.12.2013	4	25.8	23.9	48
	20.01.2014	4	32.4	30.1	43
	21.01.2014	4	29.4	23.9	73
	29.01.2014	4	28.9	28.3	36
	07.02.2014	4	31	26.3	30
	20.09.2014	4	33.5	30.1	53
	06.01.2015	4	28.6	24.9	40
Stock section	13.12.2013	4	25.6	24.1	40
	16.01.2014	4	30.6	24	52
	22.01.2014	4	30	25.4	50
	30.01.2014	4	25.9	23.9	40
	07.02.2014	4	31	26.3	30
	12.08.2014	4	33.9	31.8	54
	12.09.2014	4	33.4	31.8	79
	05.01.2015	4	29.9	27.5	41
	11.04.2015	4	29.9	31.4	44

Table 2: Fungal species isolated from the indoor environments of library sections, their CFU counts & Percent contributions

Sr. No.	Fungal species isolated	Total colonies Reading section	CFU/m^3 Reading section	%	Total colonies Stock section	CFU/m^3 Stock section	%
1	*Aspergillus niger*	55	343.75	4.51	75	468.75	4.55
2	*Aspergillus flavus*	44	275	3.61	69	431.25	4.18
3	*Aspergillus fumigatus*	17	106.25	1.39	76	475	4.61
4	*Aspergillus terreus*	06	37.5	0.49	15	93.75	0.91
5	*Aspergillus tamerri*	09	56.25	0.74	12	75	0.73
6	*Aspergillus ochraceous*	15	93.75	1.23	33	206.25	2.00
7	*Aspergillus flavipes*	11	68.75	0.90	23	143.75	1.39
8	*Aspergillus nidulans*	17	106.25	1.39	29	181.25	1.76
9	*Aspergillus oryzae*	27	168.75	2.22	39	243.75	2.37
10	*Aspergillus ustus*	36	225	2.95	22	137.5	1.33
11	*Aspergillus candidus*	02	12.5	0.16	12	75	0.73
12	*Aspergillus glaucus*	22	137.5	1.80	24	150	1.46
13	*Cladosporium herbarum*	46	287.5	3.77	79	493.75	4.79
14	*Cladosporium spp.*	39	243.75	3.20	56	350	3.40
15	*Curvularia tetramera*	86	537.5	7.06	39	243.75	2.37
16	*Curvularia geniculata*	98	612.5	8.04	48	300	2.91
17	*Curvularia lunata*	113	706.25	9.27	77	481.25	4.67
18	*Chaetomium spp.*	21	131.25	1.72	46	287.5	2.79
19	*Alternaria soloni*	45	281.25	3.69	56	350	3.40
20	*Alternaria alternata*	56	350	4.59	85	531.25	5.15
21	*Alternaria tenussima*	42	262.5	3.45	69	431.25	4.18
22	*Mucor spp.*	15	93.75	1.23	26	162.5	1.58
23	*Rhizopus nigricans*	28	175	2.30	35	218.75	2.12
24	*Fusarium spp.*	22	137.5	1.80	43	268.75	2.61
25	*Drechslera spp.*	13	81.25	1.07	19	118.75	1.15
26	*Trichoderma spp.*	11	68.75	0.90	17	106.25	1.03
27	*Nigrospora spp.*	12	75	0.98	23	143.75	1.39
28	*Candida albicans*	06	37.5	0.49	22	137.5	1.33
29	*Penicillium citrinum*	42	262.5	3.45	73	456.25	4.43
30	*Penicillium glaucus*	36	225	2.95	89	556.25	5.40
31	*Penicillium chrysogenum*	59	368.75	4.84	72	450	4.37
32	*Penicillium spp.*	22	137.5	1.80	53	331.25	3.21
33	*Torula spp.*	13	81.25	1.07	22	137.5	1.33
34	*Phoma spp.*	17	106.25	1.39	26	162.5	1.58
35	*Yeasts*	27	168.75	2.22	27	168.75	1.64
36	*Non-sporulating fungi*	89	556.25	7.30	118	737.5	7.16
Total colonies, CFU/m^3&Percentage		**1219**	**7618.75**	**100**	**1649**	**10306.25**	**100**

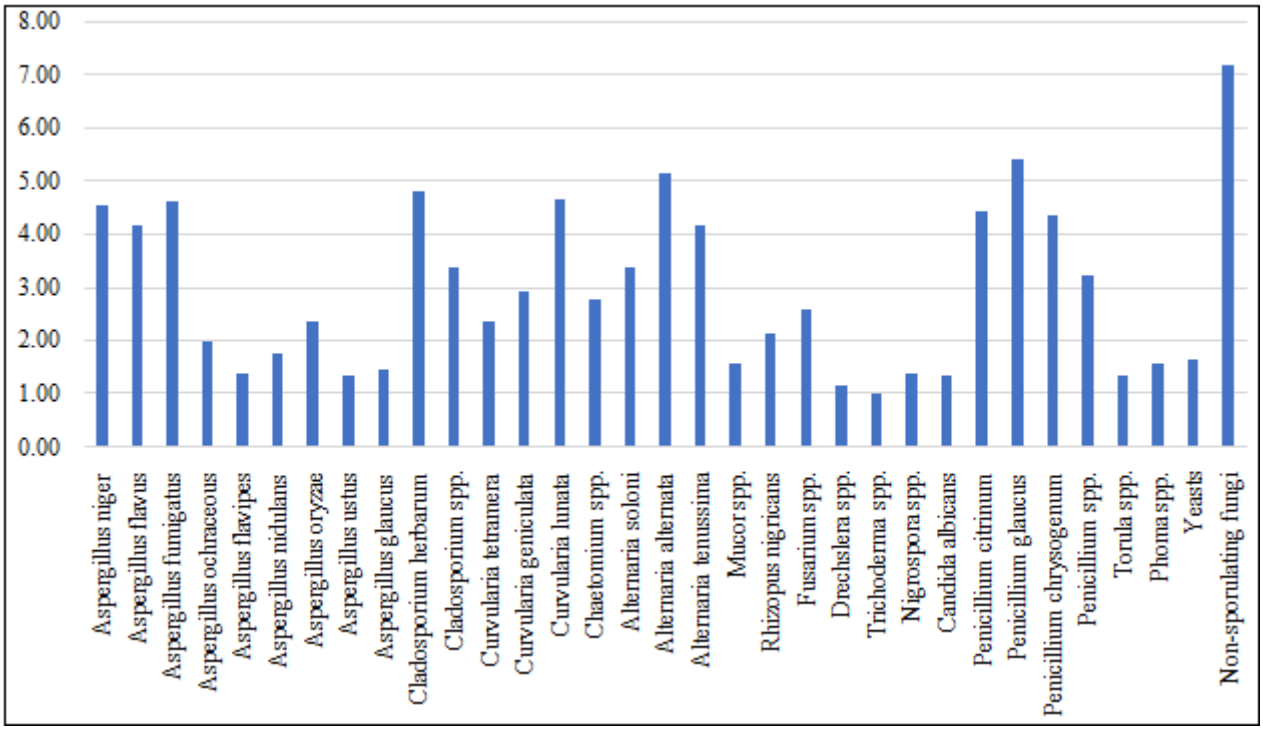


Figure 1: Dominant fungal species isolated from Reading section of library and their Percent contribution

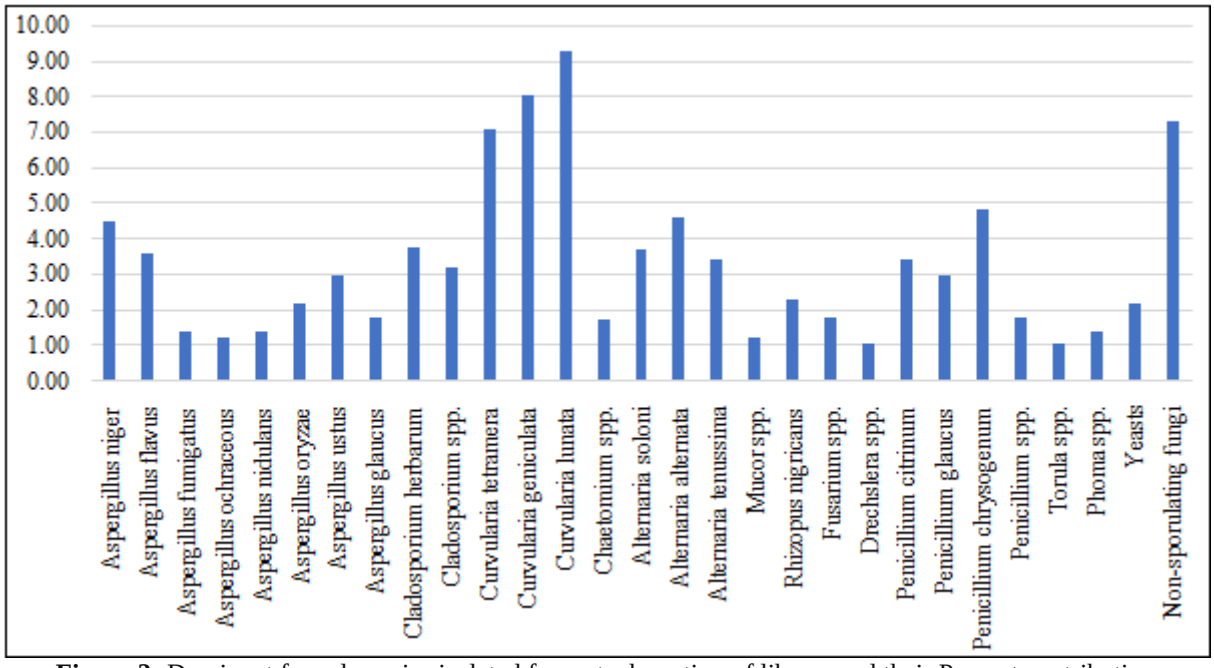
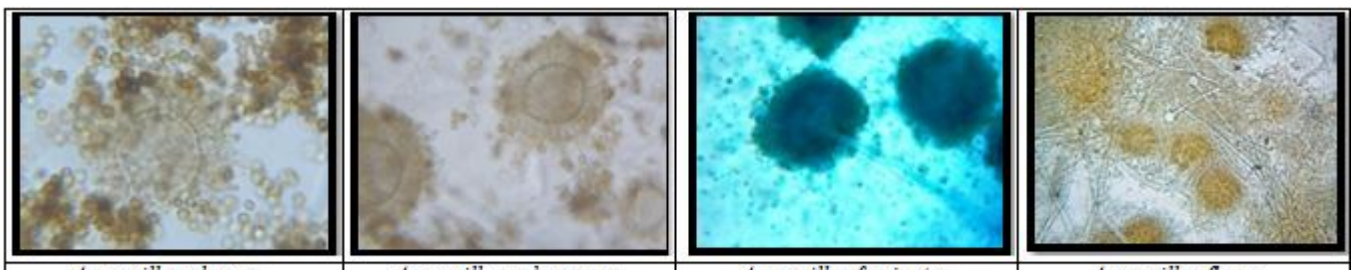


Figure 2: Dominant fungal species isolated from stock section of library and their Percent contribution



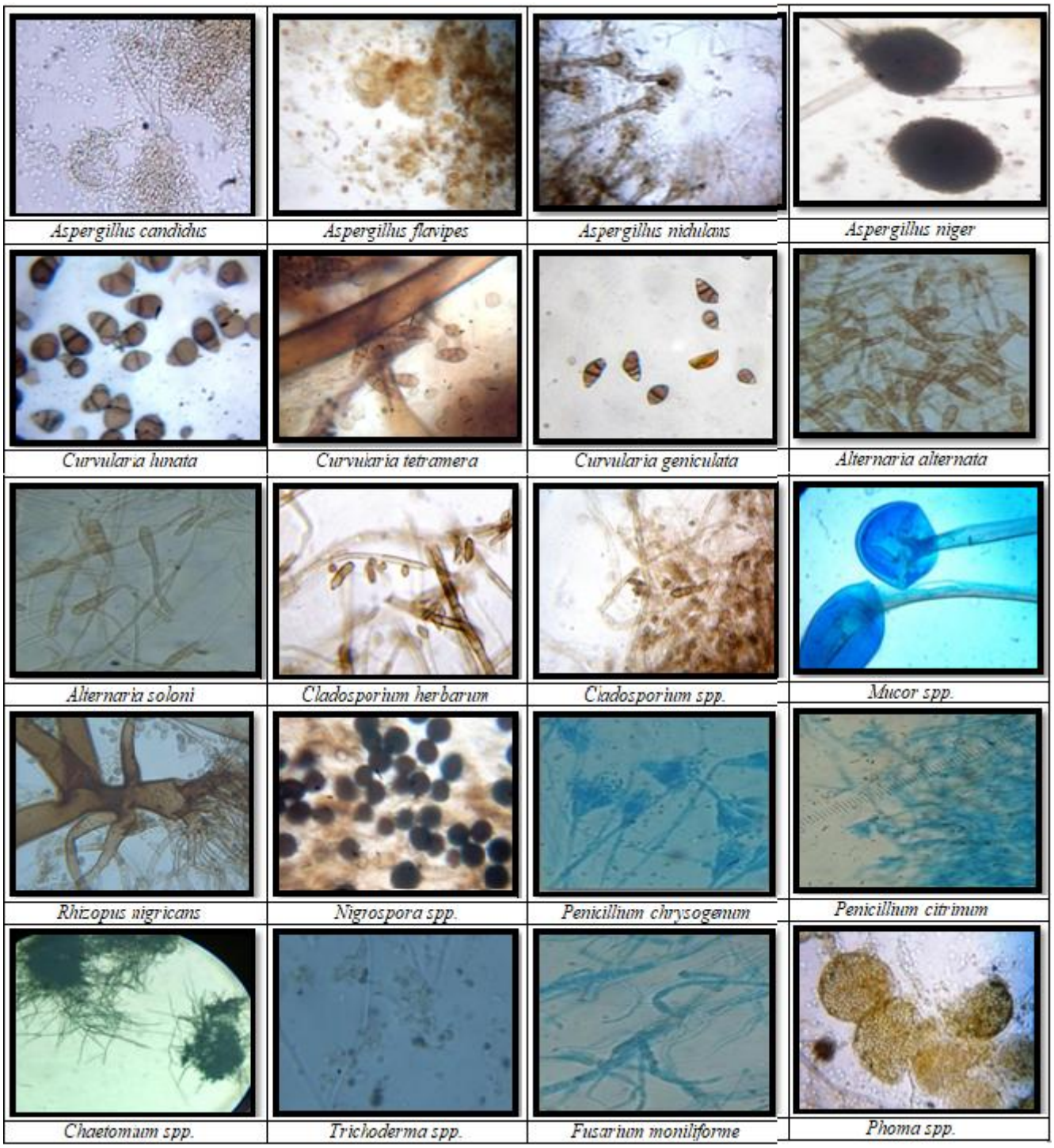


Plate 2: Micro-photographs of fungal species isolated from the indoor air of library

4. Conclusions

It is generally believed that there is a cause and effect relationship between exposure to airborne allergens and allergy symptoms; however, threshold concentrations are largely unknown. It has been suggested that concentrations of 100 *Alternaria* conidia/m^3 and 3000 *Cladosporium* conidia/m^3 are reasonable estimates for these widespread taxa. The total mean concentrations of fungi in reading section of library was 7618.75 CFU/m^3, which is minimum as compare to the stock section of library 10306.25CFU/m^3. There are no official standards, at this time, for indoor airborne fungus concentrations. However, indoor fungal levels above a range of 150 to 1,000 colony-forming units per cubic meter of air (cfu/m^3) are considered to be sufficient to cause human health problems. Indoor airborne mold or mycotoxin exposures cause many multi-system adverse human health effects, as indicated by the more than 100 references cited. There is sufficient data from the medical literature and the large number of clinical reports to substantiate the reported adverse health effects of indoor airborne fungi.

Most of the students, faculty members, and researchers studying in library and spend near about 2-4 hours per day. Moreover, fresh air has traditionally been considered more polluted and worse quality than the air we breathe indoors. However, there is lack of knowledge about the regular

cleaning, especially in relation with the preservation and cleanliness of library environments. It is recommended that, the regular cleanliness, fumigation and use of fungicides should be done on priority basis in library sections to minimize the fungal presence in indoor environment in order to prevent further fungal contaminations, which would be safe for the students, faculties, librarian & library staffs who spend most of the precious time in a library environment.

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