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STUDY OF FUNGAL BIOAEROSOLS AND MICROBIOLOGICAL DETERIORATION & DEGRADATION OF LIBRARY MATERIALS

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Abstract:
Biodeterioration of archive and library materials is commonly caused by fungi. Fungi are specialized micro-organisms which differ from the plant kingdom by the lack of chlorophyll and consequently cannot utilize energy directly from sunlight. The biodeterirative role of fungi is due to their hydrolytic enzyme activity. The cellulytic activities cause maximum damage to papers as well as binding materials of the books like leather and glue. Fungal spores in the library not only deteriorate and degrade the quality of papers but also cause the health effects like allergy and allied respiratory symptoms to the readers, students and the staff members.A study of airborne fungi was carried out in the 80 years old college library in Mumbai by using viable volumetric sampling methods. This resulted in a total of 31 identified species, of which the most abundant were: Aspergillus spp. (38.3%), Penicillium spp. (13.8%), Alternaria spp. (6.1%), Cladosporium sp. (3.8%), Curvularia sp. (4.1%), Trichoderma spp (3.9%), Chaetomium (2.7%), Unidentified fungi (9.1%) etc. Filamentous fungi of 12 genera, represented by 30 species, were isolated from library materials as books, paper, parchment, textiles, glues, inks and wood.
Key Words: Deterioration, Degradation, Library materials, Health effects, Fungi, Bio-aerosols,

Introduction:

Biodeterioration phenomena represent a complex of physical and chemical alteration processes in various materials, such as those constituting the objects that represent our cultural heritage. The biodegradation of paper is conditioned by several variables such as the materials from which cellulose is obtained, the manufacturing processes employed, the occurrence of other affecting substances such as lignin and the environmental conditions. Storage of books and documents inside structures intended for their preservation has created new manmade environments for microbial species such as fungi and bacteria to inhabit (Kowalik, 1980; Zyska, 1997; Nittérus, 2000).

Virtually all organic materials including papers are susceptible to some species of mold growth. The organic materials in library include cellulosic fiber, bookcloths, natural adhesives, including starch paste made from vegetable matter and glues; some synthetic adhesives; leathers etc. In addition, dust and moisture can provide additional nutrients required for the mold growth.

The deterioration of library material by microorganisms has attracted the attention in recent years. The role of biological agents and the deterioration with reference to libraries and museums has been reviewed by many scientists (Greathouse et al. 1954, St. George et al. 1954, Kowalik 1984). According to them many fungi, bacteria and actinomycetes were the microorganisms referred to as biodeteriorating agents in the libraries and museums. Paper is the main source used as a medium for recording and exchanging information. Depending upon the nature and the environmental conditions, paper is subjected to attack from several sources viz., physical, chemical and biological. However the most important cause of deterioration has been takes place by the biological agents. Humidity is favorable for the growth of molds which cause loosening of paste and glue, weakening of fibers of paper.

In the last decade, several investigations in libraries have reported mold contamination and growth on volume bindings made of leather, parchment or cotton fibres. In this study, common fungal species contaminating books and fungal bioaerosols is reported. Indirectly, this type of study may have public health applications, since the calculation of atmospheric fungal content and the identification of certain human pathogens can show whether an atmosphere is healthy or not and point to potential allergy risks.

Materials and methods:

A study of bioaerosols was carried out in the college library at different locations containing books and papers stored shelves and contaminated by molds.

The fungal bioaerosols sampling has been carried out by settle gravity culture plate method. Two different media i.e. Sabouraud's agar and PDA has been used. The 9 mm Petri plates containing above mentioned medium were exposed for 5 minute at different locations in the libraries after slight agitation. Sampling was conducted fortnightly intervals in the morning before the library staff started work

after cleaning activities inside the library. Inside the library the air samples were collected from reading section, distribution section, reference book section, stack room (store room), current Journal section etc. Air samples were also collected outside the library building in order to determine outdoor background and possible migration of biological contaminants into the library as control.

After the exposure to air the Petri dishes were brought to the laboratory in the pre-sterilized polythene bags and incubated at 25°C for 5-7 days. Colonies were counted and identified. The identification of colonies was based on their color, size, shape and other morphological features (Gilman 1957, Barnett 1960, Raper and Fenell 1965, Raper and Thom 1968, Smith 1969, Ainsworth et al., 1972, Ellis 1971, Ingold, 1971). The temperature and relative humidity of the air during the experiments were also recorded.

The fungi also isolated from the infested books and other library materials like leather cover, cardboard cover, binding cloths, adhesive etc. Sampling of fungal elements was performed on visible fungal spots by sterile cotton swabs were wiped across fungal spots then transferred to the laboratory in sterile tubes and used for fungal culturing and identification up to species level.

Results and Discussion:

Thirty one fungal species belongs to 18 genera were isolated from the air samples. Of these 2 belongs to Zygomycotina, one of Ascomycotina and rest of the colonies were belongs to Deuteromycotina. Non-sporulating and unidentified colonies also counted and grouped under unidentified fungi. In every air samples the spores of *Aspergillus* were dominant as well as in control samples. Many fungi like Aspergillus, Penicillium, *Trichoderma, Alternaria, Acromonium, Epicoccum, Cladosporium, Chaetomium, Rhizopus, Mucor, Torulla,* etc. were recovered from the air of library as well as from the library materials and most of these fungi are known for cellulose degrading. Many of the fungal spores registered have been associated with severe respiratory illness and skin infections as reported by many workers.

Maximum average fungal colonies were isolated from the stack or store room (28.1%) which is followed by reference book section (21.4 %), distribution section (16.5%), reading section (13.4%), Current journal section (11.1%) The average total fungal CFU and its percent contribution is depicted in the **figure 3.**

The incidence of fungi in the library exhibited seasonal variation in total counts as well as major types. It has been observed that in the months of monsoon (37.2%) the fungal counts were highest as compared to winter (33.9%) and summer (28.7%) months **(Fig.2).** Highest counts were recorded in the month of July and August. In the month of April and May less number of fungi was registered in indoor as well as in control samples **(Fig 5).**

The result of the present study reveals that *Aspegillus* spp. is the most dominant fungal component of the air in library environment as well in control samples. It seems that the weather conditions like humidity and temperature plays an important role in the development of fungi in the library environment. Fungal degradation of library materials causes different kinds of damage depending on the species of organism responsible for the attack and the characteristics of the substratum. Damage can occur because of mechanical stress, production of staining compounds or enzymatic action (Blyskal 2009; López-Miras et al. 2013; Pinzari et al. 2010; Santos et al. 2009; Sterflinger 2010). Most of the filamentous fungi associated with the damage of paper can dissolve cellulose fibres with the action of cellulolytic enzymes, or may discolour the support, dissolve glues and inks or degrade the oil binders. Majority of fungal species have been recovered in the present investigation including the cellulose degrading fungi such as *Chatomium, Torula, Fusarium, Trichoderma.*
The organic materials in library collections include cellulosic fiber; sizes and fillers of starch, casein and cellulose; natural adhesives, including starch paste made from vegetable matter and glues; some synthetic adhesives; leather. In addition, dust and dirt can provide additional nutrients required by the mold. All of these materials are hygroscopic, that is, they attract and hold moisture. Thus, in humid climates, most materials in the library contain a relatively high percentage of water. In these conditions, even a slight increase in ambient relative humidity is enough for the item to sustain mold growth, if the other requirements are present.

The distribution pattern of fungi species varies; some species are more common in libraries regardless of geographical situation. Shamsian et al. (**2006**) studied the fungal contaminations in Historical Manuscripts at Astan Quds Museum Library, Mashhad, Iran. They showed the most fungal genera were *Aspergillus, Cladosporium* spp. In the

present investigation similar results were obtained. The fungi like *Aspergillus, Penicillium, Cladosporium, Trichoderma, Torulla, Chaetomium* etc. were dominant in all the sections of library as well as in the air samples. Similarly the other fungi like *Curvularia, Drechslera, Alternaria spp.* etc. were the other common fungi associated with printed materials, books as reported by many authors.

Isolation of *Aspergillus, Penicillium, Cladosporium,* and *Alternaria* spp. are the most common isolated fungi in this study was in agreement with the fungi reported by Vittal et al. (1985) in libraries and archives. The most common ingredients used for repairing old and damaged books such as glues with animal and vegetable sources and inks and wax seals are good nutritional resources for fungal growth .

Rojas et al. (**2009**) in a study on fungi causing bio-deterioration of industrial paper reported similar results to our study. They found genera of *Cladosporium, Chaetomium, Penicillium, Aspergillus, Alternaria*. Wooden shelves can absorb humidity providing suitable environment for fungal growth. Sunil and Kumar (**2009**) suggested that library racks should be made of steel and suitably painted to avoid rusting. Some strains of *Aspergillus* and *Penicillium* would be likely to attack cellulose or one of the numerous paper additives, sizes, fillers or coatings. At least 180 genera or species of mold are known cellulose destroyers, i.e., they use the cellulose fiber as a nutrient.

Silva et al. (2006) showed that paper and wood damaging fungi will be inactivated by gamma-ray radiation. The research was performed in a Brazilian public library on common species of fungi invading books and documents such as *Acremonium, Aspergillus, Cladosporium, Fusarium, Penicillium,* and *Trichosporon* spp. Which were inactivated by gamma-ray radiation. For prevention of damage and preserving library collections, environmental conditions should be adjusted in a way that fungal growth diminishes. The optimum temperature for this purpose should be between 18 to 22°C and humidity should be adjusted below 55% Shamsian et al. (2006). Most microbial forms grow in temperatures ranging from 15º to 35° C, although there are forms which will grow at almost freezing and others which thrive at over 65º C. The average optimum for mold growth is usually stated to be in the vicinity of 30° C.

Conclusion:

It is observed that most of the fungi were encountered during the months of monsoon. In these months the relative humidity was maximum (70-90%) and temperature is relatively moderate (28-32 ◦C). The best remedy is preservation by storage books in the light as well as in well ventilated rooms where the books are kept dry. It is recommended that for cleaning of the book shelves etc. in the library instead of manual cleaning by hand or duster the use of vacuum pump should be preferred. Regular fumigation with fungicides is also advised for the better maintenance of books in the libraries.

Prevention: It is impossible to maintain the fungal spore free environment in the library or any other environment. But fungal activity and growth is much easier when the library environment is controlled naturally or by using the technology. Following measures are recommended to control the environmental conditions which prevent the mold growth in the library environment and also protect the books journals and other cultural heritage (Mary Wood Lee, 1988):

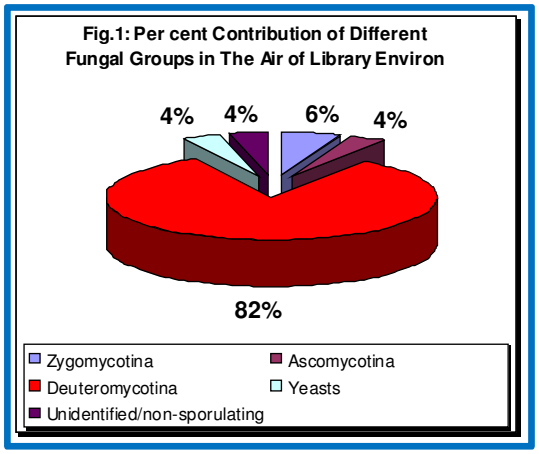
1. Well ventilated Building design and the modification of existing buildings for natural ventilation. Even buildings designed to utilize natural ventilation will require back-up systems of mechanical ventilation for those times when prevailing winds fail or shift
2. The major effort should be concentrated on improving circulation and lowering the relative humidity
3. Structural considerations in environmental modification – Temperature and circulation can be modified directly through building structures. Relative humidity can be modified only indirectly through the effective use of natural ventilation or through technological control
4. Temperature- Large windows in tropical climates can significantly increase interior temperatures.
5. High ceilings are a common feature of older buildings in the tropics and are an effective means of diffusing interior heat. The installation of ceiling fans is such environment is must for air circulation.
6. Stacks should be arranged parallel to the air flow. Stack arrangement should not block the air circulation. Space between the wall and the stack will be maintained to improve circulation and prevent condensation of moisture on the wall from creating a micro-climate.
7. Air Conditioning should be used to cool and filter the air inside the library. In hot and

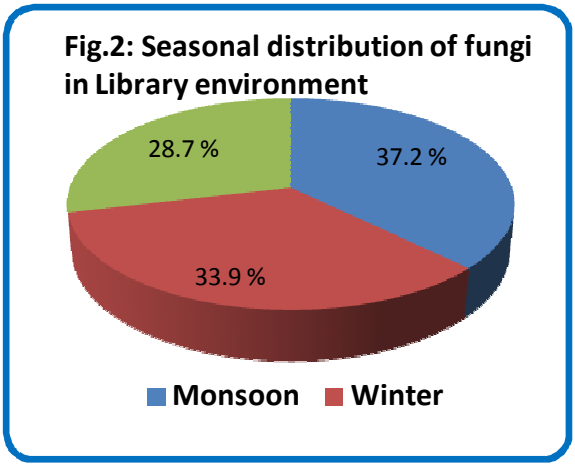
humid climates in Mumbai use of AC is important which prevent the humidity in the air in indoor environment.

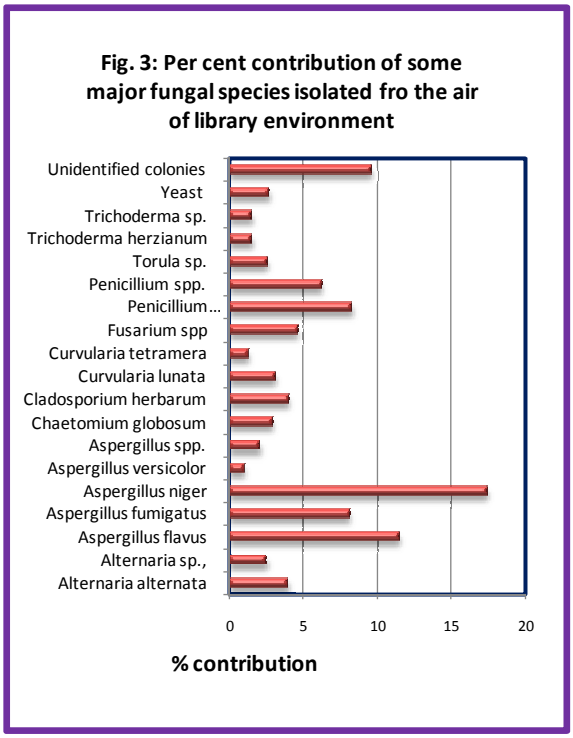
8. Dehumidification is important to control the mold growth. Dehumidification units should be installed in every library.
9. Stack maintenance, Routine cleaning should be done every library as dirt and dust particles are hygroscopic, which attract and hold moisture from the air, and since they often contain nutrients required by molds.
10. Vacuuming by vacuum pumps will also reduce the spores along with dust on materials.
11. Frequent inspection of the stack and other areas like storage areas of the library should be done.

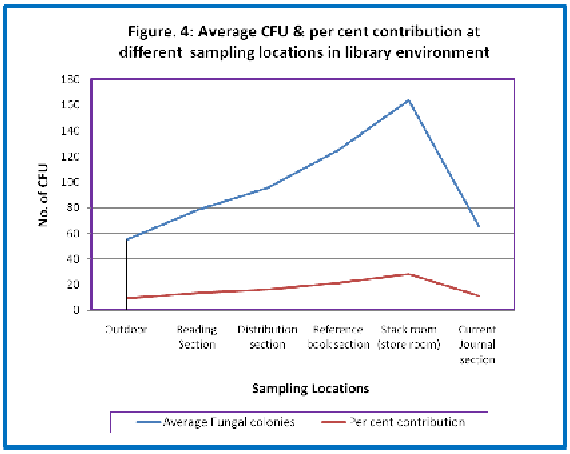
Table 1: Monthly distribution of fungal bioaerosols during the period of investigation in library environment (JUNE 2010 MAY 11)

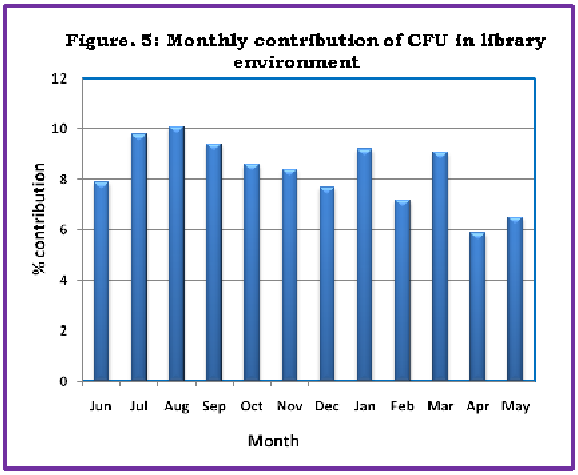
Fungal species	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	Total colonies	per cent frequency	per cent contribution
Acromonium sp.	0	0	1	1	0	2	1	1	0	1	0	0	7	50	0.4
Alternaria alternata	2	4	9	10	8	3	5	5	4	6	2	2	60	100	3.7
Alternaria sp.,	5	6	2	3	2	2	5	2	1	3	3	4	38	100	2.4
Aspergillus flavus	18	16	14	14	12	12	14	21	12	22	11	9	175	100	10.9
Aspergillus fumigatus	10	12	11	14	7	8	13	11	11	12	9	6	124	100	7.7
Aspergillus niger	32	32	22	21	15	18	15	20	21	28	18	24	266	100	16.6
Aspergillus versicolor	0	1	2	5	2		2		2	1			15	58	0.9
Aspergillus spp.	0	2	5	1		5	6	5	4	2	1		31	75	1.9
Aspergillus terreus	5	4	5	4	6	8	2	8	6	5	2	4	2	100	0.1
Botrytis cirerea		2	1	2	4		2		1				12	50	0.7
Candida albicans		1	2		1			1					5	33	0.3
Chaetomium globosum	3	5	4	4	5	3	4	6	3	2	3	2	44	100	2.7
Cladosporium herbarum	6	5	8	2	4	5	9	5	4	3	5	5	61	100	3.8
Curvularia lunata	3	6	4	5	3	8	3	4	2	3	3	3	47	100	2.9
Curvularia tetramera	0	4	4	3	2	2	0	3	0	1			19	58	1.2
Drechslera			1		2	2		2	2				9	42	0.6
Fusarium spp	5	6	8	8	8	6	5	8	2	5	4	5	70	100	4.4
Geotrichum spp.,	1	3	0	0	2	2	0	0	0	1	0	0	9	42	0.6
Helmithosporium sp	0	2		1	3	3		2	0	2	0	1	14	58	0.9
Mucor sp.	0	1		0	0	0	0	2	0	0	1	2	6	33	0.4
Neurospora sp.			2			2			2				6	25	0.4
Oidium sp.,		2	1	1	1	0		1	0	0	0		6	42	0.4
Penicillium chrysogenum	12	11	17	11	9	11	9	11	9	12	8	6	126	100	7.9
Penicillium spp.	3	4	9	12	12	9	7	8	10	9	5	7	95	100	5.9
Phoma lingam	0	0	2	1	0	2	2	0	0	2	0	1	10	50	0.6
Rhizopus sp	0	2	2	3	2	1	0	1	0	1			12	67	0.7
Syncephalestrum sp.				2				1			1		4	25	0.2
Torula sp.	3	2	4	2	5	2	3	4	3	4	3	4	39	100	2.4
Trichoderma herzianum	2	0	2	2	0	2	1	2	3	4	2	3	23	83	1.4
Trichoderma sp.	1	4	4	2	4	2	0	0	2	2	0	2	23	75	1.4
Yeast	3	4	1	3	3	4	4	4	4	3	4	4	41	100	2.6
Unidentified colonies	13	16	15	14	16	11	12	10	8	12	9	10	146	100	9.1
	127	157	162	151	138	135	124	148	116	146	94	104	1602		100.0











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