Indoor Air Quality of the Library at İstanbul University, Turkey

İstanbul Üniversitesi (Türkiye) Kütüphanesinin İç Ortam Hava Kalitesi

Research Article

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ABSTRACT

This study aimed to determine the concentration and composition of opportunistic airborne microfungal pathogens in different parts of the library of İstanbul University, Turkey. Dichloran glycerol 18 agar and malt extract agar were used for isolation and a total of 1830 and 1290 microfungal colonies were collected during the whole study period, respectively. Contamination levels in sampling areas were classified according to the Commission of European Communities report's classifications and a high contamination level was determined in Archive 1, while an intermediate contamination level was determined in other sampling areas. The most common airborne microfungi were identified as *Aspergillus flavus*, *Aspergillus amstelodami*, *Aspergillus niger* and *Aspergillus fumigatus*.

Key Words
Air quality, library, microfungi, volumetric air sampling.

ÖZ

Bu çalışmada, İstanbul Üniversitesi'nin farklı bölümlerindeki hava kökenli fırsatçı mikrofungal patojenlerin derişiminin ve kompozisyonunun belirlenmesi amaçlanmıştır. Dikloran gliserol 18 agar ve malt özüt agar izolasyon için kullanılmış ve sırasıyla tüm örnekleme süresince toplam 1830 ve 1290 mikrofungus kolonisi toplanmıştır. Avrupa Birliği Komisyon raporuna göre örnekleme alanlarındaki kirlilik seviyeleri sınıflandırılmıştır. Diğer örnekleme alanlarında orta düzeyde kirlilik seviyesi saptanırken, Arşiv 1'de yüksek seviyede kirlilik saptanmıştır. En yaygın hava kökenli mikrofunguslar *Aspergillus flavus*, *Aspergillus amstelodami*, *Aspergillus niger* ve *Aspergillus fumigatus* olarak tanımlanmıştır.

Anahtar Kelimeler
Hava kalitesi, kütüphane, mikrofungus, volümetrik hava örneklemesi.

Article History: Received: Apr 22, 2016; Revised: Feb 16, 2017; Accepted: Feb 16, 2017; Available Online: Apr 1, 2017.

DOI: 10.15671/HJBC.2017.140

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INTRODUCTION

People spend most of their time in indoor environments, and therefore indoor air quality appears to be a very important aspect for public health. Biological and physical factors and chemical particles are major components and determinants of indoor air quality, and they play an important role as pollutants. Biological particles consist of microorganisms (bacteria, microfungi, viruses, algae, protozoa), pollens of various plants and their fragments [1,2]. There are many studies concerning how poor microbiological air quality can lead to respiratory infections, allergy and irritation of mucous membranes particularly in hypersensitive and immunosuppressed people [2-5]. Presence of quality decreasing microbial agents in indoor enrivonments can also cause health problems for public in general and for employees operating indoors. For instance, in two different studies performed in Sweden and the United States, archives employees were reported to have upper respiratory irritation, allergies and hypersensitivity pneumonitis problems which were associated with mold contamination in their work environment [6,7].

The indoor environments of libraries may have high concentrations of microorganisms and dust originating from human sources, i.e employees and temporary library visitors, books, magazines, newspapers and the use of ventilation systems associated with air conditioning, photocopiers and printers [8,9]. High levels of organic matter, humidity and temperature are the most pronounced factors which provide the optimal conditions for microfungal growth. Studies on indoor air quality of library environment reported that *Aspergillus*, *Penicillium*, *Alternaria*, and *Cladosporium spp*. representatives were the predominant microfungi of the airborne microfungal load. Many members of these genera are known to be opportunistic pathogens whose antigens cause cases of diseases such as asthma, allergic rhinitis, allergic sinusitis and cutaneous infections [9-15].

Although previous studies reported data on the diversity of microflora in indoor air environments of libraries [9,10,13,14] to the author's knowledge, the present study is the first to focus on opportunistic microfungal pathogens. A number of comprehensive studies on indoor air quality of different environments such as primary schools, hospitals and residential structures in Turkey were performed [16-19], but only a limited number of studies have focused on libraries in special [13], raising the importance of need of further investigations. This study was performed in order to determine the concentration and composition of culturable opportunistic microfungal pathogens in the university library of İstanbul University using two different growth media.

MATERIALS and METHODS

Study Area

The indoor samplings of microfungi was performed at İstanbul University's library, located in the suburb of Beyazıt, İstanbul, Turkey. The library consists of an information desk-entry (E), two reading halls (RH1 and RH2), three archives (A1, A2 and A3) and a photocopy room (PR). It serves not only for university staff and students but also the public. About 500 people visited the library per day and 10 employees were actively working in archives during the study period. Although the library had a central heating and mechanical ventilation system, natural ventilation with windows was used in the archives. Radiators were used for the heating of archives. The sampling area was free of carpets during the study.

Air Sampling

Air samples were collected for a one year period at one-month intervals using a portable volumetric microbiological air sampler (HiAirflow, HiMedia) in the seven sampling areas given above (E, RH1, RH2, A1, A2, A3, and PR). The sampling was performed from 10.30 a.m. to 13.00 p.m. when the library was actively used. Air sampler was operated two times per two media for each sampling area and for each individual sampling, the air sampler was used to collect 100 L of air for one min, at 1.4 m above the floor level [20]. Samples were then transferred to the laboratory within one hour. During all samplings, ambient temperatures and relative humidity values were recorded using a digital recorder (TM Instruments).

Isolation and Identification of Microfungi

Dichloran glycerol 18 agar (DG18) and malt extract agar (MEA) plates were used for isolation and enumeration of opportunistic microfungal pathogens. The plates used in samplers during isolation were incubated at 37°C (above mentioned microfungi grow well this temperature) for up to 14 days [2,21,22]. After the incubation period, microfungal colonies on each plate were counted and the colonies isolated were calculated by colony forming unit per cubic meter (CFU/m^3) measuring. The mean and standard deviations of fungal counts were calculated. Then the colonies were subcultured on potato dextrose agar slants. Microfungi were inoculated into various media (Czapek yeast autolysate agar, Czapek-Dox agar, Czapek yeast autolysate agar with 20% sucrose, 25% glycerol nitrate agar, malt extract agar, and potato dextrose agar) and identified at genus and species levels by microscopic and macroscopic methods according to generally accepted standards [23-27]. Fungal author names and fungal names, in this article, are standardised according to the Index Fungorum website and Hawsksworth et al. [28,29].

RESULTS

Determination of Colonial Counts of Microfungi in Different Parts of the Library

A total of 1830 and 1290 microfungal colonies were collected from the air samples during the study period in DG18 and MEA, respectively (Table 1). When DG18 was used as the sampling media, July was found to be the month during when the highest microfungal colonies were isolated with 380 CFU/m^3 (20.76%), followed by October with 330 CFU/m^3 (18.03%), September with 310 CFU/m^3 (16.93%), May with 290 CFU/m^3 (15.84%), January with 150 CFU/m^3 (8.19%), December with 100 CFU/m^3 (5.46%), March and November with 90 CFU/m^3 (4.91%), August with 60 CFU/m^3 (3.27%), April with 20 CFU/m^3 (1.09%) and June with 10 CFU/m^3 (0.54%). The lowest colony number was obtained during February (0 CFU/m^3). When the sampling areas were taken into consideration, RH1 had the lowest and A1 had the highest colony numbers of microfungi during the sampling period (Table 1). When the sampling media was MEA, November was the month with the highest colony number [400 CFU/m^3 (31%)], followed by May with 300 CFU/m^3 (23.25%), October with 220 CFU/m^3 (17.05%), September with 170 CFU/m^3 (13.17%), July with 60 CFU/m^3 (4.65%), December with 50 CFU/m^3 (3.87%) and January, February, April, and August with 20 CFU/m^3 (1.55%). The lowest colony numbers were obtained during March and June (10 CFU/m^3, 0.77%). PR and A2 had the lowest and A3 had the highest colony numbers during the sampling period (Table 1). According to the Commission of European Communities classifications (CEC) [30], A1 had a high contamination level, while the other sampling areas had an intermediate contamination level with respect to the colonial counts obtained with DG18 and all sampling areas had an intermediate contamination level with MEA.

The lowest and highest temperature values (20.19°C and 25.97°C) were measured in A3 and E. The mean of the lowest and highest temperature values was measured in February and August (19.34°C and 27.64°C, respectively) (Table 2). The lowest and highest humidity values (45.13% and 54.64%) were measured in RH2 and A3. The mean of the lowest and highest humidity values was measured in December and October (29.62% and 61.11%, respectively) (Table 3).

Identification of the Microfungal Isolates

A total of 12 genera and 23 species were identified in indoor air of the library during the one-year sampling period (Table 4). The most isolated microfungal genera were *Aspergillus* and *Penicillium* with 1920 CFU/m^3 and 400 CFU/m^3, respectively. *Aspergillus* was detected in high numbers in May (450 CFU/m^3) and *Penicillium* was detected in high numbers in January (100 CFU/m^3). The other common genera were *Alternaria*, *Cladosporium*, *Chaetomium* and *Fusarium* with 120 CFU/m^3, 110 CFU/m^3, 80 CFU/m^3, and 30 CFU/m^3, respectively. Among the species isolated, *Aspergillus flavus* was the most common microfungi with 670 CFU/m^3, followed by *A. amstelodami*, *A. niger* and *A. fumigatus* with 340 CFU/m^3, 310 CFU/m^3 and 290 CFU/m^3, respectively. Dark colored-pigmented fungi (a non-identified Dematiaceous group in this study), non-sporing fungi and yeasts were detected in

Table 1. The monthly distributions of microfungal concentrations (CFU/m^3) in the seven sampling stations.

DG18	January	February	March	April	May	June	July	August	September	October	November	December	Total
RH1	0	0	10	0	30	0	0	0	30	10	0	20	100
RH2	20	0	0	0	70	0	10	0	100	10	10	0	220
PR	10	0	0	10	0	0	20	10	0	20	40	20	130
E	0	0	0	0	10	0	10	0	0	60	30	10	120
A1	120	0	70	0	110	0	310	10	70	50	10	20	770
A2	0	0	10	0	40	0	0	10	20	40	0	30	150
A3	0	0	0	10	30	10	30	30	90	140	0	0	340
Total	**150**	**0**	**90**	**20**	**290**	**10**	**380**	**60**	**310**	**330**	**90**	**100**	**1830**

MEA	January	February	March	April	May	June	July	August	September	October	November	December	Total
RH1	10	0	0	0	0	10	0	0	20	40	50	20	150
RH2	0	0	0	20	20	0	10	0	0	30	80	10	170
PR	10	0	0	0	20	0	10	0	0	20	50	0	110
E	0	0	10	0	50	0	30	0	10	10	100	10	220
A1	0	0	0	0	100	0	0	0	10	20	120	0	250
A2	0	20	0	0	30	0	0	10	0	40	0	10	110
A3	0	0	0	0	80	0	10	10	130	60	0	0	290
Total	**20**	**20**	**10**	**20**	**300**	**10**	**60**	**20**	**170**	**220**	**400**	**50**	**1290**

Table 2. Temperature values (°C) recorded in the seven sampling stations.

	January	February	March	April	May	June	July	August	September	October	November	December	Mean
RH1	22.4	21.5	22	24.15	26.1	26.35	27.5	28.4	27.5	27.5	24.1	24.7	24.8
RH2	23.1	22.5	22.7	24.3	26.2	26.5	26.8	28.7	27.5	30	25	24.5	25.1
PR	20.6	19.6	20.3	24	24.4	24.8	28.4	28.6	27.2	28.2	23	26.7	23.83
E	23.2	24.4	26.1	24.7	26.1	26.43	27.8	28.9	27.4	27.6	24.7	24.4	25.95
A1	17.8	17.1	18	21.85	20.8	23.4	25.5	27.4	24.8	25	21.8	20.4	21.48
A2	18.1	15.9	15.6	18.7	21.3	22.15	24.4	26.1	24.5	25.5	20.2	21.3	20.28
A3	15.4	14.4	13.5	16.5	19.4	21	23.3	25.4	24.7	25.9	20.7	22.1	18.61
Mean of indoor air temperature	**20.08**	**19.34**	**19.74**	**22.02**	**23.47**	**24.37**	**26.24**	**27.64**	**26.22**	**27.1**	**22.78**	**23.44**	

RH1: Reading hall 1, RH2: Reading hall 2, PR: Photocopy room, E: Information desk-Entry, A1: Archive 1, A2: Archive 2, A3: Archive 3.

Table 3. Relative humidity values (%) recorded in the seven sampling stations.

	January	February	March	April	May	June	July	August	September	October	November	December	Mean
RH1	44.9	39.3	36	43.85	50.5	46.7	48.2	62.4	58.2	59	52.1	31.5	46.48
RH2	41.8	36.8	32	42.85	48.8	45	48.8	55.1	56.2	54	48.8	31.5	43.89
PR	43.8	41.5	34.2	44.4	55.5	52.54	50.2	55.2	63.1	60.2	57.3	24.3	47.16
E	43.3	35.5	29.9	43.7	50.4	45.46	47.9	54.2	56.3	57.8	48.8	29.9	43.79
A1	48	40	40.9	44.9	59.4	52.7	58.5	56.7	63.7	65.4	57.8	32.4	50.13
A2	46.3	43.9	42.8	48.8	56.1	56	59.7	59	63.5	65	57.9	29.3	51.57
A3	51.8	45.7	44.7	52.6	60.4	62.2	63.6	59.26	62.9	66.4	57.7	28.5	55.03
Mean of indoor air relative humidity	**45.7**	**40.38**	**37.21**	**45.87**	**54.44**	**51.51**	**53.84**	**57.40**	**60.55**	**61.11**	**54.34**	**29.62**	

RH1: Reading hall 1, RH2: Reading hall 2, PR: Photocopy room, E: Information desk-Entry, A1: Archive 1, A2: Archive 2, A3: Archive 3.

Table 4. The list of the identified microfungi in different parts of library.

Microfungal species	Sample station	Isolation month	Isolation media	Total microfungal concentration (CFU/m³)
Acremonium zonatum (Sawada) W. Gams	RH1	N	MEA	10
Alternaria alternata (Fr.) Keissl.	A1, A2, A3, RH1	S, O, D	DG18, MEA	70
Alternaria sp. 1 Nees	E	M	MEA	10
Alternaria sp. 2 Nees	A1, E	S, O	DG18	40
Aspergillus sp. 1 P. Micheli	A1	N	MEA	10
Aspergillus amstelodami Thom & Church	A1, A2, A3	M, Jy, S	DG18	340
Aspergillus flavus Link	RH1, RH2, PR, E, A1, A2, A3	My, Au, S, O, N, D	DG18, MEA	670
Aspergillus fumigatus Fresen.	A3	Au, S	DG18, MEA	290
Aspergillus niger Tiegh.	A1, A2, A3, RH1, RH2, E	M, A, My, S, O, N	DG18, MEA	310
Aspergillus ochraceus Wilh.	A1, A3	M, Au, S, O, N	DG18, MEA	230
Aspergillus sydowii (Bainier & Sartory) Thom & Church	RH1	My,	DG18	20
Aspergillus terreus Thom	A3	Au	DG18	10
Aspergillus versicolor (Vuill.) Tirab.	RH1, A3	M, My, O	DG18	40
Chaetomium globosum Kunze	A1, A2, A3	F, My, Au, S,D	DG18,MEA	80
Cladosporium sp. 1 Link	PR	J,	MEA	10
Cladosporium sp. 2 Link	S2,	F,	MEA	10
Cladosporium sp. 3 Link	RH1	D	MEA	20
Cladosporium sp. 4 Link	E	D	MEA	10
Cladosporium sp. 5 Link	A2	D	DG18	10
Cladosporium sp. 6 Link	A2	D	DG18	10
Cladosporium cladosporioides (Fresen.) G.A. de Vries	A2	S,	DG18	10
*Cladosporium sp*ongiosum Berk. & M.A. Curtis	RH2	S, O	DG18, MEA	30
Fusarium sp. 1 Link	PR	O	DG18	10
Fusarium sp. 2 Link	PR	O	MEA	10
Fusarium sp. 3 Link	A2	O	MEA	10
Penicillium sp. 1 Link	A1	M,	DG18	10
Penicillium sp. 2 Link	A1	M,	DG18	10
*Penicillium sp.*3 Link	PR	A	DG18	10
Penicillium sp. 4 Link	E	D	DG18	10
Penicillium citrinum Thom	E, A1, PR	My, O, N	DG18	80

Table 4. The list of the identified microfungi in different parts of library (continue).

Penicillium chrysogenum Thom	E, RH2,A1, A2, A3	J, M, My, A, S, N,D	DG18	160
Penicillium funiculosum Thom	A1	My,	DG18	10
Penicillium janthinellum Biourge	RH2,A1	J, A	DG18, MEA	80
Penicillium oxalicum Currie & Thom	RH1	My, D	DG18	20
Penicillium simplicissimum (Oudem.) Thom	PR	Jy	DG18	10
Phoma sp. Sacc.	RH2	D	MEA	10
Rhizopus stolonifer (Ehrenb.) Vuill.	RH2, A1	O	DG18	20
Talaromyces flavus (Klöcker) Stolk & Samson	A2	Au	MEA	10
Trichoderma pseudokoningii Rifai	RH1, A3	Jn, S	DG18, MEA	40
Ulocladium botrytis Preuss	A3	My	DG18	10
Yeast	RH1, RH2, A2, PR, E	J, Au, N	DG18, MEA	270
Dematiaceous	PR, A1, A3, RH2, E	J, M, My, Jn, Jy, Au, S, O, D	DG18, MEA	240
NSF	RH1, PR, E, A2	J, O, N	DG18, MEA	110

NSF: Non sporing fungi, RH1: Reading hall 1, RH2: Reading hall 2, PR: Photocopy room, E: Information desk-Entry, A1: Archive 1, A2: Archive 2, A3: Archive 3, DG18: Dichloran glycerol 18 Agar, MEA: Malt extract Agar, J: January, F: February, M: March, A: April, My: May, Jn: June, Jy: July, Au: August, S: September, O: October, N: November, D: December.

different parts of the library's air with 240 CFU/m^3, 110 CFU/m^3 and 270 CFU/m^3, respectively (Table 4).

DISCUSSION

The reports on exposure of library and archive employees to skin allergy and respiratory illness is limited a few studies [6,7] since previous studies concerning libraries mainly focused on the biodeterioration of documents [31-34], a fact which can be considered to account for the low number of microbiological air quality studies. However, libraries and particularly archives, which harbour thousands of books, magazines or other paper-based records, could be microbiologically risky places. The microfungi in such environments were mainly isolated from dust, damp books, the outdoor air via the natural ventilation and from the footwear of the employees and visitors. If climatic conditions and hygiene levels remain at acceptable levels (the presence of an Heating, Ventilation & Air Condition system and regular cleaning), the rate of significant health issues will come to negligible levels.

Although there are different recommended standarts for microbial control of indoor air environments [30,35], the quality of indoor air is not controlled by law within specified standards in no countries except Korea. The CEC [30] identified a microbiological category in non-industrial indoor environments and proposed that the air concentration of microorganisms lower than 500 CFU/m^3 should be termed as 'intermediate contamination level, while values exceeding 2000 CFU/m^3 as 'very high contamination. According to the CEC report classifications, only A1 in the present study had a high contamination level (14.28%) and the other departments had

an intermediate contamination level (85.72%) considering the colonial counts obtained with DG18. On the other hand, all sampling areas had an intermediate contamination level with MEA. The level of contamination is an important issue to be considered on. The number of microorganisms may increase and lead to infections if people do not take necessary precautions. Similar previous studies performed on indoor air quality of libraries reported different contamination levels. For instance, Hayleeyesus & Manaye [14], Karbowska-Berent et al. [36] and Zielinska-Jankiewicz et al. [37] reported a high microfungal concentration while Kalwasinska et al. [38] and Stryjakowska-Sekulska et al. [10] reported an intermediate microfungal concentration in libraries, the same level as detected in the present study. These difference in contamination levels is a result of the differences in geographical and meteorological conditions, the media used and the air sampling methods since there exists no internationally standard material and method. Although there are many advantages and disadvantages between the two media used in the present study, Samson et al. [22] recommended the use of a combination of DG18 and MEA particularly in indoor environments. DG18 is a media mainly developed for xerophilic microfungi such as *Aspergillus* and *Penicillium* but is also suitable for mesophilic microfungi and is thus one of the most preferred media for indoor studies. The ingredients in DG18 are known to have a few disadvantages. Dichloran, for instance, inhibits the fast growth fungi and *Stachybotrys* is restricted growth in this medium [2,21]. MEA is used to isolate yeast and mold, including hydrophilic and fast-growing species from environmental sources. Malt extract provides an acidic environment and nutrients favorable for the growth and metabolism of yeasts and microfungi while restricting bacterial growth. Mycological peptone allows for a rapid and luxuriant growth with typical morphology and pigmentation for microfungi [21,22]. These advantages reported for MEA makes it the most preferred media for library and archive studies. For these reasons, both DG18 and MEA were used in present study.

The lowest colony numbers were detected in RH1, PR, and A2. Although the number of visitors in the library was high during the study period, presence of a mechanical ventilation system, which might have diluted the microbial load of air, and regular cleaning in RH1 and PR could account for the low levels. Microorganisms that attach to any surface in archives move easily through the indoor air. However, there are thousands of magazines with waterproof glossy paper in A2 and this kind of paper is not a suitable source for microbial growth, reducing the likelihood of a mold problem in magazine containing areas. Furthermore, few number of employees are allowed to enter the archives, which means the number of dust borne microfungi may be reduced accordingly. However, this was not the case in our study and the highest microfungal colony number was obtained with samples in A1 and A3. The discrepancy between low number of employess and high level of microfungal isolation can be explained by two factors. Firstly, these storerooms include books and newspapers composed of cellulose, hemicellulose and lignin which can easily be used by microorganisms as organic carbon sources. Therefore, presence of books and newspapers is a condition increasing microbial growth. These archives in the library were regularly flooded by rainwater during the winter months of the study period leading to favorable conditions for microfungal colonization. As a result, microfungi had the opportunity to penetrate the documents and then disperse through droplets. Secondly, natural ventilation was frequently used to dilute the air and remove the bad smell occurred as a result of the dampness inside but this ventilation transported a new mycoflora from outdoor to indoor air.

Meteorological changes were reported to influence the diversity and level of microbial load of indoor environments [16,17,21]. Microfungal counts seem to be associated with sampling months in the present study (Table 1). A same result was obtained in the study of Kim et al. [39]. This might be explained by the fact that, (i) although natural ventilation was frequently used in the archives, air flow was controlled by the mechanical ventilation system in most parts of library. Different applications are likely to affect the distribution of microfungi. (ii) The culture-based method is used to quantify the

concentrations of bioaerosols. However, this method could not evaluated the bioaerosol concentration on a real-time basis. Air has unfavorable conditions for microbial growth due to sudden changing of temperature, lack of water and nutrients. Therefore many microorganisms can exist in viable but non-culturable state that can proliferate under suitable conditions. They are not isolated and identified by traditional cultured based method [40-42]. Chi and Li [41] measured the total bioaerosol concentrations by the non culture-based methods were 100 to 1000 times higher than those by the culture-based method. In this study, microfungi were not detected in February. Depending on the lowest temperature, microfungi possibly could form in viable but non-culturable.

The lowest temperature and the highest relative humidity were measured in A3. The archives are located in the basement and no daylight is present in these rooms. Furthermore, the temperature is kept low to control the dampness of the books. The relative humidity level was found to be high because of the flooding occurred during winter season. Daylight is present in other departments of the library, especially in E, and the main gate is open all day, which means that the central heating and mechanical ventilation system does not work effectively. While it is known that the growth and distribution of indoor microfungi are associated with relative humidity and temperature, no significant relationship between microfungi and these parameters was determined. Goh et al. [43] reported that indoor temperature and humidity had no significant impact on concentrations of microfungi in libraries. These findings might be due not only to the efficient performance of the central heating & mechanical ventilation system but also to the location of the library building (e.g., local external temperature, humidity, rainfall and sunlight).

Dark colored-pigmented fungi (a non-identified group in this study), non-sporing fungi and yeast were detected in different sampling areas at high concentrations. The majority of airborne fungi in indoor environments originate from multiple outdoor origins such as vegetation, soil and air. Particularly, dark-colored fungi, with their resistance to a variety of environmental conditions (desiccation, ultraviolet radiation, and temperature changes) are the leading genus in outdoor air [2]. These fungi can survive and travel over long distances. Non-sporing fungi are any fungal colony that does not produce a reproductive structure. If the fungus has clamp connections, it is identified as *Basidiomycete*. However, it is known that many *Basidiomycete* fungi do not produce clamp connections. Most *Basidiomycetes* show limited growth in artificial media and often only form sterile mycelium. The presence of high concentrations of *Basidiomycetes* is relative to outdoor air microfungi [2,21]. Recent studies reported presence of yeasts, especially *Candida* and *Geotrichum* in air and settled dust samples. The members of these genera commonly exist in soil. Streams of air caused by wind and human movement can carry these microfungi and yeasts into libraries [36,44,45]. This means that outdoor air could be a main contributor to the biodiversity of indoor environments.

Cladosporium, *Alternaria*, *Penicillium* and *Aspergillus* are the most frequently detected microfungi in both outdoor and indoor air [16-18]. *Aspergillus* and *Penicillium* were also reported to be the most hazardous microfungal allergens indoors, whereas *Alternaria* and *Cladosporium* are known outdoor microfungal allergens [2,21]. In the present study, *Aspergillus* and *Penicillium* were the predominant genus. *Aspergillus flavus*, *A. amstelodami*, *A. fumigatus*, and *A. niger* were the most detected microfungi and *P. chrysogenum*, *P. citrinum* and *P. janthinellum* are common among *Penicillium* spp. (Table 4). *Aspergillus* and *Penicillium* are known to be potential allergens. The majority of respiratory opportunistic pathogenic microfungi belong to the phylum *Ascomycota*. Most *Aspergillus* infections are associated with *A. fumigatus*, *A. niger* and *A. flavus*. These microfungi grow well at 37°C. *A. flavus* has toxigenic and allergenic properties. It can be rather tolerant to low water activity and is therefore one of the most commonly detected microfungi in indoor air. It is the common aetiological agent of noninvasive aspergillosis, such as fungal sinusitis and cutaneous infections. It is also one of the main agents of pulmonary

aspergillosis [22,46,47]. *A. niger* is an agent of hypersensivity pneumonitis. *A. fumigatus* is the most prevalent airborne microfungal agent of invasive aspergillosis in immunocompetent hosts and is often found in indoor air. *A. amstelodami* is a xerotolerant species with a global proliferation, especially indoors, but there is no information about its harmful effects [22]. Although *Penicillium* citrinum and P. chrysogenum are known as opportunistic pathogens, they are rarely found to be frequent in respiratory tract infections. The other common genera members, such as *Alternaria* alternata, *Cladosporium cladosporioides*, *Chaetomium globosum*, and *Fusarium* spp. (Table 4) are also opportunistic in pulmonary and bronchial infections [2]. Any type of microfungal proliferation could cause several allergies and chemical irritation effects in immunocompetent people.

Chemical and physical methods are therefore suggested to prevent or reduce microbial contamination in libraries. However, many of these methods produce unwanted side-effects. Although the use of gamma radiation completely kills microfungi, it significantly damages the composition of books. Ethylene oxide, alcohols, formaldehyde, phenolic compounds, peroxides and heavy metals are commonly used in disinfection. The most effective chemical agent is ethylene oxide but it also has carcinogenic and mutagenic effects [48]. The use of silver nanoparticles is a new approach. A sensitivity to nanosilver has been shown, with different levels of sensitivity among species. Gutarowska et al. [49] reported that *Aspergillus*, *Penicillium* and *Rhizopus* are silver nanoparticle-resistant microfungi, while *Alternaria*, *Cladosporium* and *Mucor* are sensitive. Therefore, more studies are needed on the optimization of using silver nanoparticles and developing human-environmental friendly solutions.

The present study showed that occupants and visitors, especially those with immunosuppressives, might be at risk in terms of health problems related with presence of airborne microfungi in the environment. The results also contribute to the present data in this research area and underline the importance of taking precautions for and effective fight against airborne microbial load to improve the quality of actively used indoor environments.

ACKNOWLEDGEMENTS

This work was supported by the "Research Fund of İstanbul University" (project number 24935). I wish to thank Assoc. Prof. Volkan AKSOY for revising the English corrections.

References

1. R.B. Gammage, B.A. Berven, Indoor air and human health, CRC Press, Lewis Publisher, Boca Raton-Florida, USA, 1996.
2. B. Flannigan, R.A. Samson, J.D. Miller, Microorganisms in home and ındoor work environments. Diversity, health ımpacts, ınvestigation and control, CRC Press, Taylor and Francis Group, New York, USA, 2011.
3. J. Singh, Toxic moulds and indoor air quality, Indoor Built. Environ., 14 (2005) 229–234.
4. S. Tasic, N. Miladinovic Tasic, *Cladosporium spp*. cause of opportunistic mycoses, Acta. Fac. Med. Naiss., 24 (2007) 15–19.
5. H. Gül, H. Issever, Ö. Ayraz, G. Güngör, Occupational and environmental risk factors for the sick building syndrome in modern offices in İstanbul: A cross sectional study, Indoor Built. Environ., 16 (2007) 47-54.
6. B. Kolomodin-Hedman, G. Blomquist, E. Sikstrom, Mould exposure in museum personnel, Int. Arch. Occ. Env. Hea., 57 (1986) 321-323.
7. A.M. Krake, K.A.Worthington, K.M. Wallingford, K.F. Martinez, Evaluation of microbiological contamination in a museum, Appl. Occup. Environ. Hyg., 14 (1999) 499-509.
8. L.X. Ito, M.L. Aguiar, Indoor air quality of libraries in Sao paulo, Brazil, Indoor Built. Environ., 16 (2007) 190-193.
9. D.P.L. Junior, A.C.A. Yamamoto, J.V. Ribeiro de Souza Amadio, E.R. Martins, F.A. Leal do Santos, S. de Almeida Alves Simoes, R.C. Hahn, Trichocomaceae: biodiversity of *Aspergillus spp* and *Penicillium* spp residing in libraries, J. Infect. Dev. Ctries., 6 (2012) 734-743.
10. M. Stryjakowska-Sekulska, A. Piotraszewska-Pajak, A. Szyszka, M. Nowicki, M. Filipiak, Microbiological quality of indoor air in university rooms, Pol. J. Environ. Stud., 16 (2007) 623-32.
11. L. Ruga, T. Bonofiglio, F. Orlandi, B. Romano, M. Fornaciari, analysis of the potential fungal biodeteriogen effects in the "Doctorate Library" of the university of Perugia, Italy. Grana., 47 (2008) 60-69.
12. S. Borrego, P. Guiamet Gómez de Saravia, P. Batistini, M. Garcia, P. Lavin, I. Perdomo, The quality of air at archives and the biodeterioration of photographs, Int. Biodeter. Biodegr., 64(2010) 139-145.

13. L. Dalal, M. Bhowal, S. Kalbende, Incidence of deteriorating fungi in the air inside the college libraries of Wardha city, Arch. Appl. Sci. Res., 3 (2011) 479-485.
14. S.F. Hayleeyesus, A.M. Manaye, Microbiological quality of indoor air in university libraries, Asian Pac. J. Trop. Biomed., 4 (2014) 312-317.
15. V.K. Özkan, Microfungal contaminants on the surface of the books and the atmosphere of the library of health services vocational school in Marmaris, Turkey. IJMM., 2 (2014) 1-5.
16. H. Aydogdu, A. Asan, Airborne fungi in child day care centers in Edirne City, Turkey, Environ. Monit. Assess., 147 (2008) 423-444.
17. B. Sen, A. Asan, Fungal flora in indoor and outdoor air of diffrent residential houses in Tekirdag city (Turkey): Seasonal distribution and relationship with climatic factors, Environ. Monit. Assess., 151 (2009) 209-219.
18. A. Haliki-Uztan, M. Ateş, Ö. Abacı, O. Gülbahar, N. Erdem, Ö. Çiftçi, H. Boyacioğlu, Determination of potential allergenic fungal flora and its clinical reflection in suburban elementary schools in Izmir, Environ. Monit. Assess., 168 (2010) 691-702.
19. S. Okten, A. Asan, Airborne fungi and bacteria in indoor and outdoor environment of the pediatric unit of Edirne government hospital, Environ. Monit. Asssess., 184 (2012) 1739–1751.
20. R.L. Gorny, J. Dutkiewicz, E. Krysinska-Traczyk, Size distribution of bacterial and fungal bioaerosols in indoor air, Ann. Agr. Env. Med., 6 (1999) 105-113.
21. C.S. Yang, P.A. Heinson, Sampling and analysis of indoor microorganisms. John Wiley and Sons Inc. Hoboken, New Jersey, USA, 2007.
22. R.A. Samson, J. Houbraken, U. Thrane, J.C. Frisvad, B. Andersen, Food and indoor fungi, CBS Laboratory Manuel Series, CBS-KNAW Fungal Biodiversity Centre Utrecht, Netherlands, 2010.
23. M.B. Ellis, Dematiaceous Hyphomycetes, The Eastern Press, London, UK, 1971.
24. H.L. Barnett, B.B. Hunter, Illustrated genera of imperfect fungi, APS Press, St. Paul-Minnesota, USA, 1999.
25. J.I. Pitt, A laboratory guide to common *Penicillium* species, Food Science Australia, North Ryde- New South Wales, Australia, 2010.
26. M.A. Klich, Identification of common *Aspergillus sp*ecies, Centraalbureau voor Schimmelcultures, Utrecht, Netherlands, 2002.
27. A.D. Sime, L.L. Abbott, S.P. Abbott, Mounting medium for use in indoor air quality spore-trap analyses, Mycologia., 94 (2002) 1087–1088.
28. Index fungorum web site: http://www.indexfungorum.org/names/names.asp
29. D.L. Hawksworth, P.W. Crous, S.A. Redhead et. al., The Amsterdam declaration on fungal nomenclature, IMA Fungus., 2 (2011) 105–112.
30. Commission of the European Communities (CEC) European collaborative action indoor air quality and its impact on man, Environment and quality of life report no. 12 biological particles in indoor environments. Brussels: Commission of the European Communities Directorate-General XIII Information. Technologies and Industries, and Telecommunications, 1993.
31. K.L. Southwell, The use of chlorine dioxide as a mold treatment and its effect on paper acidity: A case study, J. Acad. Libr., 28 (2002) 400–405.
32. A. Michaelsen, F. Pinzarib, K. Ripkaa, W. Lubitza, G. Pinar, Application of molecular techniques for identification of fungal communities colonising paper material, Int Biodeter. Biodegr., 58 (2006) 133-141.
33. K. Sterflinger, Fungi: Their role in deterioration of cultural heritage, Fungal. Biol. Rev., 24 (2010) 47–55.
34. S.A.F. El-Nagerabi, A.E. Elshafie, U.A. Al-Hinai, The mycobiota associated with paper archives and their potential control, Nusantara. Bioscience., 6 (2014) 19-25.
35. Korean Ministry Environment: Act of Indoor Air Quality Management: The sustainable limit of airborne bacteria; Seoul, Korea, 2004.
36. J. Karbowska-Berent, R. Gorny, A.B. Strzelczyk, A. Wlazlo, Airborne and dust borne microorganisms in selected Polish libraries and archives, Build. Environ., 46 (2011) 1872-1879.
37. K. Zielinska-Jankiewicz, A. Kozajda, M. Piotrowska, I. Szadkowska-Stanczyk, Microbiological contamination with moulds in work environment in libraries and archive storage facilities, Ann. Agr. Env. Med., 15 (2008) 71–78.
38. A. Kalwasinska, A. Burkowska, I. Wilk, Microbial air contamination in indoor environment of a university library, Ann. Agr. Env. Med., 19 (2012) 25-29.
39. K.Y. Kim, J.B. Park, G.Y. Jang, C.N. Kim, K.J. Lee, Assessment of bioaerosols in the public buildings of Korea, Indoor Built. Environ., 16 (2007) 465-471.
40. M.S. Rakotonirainy, C. Heraud, B. Lavedrine, Detection of viable fungal spores contaminant on documents and rapid control of the effectiveness of an ethylene oxide disinfection using ATP assay, Luminescence, 18 (2003) 113–121.
41. M.C. Chi, C.S. Li, Fluorochrome in monitoring atmospheric bioaerosols and correlations with meteorological factors and air pollutants, Aerosol. Sci. Tech., 41 (2007) 672–678.
42. L. Weaver, H.T. Michels, C.W. Keevil, Potential for preventing spread of fungi in air-conditioning systems constructed using copper instead of aluminium, Lett. Appl. Microbiol., 50 (2010)18–23.
43. I. Goh, P.J. Obbard, V. Iswanathsan, H. Uangy, Airborne bacteria and fungal spores in the ındoor environment: A case study in Singapore, Acta. Biotechnol., 20 (2000) 67-73.
44. A. Harkawy, R.L. Gorny, L. Ogierman, A. Wlazło, A. Kawniczek-Wałczyk, A. Niesler, Bioaerosol assessment in naturally ventilated historical library building with restricted personnel, Ann. Agr. Env. Med., 18 (2011) 323-329.
45. A. Botha, The importance and ecology of yeasts in soil, Soil. Biol. Biochem., 43 (2011) 1-8.
46. M. Kameswaran, A. Al-Wadei, P. Khurana, Rhinocerebral aspergillosis, J. Laryngol. Otol., 106 (1992) 981-985.
47. A.C. Pasqualo, Differences in pathogenicity and clinical syndromes due to *Aspergillus fumigatus* and *Aspergillus flavus*, Med. Mycol., 47(2009) 261-270.
48. K. Sterflinger, Fungi: Their role in deterioration of cultural heritage, Fungal. Biol. Rev., 24 (2010) 47–55.
49. B. Gutarowska, J. Skora, K. Zduniak, D. Rembisz, Analysis of the sensitivity of microorganisms contaminating museums and archives to silver nanoparticles, Int. Biodeter. Biodegr., 68 (2012) 7-17.