



Proposal for monitoring approach and control of air mycobiota in the Grand Egyptian Museum—Conservation Center

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Abstract Cultural property preserved in indoor environments is subjected to fungal deterioration which resulted from air biocontamination and can lead to a heavy cultural loss. This study aimed to monitor and assess the biodiversity and concentration of airborne fungi for all areas of the Grand Egyptian Museum—Conservation Center (GEM-CC), such as conservation laboratories, scientific laboratories, corridors, storerooms, and outside in each season during 2013 using the air sampler machine. Results of the quantitative analysis of fungal aerosol demonstrated that the air quality level in GEM-CC was generally acceptable, though some areas showed deviation from the threshold limit value of the GEM-CC (200 CFU m⁻³). Also, the fungal load in all storerooms was lower than inside the laboratories.

Quantitative analysis revealed that 22 fungal species were isolated and identified. The genus *Penicillium* appeared with high relative distribution (42.6%), followed by *Cladosporium* and *Aspergillus*. In vitro study revealed the effectiveness of ethanol with 70% concentration, against the most common airborne fungus: *Aspergillus flavus*. However, the concentration rose to 95% when applying in vivo. Finally, we suppose that weekly spraying the GEM-CC environment with 95% ethanol is a protective measure for both our valuable artifacts and staff health.

Keywords Mycobiota · Air quality · Indoor environment · Biodeterioration · Threshold limit value

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1 Introduction

In cultural-heritage-related indoor environments, microbes inhabiting air (bioaerosols) represent a hazard for both cultural property and human beings, such as staff and visitors. The hazard caused for cultural property which is known as biodeterioration is considered one of the major threats. It can make complete damage to the artifact objects over extended periods, especially when environmental conditions favor their growth, where the nutrient in the artifacts with sufficient moisture could provide the conditions that allow microorganisms to grow and proliferate (Strzelczyk 2004). Bioaerosols play vital roles; First,

they have a role in atmospheric chemistry and physics by modifying the chemistry of the atmosphere through microbiological degradation, altering the chemical composition of other organic compounds upon collision as described by Ariya and Amyot (2004). Second, they have a role in the earth system, especially in the atmospheric, climate, biosphere, and public health interactions. Third, they may act as nuclei for cloud droplets, ice crystals, and precipitation, thereby impacting the hydrological cycle and climate (Fröhlich-Nowoisky et al. 2016). Fourth, they have hygroscopic features as they can absorb water at sub-saturated conditions (Lin et al. 2015; Tang et al. 2019).

The hazard caused for human beings due to the exposure to fungal bioaerosol (mycobiota) in museum environment may cause serious respiratory infections in immunocompromised people and can cause bronchial irritation and allergy (allergic sinusitis, allergic rhinitis, allergic asthma, bronchopulmonary mycoses, and hypersensitivity pneumonitis) (Khan and Karuppayil 2012). Additionally, Tang et al. (2019) confirmed that 31% of staff working at the National Museum in Warsaw suffers from fungal allergy, and in general, 10% of people worldwide have a fungal allergy (Pasanen et al. 1996; Bush and Portnoy 2001). *Aspergillus flavus*, *A. parasiticus*, *A. versicolor*, *Penicillium chrysogenum*, *P. expansum*, and *Stachybotrys chartarum* often isolated from museums, libraries, and archive facilities produced mycotoxins which have harmful effects (Halstensen 2008; Eduard 2009). The mycotoxins and microbial volatile organic compounds may constitute etiological factors in sick building syndrome (Korpi et al. 2009).

The basis for a proper conservation strategy is the monitoring of biopollutants, both on artifact surfaces and in the surrounding air for gathering information to identify specific hazard, which therefore leads to a prompt intervention providing conservative action (Di Carlo et al. 2016). Many researches on the monitoring of the indoor–outdoor air pollution in cultural heritage environments as museums, libraries, and archives such as the Correr Museum, Venice (Italy), Kunsthistorisches Museum, Vienna (Austria), Royal Museum of Fine Arts, Antwerp (Belgium), Sainsbury Centre for Visual Arts, Norwich, Museum of La Plata, Argentina, National Library of Greece, and others have been studied (Baer and Banks 1985; Brimblecombe 1990;

Camuffo et al. 2001; Gysels et al. 2002; Harkawy et al. 2011; Pasquarella et al. 2012; Ljaljević Grbić et al. 2013; Di Carlo et al. 2016; Nitiu et al. 2019; Pyrri et al. 2020). In this work, we monitor the fungal load indoor and outdoor Grand Egyptian Museum—Conservation Center (GEM-CC) and fungal load on the surface of some selected preserved archeological artifacts and, finally, study the possible use of alcohol as a preventive measure.

2 Materials and methods

2.1 Sampling strategies

2.1.1 Air mycobiota

In all GEM-CC areas, mainly 7 conservation laboratories, 6 scientific laboratories, 3 corridors, 10 store-rooms, and outdoor, active air sampling was conducted in each season during 2013. For active sampling, a portable SAS Super IAQ sampler with a flow rate of 100 L min⁻¹ is used. The sampler is positioned in the monitored room 1–1.5 m above the floor and about 1 m away from any physical obstacle. The sampling began at 11 am and lasted approximately 2 h. A 9-cm-diameter Petri dish with potato dextrose agar (PDA) as a nutrient medium was exposed for 1 min in each site and then incubated at 28 °C for 7 days. Isolated fungi were identified on Czapek's agar, malt extract agar, and PDA media with chloramphenicol as an antibacterial agent. The fungi were identified using identification keys (Raper and Thom 1968; Raper and Funnell 1977; Ellis 1971; Domsch et al. 2007).

Relative fungal distribution was measured according to Smith (1980), i.e., the number of colonies of genera or species/total colonies of all genera or species $\times 100$. The growing fungi were qualitatively and quantitatively analyzed. The fungal concentration in air was expressed as colony-forming units per cubic meter of air (CFU m⁻³). The environmental conditions of the GEM-CC, temperature (T) and relative humidity (RH), were recorded during sampling with a data logger (HOBO U12-012).

2.1.2 Surface sampling of archeological objects

Four archeological objects were chosen for this study: two canopy jars made of limestone at the stone laboratory, a book of death made of papyrus at the organic laboratory, and a food box made of wood at the wood laboratory (Table 1). Sampling was performed from 2 cm² of each object with a sterile cotton swab using different kinds of isolation media: PDA, modified Czapek's agar (by replacing carbon source with one of powdered limestone, papyrus, or wood), and malt extract agar. The concentration of fungi colonizing archeological objects was expressed as the colony-forming unit per m² (CFU m⁻²).

2.2 In vitro antifungal activity of ethanol

It was made using the inverted Petri dish technique as described by Pandey et al. (1982). Different concentrations of ethanol (from 50 to 95%) were tested against the most common fungal species in the air. The antifungal activity is reported as the inhibition ratio (IR) and calculated in accordance with the equation set by Ikeura and Kobayashi (2015).

$$IR (\%) = \left[\frac{\text{diameter of inhibition circle (mm)}}{\text{diameter of plate (100 mm)}} \right] \times 100$$

2.3 In vivo antifungal activity of ethanol

Microbiology laboratory (about 150 m³) was a case study for in vivo treatment. It was made by spraying the microbiology laboratory with 200 ml of different ethanol concentrations (65–95%). The percentage of fungal reduction (R) was determined according to the following equation where A and B are the number of CFU m⁻³ after and before treatment, respectively.

$$R(\%) = \frac{B - A}{B} \times 100$$

2.4 Duration of effectiveness of ethanol in certain area

After treatment (95% ethanol) of the microbiology laboratory environment, air sampling was carried out daily for 14 consecutive days. The duration of ethanol efficacy was determined by daily measuring of fungal concentration.

3 Results and discussions

3.1 Air mycobiota investigation for GEM-CC

Qualitative analysis revealed that twenty-two fungal species belonging to fourteen genera were isolated from air indoor and outdoor GEM-CC as presented in

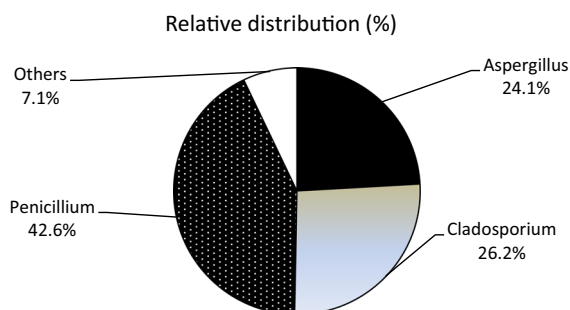
Table 1 Analyzed archeological objects

Code no.	Object name	Object photograph	Material analyzed	GEM no.	Location
1	Canopy jar		Limestone	4938	Stone laboratory
2	Canopy jar		Limestone	4845	Stone laboratory
3	Book of the death from Saqqara excavation		Papyrus	21553	Organic laboratory
4	Food box		Wood	4901	Wood laboratory

Table 2 Viable fungal species isolated from indoor air of GEM-CC and their frequencies

No.	Isolated fungi	Frequency (%)
1.	<i>Acremonium</i> spp.	25
2.	<i>Alternaria</i> spp.	100
3.	<i>Aspergillus calidoustus</i>	50
4.	<i>A. fumigatus</i>	75
5.	<i>A. flavus</i>	100
6.	<i>A. glaucus</i>	25
7.	<i>A. niger</i>	100
8.	<i>A. ochraceus</i>	100
9.	<i>A. sydowii</i>	25
10.	<i>A. versicolor</i>	75
11.	<i>Aspergillus</i> spp.	25
12.	<i>Emicella nidulans</i>	25
13.	<i>Engyodontium album</i>	25
14.	<i>Eurotium glaucus</i>	50
15.	<i>Chaetomium globosum</i>	25
16.	<i>Chrysonilia sitophila</i>	25
17.	<i>Cladosporium</i> spp.	100
18.	<i>Penicillium</i> spp.	100
19.	<i>Petromyces flavus</i>	25
20.	<i>Rhizopus</i> spp.	100
21.	<i>Trichoderma viride</i>	50
22.	<i>Ulocladium</i> spp.	50

Table 2. The genus *Penicillium* appeared with high relative distribution (42.6%), followed by *Cladosporium* (26.2), and *Aspergillus* (24.1) (Fig. 1). Both *Penicillium* and *Cladosporium* genera were isolated from all examined areas (Table 3). Di Carlo et al. (2016) confirmed the presence of *Aspergillus* spp.,

**Fig. 1** Relative distribution of fungal genera isolated from indoor GEM-CC

Alternaria spp., and *Penicillium* spp. in both Diocesan Historic Archive and Saint Cave environments, while *Cladosporium* genus was revealed in the Sibilla Antrum environment. In the indoor air of the National Library of Greece, the genera *Cladosporium*, *Penicillium*, and *Aspergillus* were common, with *Penicillium* exceeding only in the book storage area as mentioned by Pyrri et al. (2020). Fungi are usually considered as biodeterioration agents in different habitats and materials, including those considered as a representative of historical and cultural heritage (Abrusci et al. 2005).

A. flavus was isolated from 19 out of 27 examined area in the GEM-CC with percent 70.3%, while *Acremonium* sp., *Chaetomium globosum*, *Chrysonilia sitophila*, *Petromyces flavus*, and *Trichoderma viride* rarely appeared as they were isolated from only one area in one season during 2013 (Table 3). *A. flavus* was dominant in the air of the mummy chamber at Baroda museum, while *A. versicolor* was predominant in the air of the storerooms at the Auschwitz-Birkenau Museum as reported by Arya et al. (2001) and Niesler et al. (2010).

Result of the quantitative analysis of fungal aerosol (mycobiota) demonstrated that the fungal quality level in GEM-CC was generally appreciable and acceptable, though it had some deviation. The average fungal concentrations range from 133 to 232 CFU m⁻³ during all seasons of 2013. The fungal concentration of air in the quarantine room of the Cultural Center of Belgrade estimated as 210.09 ± 8.06 CFU m⁻³ by Ljaljević Grbić et al. (2013), while the annual indoors fungal concentration in the National Library of Greece was 180 to 410 CFU m⁻³ (Pyrri et al. 2020). In the air outside the GEM-CC, low fungal load (140 CFU m⁻³) was detected in the winter, while the highest fungal load (1245 CFU m⁻³) was detected in the autumn as shown in Fig. 2. Gysels et al. (2004) reported that in the winter fungal spores in the air are less abundant than others. In case of indoor air of GEM-CC, the situation differed completely from the outside, because the environment of GEM-CC is controlled with a well-operating HVAC system where the temperature ranged between 19 and 26 °C and the relative humidity ranged between 50 and 60%. Airborne fungal concentrations in the Jasna Gora monastery library room ranged from 14 to 63 CFU m⁻³ and from 219 to 353 CFU m⁻³ for the indoor and outdoor air, respectively (Harkawy et al. 2011).

Table 3 Appearance of each fungal isolate in each area of the GEM-CC during the four seasons of 2013

Examined areas		Fungal species																					
		Ac	Al	Acl	Afu	Af	Ag	An	Ao	As	Av	Asp	Em	Ea	Eg	Chg	Chs	Cl	Pe	Pf	Rz	Tv	Ul
1	LARA	–	2	–	–	2	–	2	2	–	1	–	–	–	–	–	1	4	4	–	2	–	–
2	SL	–	2	–	–	1	–	1	–	–	–	–	–	–	–	–	–	3	4	–	–	–	–
3	WL	–	1	–	–	1	–	1	–	–	–	–	–	–	–	–	–	1	1	–	1	–	–
4	ML	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	3	2	–	1	–	–
5	OL	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–	–	–
6	FA	–	2	–	1	3	–	2	–	–	–	2	–	–	–	–	–	4	2	–	1	1	2
7	HR	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–	1	–
8	FL	–	–	–	–	1	–	2	–	1	–	–	–	–	–	–	–	3	1	–	–	–	–
9	XL	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2	–	1	–	–
10	ML	–	–	–	2	2	–	1	–	–	–	–	–	–	–	–	–	1	2	–	–	–	–
11	SL	–	1	–	1	2	–	2	–	–	–	–	–	–	–	–	–	2	3	–	1	–	–
12	TL	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	1	2	–	–	–	–
13	AL	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	2	1	–	–	–	–
14	S 91	–	1	–	–	3	–	1	1	–	–	–	1	–	–	–	–	4	4	1	–	–	–
15	S92	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	4	4	–	–	–	–
16	S93	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	2	–	–	–	–
17	S94	–	–	1	2	2	–	1	–	–	–	–	1	–	1	–	–	2	2	–	–	–	–
18	S95	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	1	2	–	–	–	–
19	S96	–	–	–	–	1	–	2	–	–	–	–	–	–	–	–	–	1	3	–	–	–	–
20	S97	–	–	–	1	1	–	–	–	1	–	–	–	1	–	–	–	1	2	–	–	–	–
21	S98	–	–	–	1	–	–	1	1	–	1	–	–	–	–	–	–	2	2	–	–	–	–
22	S99	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–
23	S100	–	–	–	–	–	–	–	–	–	1	1	–	–	–	1	–	2	2	–	–	–	–
24	C1	–	2	–	–	2	2	2	2	–	2	1	–	–	1	–	–	4	4	–	3	–	1
25	C2	–	–	1	1	2	–	2	1	1	1	–	–	–	2	–	–	3	3	–	–	–	–
26	C3	–	–	–	–	1	–	1	–	–	–	1	–	–	–	–	–	2	2	–	–	–	–
27	OT	–	2	–	–	3	–	3	4	–	–	–	–	–	–	–	–	4	4	–	1	–	1

Isolated fungi (Ac., *Acremonium* sp.; Al., *Alternaria* sp.; Acl., *Aspergillus calidoustus*; A.fu., *Aspergillus fumigatus*; A.f. *A. flavus*; Ag, *A. glaucus*; An, *A. niger*; Ao, *A. ochraceus*; As, *A. sydowii*; Av, *A. versicolor*; Asp, *Aspergillus* spp.; Em, *Emericella nidulans*; Ea, *Engyodontium album*; Eg, *Eurotium glaucus*; Chg, *Chaetomium globosum*; Chs, *Chrysosporium sitophila*; Cl, *Cladosporium* spp.; Pe, *Penicillium* spp.; Pf, *Petromyces flavus*; Rz, *Rhizopus* spp.; Tv, *Trichoderma viride*; Ul, *Ulocladium* spp.). **Isolation sites** LARA large artifact receiving area, SL stone laboratory, WL wood laboratory, ML metal laboratory, FA fumigation area, HR human remains laboratory, FL Fourier transform infrared spectroscopy laboratory, XL X-ray diffraction laboratory, ML microbiology laboratory, SL scan electron microscope laboratory, TL transmission electron microscope laboratory, mechanical properties laboratory, S91 storage 91; S92, storage 92; S93, storage 93; S94, storage 94; S95, storage 95; S96, storage 96; S97, storage 97; S98, storage 98; S99, storage 99; S100, storage 100; C1 main corridor, C2 storages corridor, C3 scientific laboratories corridor, OT outdoor

The fungal concentration in all storerooms was detected to be lower than that of other indoor areas in GEM-CC. This could be attributed to low human activities in storerooms comparing with other areas and well-operating HVAC system, as shown in Fig. 3. This result corresponds with that of the researches by

Niesler et al. (2010) and Di Carlo et al. (2016), where they reported that a correctly operated air-conditioning system and limiting the number of visitors in the storerooms of the Auschwitz-Birkenau Museum and Sibilla Antrum environment can inhibit microbial contamination of air.

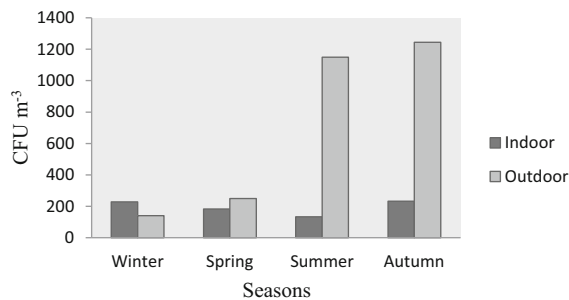


Fig. 2 Average fungal concentration (CFU m⁻³) for each season during 2013 in indoor and outdoor GEM-CC

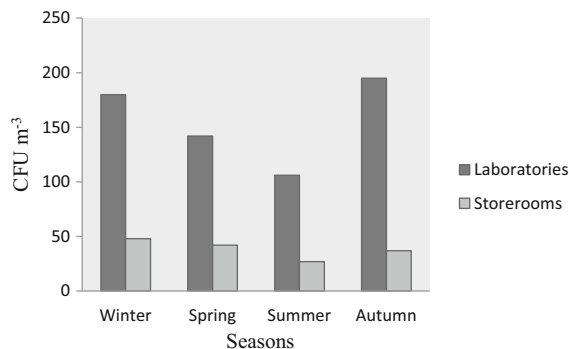


Fig. 3 Average fungal concentration (CFU m⁻³) in air of conservation and scientific laboratories and storerooms of GEM-CC

Regarding museums or libraries, no international standards on the threshold limit value (TLV) of risk, only national recommendations are available (Capitelli et al. 2010). The TLV for mycobiota in the GEM-CC has set at 200 CFU m⁻³. This TLV was established according to the result of the seasonal air sampling examination during 2011 and 2012 (data not published). Our TLV is the same as that for the selected Polish libraries or archives (Karbowska-Berent et al. 2011) and higher than that was set by the Italian Ministry of Cultural Heritage (MIBAC) (150 CFU m⁻³) as mentioned by Micheluz et al. (2015). However, Cieplik (1997) allowed a concentration of 500 CFU m⁻³ if the fungi belong to typical microbial genera present in the atmospheric air, such as *Cladosporium* and *Alternaria*. According to a report by the World Health Organization (WHO 2009), the fungal density in an indoor environment should be lower than 500 CFU m⁻³. Despite our TLV is below WHO recommendations, this value should not be neglected. For two reasons; first due to fungal ability

to cause the biodeterioration of archeological collections housing conservation laboratories and storerooms; besides their negative impact on human health even with low concentration, especially for immunocompromised people, for example, Tang et al. (2019) identified fungal allergy in 31% of staff working at the National Museum in Warsaw.

Some areas in GEM-CC exhibited deviation from the established TLV (Table 4) and considered as a signal for the presence of moisture or temperature problem or the presence of internal microbial sources. Large artifact receiving area (LARA) has been daily opened widely to outside, where temperature and relative humidity have been uncontrolled, and numbers of human activities by the workers and trainers have been observed so this area was considered to exhibit high fungal concentration in two seasons: summer and autumn. If the microclimate parameters are not stable, biological particles can be increased (Grau-Bové and Strlič 2013; Lazardis et al. 2015). Carrying fungus-affected artifacts into GEM-CC from outside without microbial examination and sterilization will supposedly lead to a higher fungal load; as observed in the wood laboratory where the fungal load reached 1205 CFU m⁻³, it will be discussed in the following section. Movement of workers and visitors and their activities could also lead to an increase in the fungal load in the indoor air, as the case of the laboratory corridor. Microorganisms could be introduced to museums through transport by the workers and visitors through their bodies, clothes, and carried items or with outdoor air through natural gates such as windows and doors. Incorrectly operating the HVAC system could also be a source of increasing biological particles (Ljaljević Grbić et al. 2008; Niesler et al. 2010).

3.2 Surface sampling of archeological objects

Penicillium is the genus commonly isolated from the surface of the analyzed archeological objects and their ambient environment. As presented in Table 5, there is a significant linear relationship between fungal concentration on artworks and concentration of the air mycobiota in the environment, they are in. The obtained result corresponded with that obtained by Saiz-Jimenez and Gonzalez (2007) as they concluded that the surface contamination is closely related to the existence and concentration of microbes in the aerosol.

Table 4 Areas of GEM-CC showed deviation from TLV during 2013

Season	LARA* (CFU m ⁻³)	Wood laboratory (CFU m ⁻³)	Corridor of laboratories (CFU m ⁻³)
Fungal concentration in areas			
Winter	–	–	–
Spring	–	1205	–
Summer	930	–	325
Autumn	736	–	452

*LARA large artifact receiving area

Table 5 Fungal species isolated from different archeological objects and their concentrations

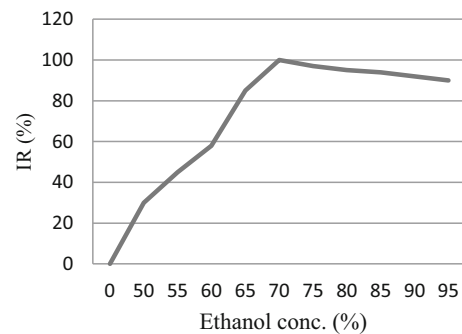
Object code	Surface fungal concentration				Fungal aerosol concentration	
	Fungal species	Concentration (CFU m ⁻²)	T(°C)	RH(%)	Fungal species	Concentration (CFU m ⁻³)
1	<i>Aspergillus flavus</i> <i>A. candidus</i> <i>Chaetomium</i> sp.	3	21	55	<i>Aspergillus flavus</i> <i>Penicillium</i> spp.	25
2	<i>Aspergillus niger</i> <i>A. ochraceus</i> <i>Penicillium</i> sp.	21	21	55	<i>Penicillium</i> sp.	90
3	–ve*	0	20.5	48.5	<i>Penicillium</i> sp.	15
4	<i>Penicillium</i> sp.	100	21.3	51.2	<i>Penicillium</i> sp. <i>Rhizopus</i> sp.	1205

* – ve means there is not any surface fungal contamination

Moreover, in the Diocesan Historic Archive, *Aspergillus* spp., *Alternaria* spp., and *Penicillium* spp. found in the aerosol were confirmed on paper documents as described by Di Carlo et al. (2016). The heavy fungal load colonizes the wooden food box (Table 4) was supposed to result from the previously uncontrolled environment (Egyptian museum in Tahrir, Cairo) that it had been belonged to before coming to GEM-CC and subsequently result in increasing the fungal concentration in the wood laboratory environment after its entrance (1205 CFU m⁻³).

3.3 In vitro antifungal activity of ethanol

Since ethanol is the most commonly used alcohol for treating mold-contaminated heritage objects (Kigawa et al. 2010; Sequeira et al. 2016; Karbowska-Berent et al. 2017), we used it in different concentrations against *Aspergillus flavus* for in vitro treatment (Fig. 4). *A. flavus* was the predominant fungal species isolated from 70.3% of the examined areas and it was isolated from different archeological artifacts in

**Fig. 4** In vitro antifungal activity of ethanol against *Aspergillus flavus*

GEM-CC such as papyrus and linen (Othman et al. 2020). It was cleared that 70% ethanol (v/v: water) can inhibit the growth of the tested fungus. Several researches confirmed that the greatest efficacy of ethanol reached at 60–70% against many fungal species as *Aspergillus flavus*, *A. niger*, *Cladosporium cladosporioides*, *Chaetomium globosum*, *Penicillium chrysogenum*, and *Trichoderma viride* (Nitiu et al.

Table 6 In vivo antifungal activity of ethanol and its duration of effectiveness

In vivo antifungal activity		Duration of effectiveness	
Ethanol concentration (%)	R (%)	Time (Days)	Fungal concentration (CFU m ⁻³)
65	55	1–7	0
70	70	8	10
75	80	9	30
80	85	10	30
85	90	11	55
90	96	12	62
95	100	13	80
		14	108

2019; Block 2001; Meier 2006; Fraise et al. 2013; Sequeira et al. 2016). Ethanol acts through coagulation/denaturation of proteins and membrane damage, which interferes with the metabolism and leads to cell lysis (Lin et al. 2015; Block 2001).

3.4 In vivo antifungal activity of ethanol

In vivo treatment to decontaminate the GEM-CC environment using the microbiology laboratory of 150 m³ as a case study revealed the effectiveness of ethanol (200 ml) in concentration 95% (Table 6). Ethanol is frequently used as a fungicide for the storage room in museums as mentioned by Kigawa et al. (2010).

3.5 Duration of effectiveness of ethanol in treating the area

The result of fungal concentration in the microbiology laboratory environment for fourteen days after treatment with 95% ethanol (Table 6) indicated that ethanol could keep the environment clean for 7 days after which re-appearing of fungi was observed. The re-growth of the fungi occurs within 14 days after the ethanol treatment as reported by Nitiu et al. (2019). We suppose that a weekly treatment of GEM-CC areas with 95% ethanol can be used as a preventive measure.

4 Conclusion

This study revealed that almost suitable air quality in its fungal environment has been obtained owing to a well-operated air-conditioning system and a few

visitors to GEM-CC. However, in some areas, due to the reasons, risks were observed to a limited extent, so, it is advisable to periodically control GEM-CC environment areas by weekly spraying with 95% ethanol as a preventive measure to protect the health of staff in GEM-CC and our cultural collections.

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