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THE A-BIOS SYSTEM FOR AIR PURIFICATION FROM BIOLOGICAL CONTAMINANTS IN THE INDOOR ENVIRONMENTS

Corrado Fanelli[1]*, Flavia Pinzari[2], Paola Valenti[2], Piero Colaizzi[2], Slaven Zjalic[1], Massimo Reverberi[1]

1. Dipartimento di biologia Vegetale, Università di Roma "La Sapienza", Largo Cristina di Svezia 24, 00165 Rome, Italy

2. Istituto Centrale per la Conservazione ed il Restauro del Patrimonio Archivistico e Librario, Ministero per i Beni e le Attività Culturali, Via Milano, 76, 00184 Rome, Italy

corresponding author:
corrado.fanelli@uniroma1.it

A new easy-to-use air purification system called "A-Bios", based on UVC radiation with the addition of special graphite filters to eliminate traces of ozone, to be used in the indoor environment has been developed in the framework of the EC financed project "An innovative technology, based on UV radiation, to strongly reduce the microbial activity of the air inside the store rooms of the cultural heritage conservation institutes". The objectives of the research presented in this paper were to evaluate the relative efficiency of the A-Bios air purification system in the abatement of airborne fungal spores' vitality and to determine the effect of time exposure to A-Bios on the fungal colony forming units (CFU) recovery. Aerobiological monitoring was conducted in the "David Lubin memorial library" of the Food and Agriculture Organization (FAO) in Rome before and after operation of the A-Bios system. The results obtained in this research indicate that the difference between fungal airborne concentration data before and after A-Bios treatment is statistically significant, and independent both on the agar type used for spores collection, the sampled air volume and the sampling heights. The A-Bios device appeared to be a promising tool to lower and to maintain low the risk of microbial contamination in closed spaces, like libraries and other exposing spaces for cultural heritage.

1   Introduction

Most of the fungal species that are commonly associated with biodeterioration phenomena in objects of cultural heritage stored in closed environments are present as spores in the air, both indoors and outdoors.[1] The input of spores in indoor air from outside is usually correlated with weather conditions, such as wind speed, precipitation and daily temperature variations, that have a role in defining the mechanisms through which spores and propagules are dispersed in the natural environments.[2,3] Moreover, normal indoor conditions provide a suitable environment for the growth of a wide range of fungal

spores. The presence of moisture or high relative humidity is a sufficient catalyst for the germination and growth of fungal spores. Some of these fungi can cause allergic or toxic reactions, while a few may cause infections in susceptible individuals. The number of different fungal and bacterial species that can be found in the indoor environment is variable, depending on the sampling methods and on the peculiarities of the examined environments. Besides the small number of comparable studies on this topic, there is agreement on the need for systems that can limit the settlement of microbial and fungal spores on cultural heritage stored in closed environments. A new, easy-to-use air purification system, based on UVC radiation with the addition of special graphite filters to eliminate traces of ozone, for the indoor environment has been developed in the framework of the EC financed project *"An innovative technology, based on UV radiation, to strongly reduce the microbial activity of the air inside the store rooms of the cultural heritage conservation institutes"* (FP6-SME-032192, www.abios.eu). The A-Bios device was thought as a system that can control the biological air contamination in the indoor environment. The objectives of the research presented in this paper were to evaluate the relative efficiency of the A-Bios air purification system in the abatement of indoor airborne fungal spores' vitality and to determine the effect of exposure time to A-Bios on their viability.

2 Materials and Methods

2.1 A-Bios device and sampling

The A-Bios device is based on UVC technology (253.7 nm) with special graphite filters based on manganese dioxide to eliminate traces of ozone (Figures 1, 2). Air samples were collected with a SAS (Surface Air System Super 180TM, PBI International) under undisturbed conditions before, and after 3 and 6 h of continuous A-Bios treatment in the room.[4] Human activity, which could result in the release of significantly higher concentrations of airborne spores, was avoided both before and during A-Bios operation.[5] The considered room located in the David Lubin Memorial library of FAO in Rome was of 320 m^3. This room was cooled by an air-conditioning system to 23 °C without the control of RH. Sampling was performed using two different substrates in the SAS plates and two air-sampling volumes (60 and 100 dm^3). Fungal spores were collected[6] on MEA (Malt Extract Agar, Oxoid SpA, Milano) and on Sabouraud Agar (DIFCO, Becton Dickinson, USA) and incubated at 26 °C. Three replicates for each agar type, sampling volume and sampling time were considered.

Figure 1: A prototype of the A-bios device positioned in the "David Lubin memorial library" of the FAO in Rome.
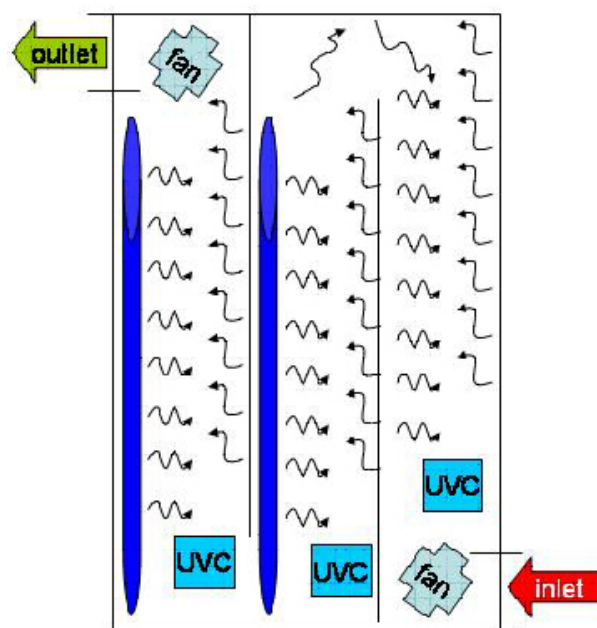

Figure 2: Schematic representation of the inside components of the A-Bios device. The curved arrows are a schematic representation of the UVC radiation dispersal into the A-Bios device whereas the straight dotted red line represents the air flow into the device.

The plates used in the SAS were 84 mm polystyrene contact Petri dishes. The count of the colony forming units (CFU) appearing on the agar plates during the incubation time was performed daily for two weeks by means of a trans-illuminator with a magnification device.

2.2 Statistics

ANOVA (Analysis of Variance) was employed to investigate the differences in the number of Colony Forming Units relevant to sampling times, culturing substrates, sampling heights and sampling volumes. The statistical package included in XLStat (Addinsoft, XLStat 2006.3, Paris, France) was used. One of the main applications of ANOVA is multiple comparisons testing whose aim is to check if the parameters for the various categories of a factor differ significantly or not. For each comparison the test is considered significant (meaning that the difference is significant) if the probability exceeds the critical value. Tukey's HSD test provides the HSD (Honestly Significant Difference)[7] which compares all possible pairs of means, i.e. it finds which means are significantly different from one another. In the tables, both significant and insignificant differences between samples are listed. The critical value (for a given number of replicates) is the value that the standardised difference must achieve to reach statistical significance (i.e. for table 1, at the 0.05, considering the number of replicates used its level is 2.521).

3 Results

The A-Bios device was positioned inside a 320 m^3 room used as library, the microbiological contamination level of this room was considered before the sterilization treatment (t0) and after 3 and 6 h of device operation (t3, t6). The difference between sampling time t0 (control) and t3 is significant according to the statistical test used (Tukey), as well as the difference between t0 and t6 (Table 1). The difference between sampling time t3 and t6 resulted not significant, indicating that, after 3 h of
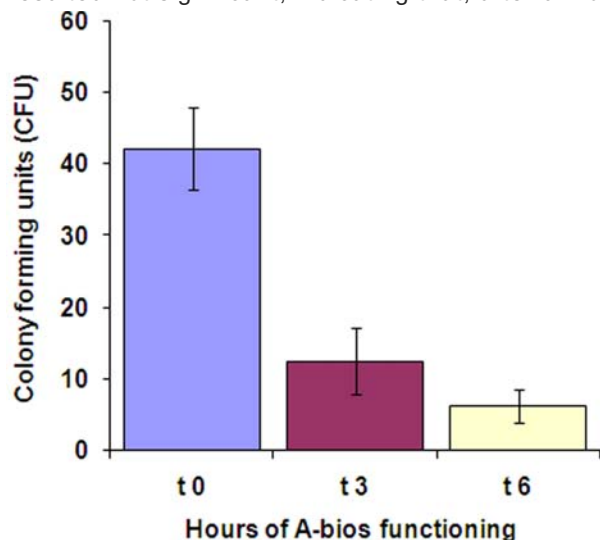

Figure 3. Average values of Colony Forming Units/m3 of air samples after different time of A-Bios operation. Bars indicate standard errors.

A-Bios operating, the results are comparable with those obtained after 6 h of air purification. These results cannot be extrapolated, of course, to all the environments since the variability and the degree of fungal air contamination can require a different time of air sterilization to obtain a significant abatement of CFUs. The results obtained in these tests indicate that the difference between fungal airborne concentration data before and after A-Bios operation are independent both on the substrate used for spores collection, and the sampled air volume. In fact, both the differences between substrates used for sampling spores and the differences between sampling volumes appeared non significant (Table 2, Table 3). The differences between the three sampling heights assayed (0.2 m – height 1; 1.5 m – height 2; 2.5 m – height 3) were not statistically significant (Table 4). This could indicate that the airflow provided by A-Bios was enough to provide an homogeneous sterilization effects on the spores of the airborne fungi after 3 and 6 h of running.

Comparison	Difference	Standardized difference	Critical value	Pr > Diff	Significant
t 0 vs t 6	2.875	5.634	2.521	<0.0001	Yes
t 0 vs t 3	2.375	4.654	2.521	0.0004	Yes
t 3 vs t 6	0.500	0.980	2.521	0.597	No

Table 1: Comparison between sampling times. Tukey's Honestly Significance Difference – HSD; see 2.2 for description). Confidence level of 95%. In the last column the significance of the difference between couples of data is indicated.

Comparison	Difference	Standardized difference	Critical value	Pr > Diff	Significant
100 vs 60	0.417	0.625	2.074	0.538	No

Table 2: Comparison between sampling volumes (in L). Tukey's HSD. Confidence level of 95%.

Comparison	Difference	Standardized difference	Critical value	Pr > Diff	Significant
Sab vs MEA	0.583	0.883	2.074	0.387	No

Table 3: Comparison between substrates (MEA and Saboraud). Tukey' HSD. Confidence level of 95%.

Comparison	Difference	Standardized difference	Critical value	Pr > Diff	Significant
3 vs 2	1.000	0.931	2.521	0.627	No
3 vs 1	0.125	0.116	2.521	0.993	No
1 vs 2	0.875	0.815	2.521	0.698	No

Table 4: Comparison between sampling heights. (1- 0.2 m from the floor, 2 - 1.5 m from the floor; 3 - 2.5 m from the floor). Tukey's HSD. Confidence level of 95%.

4 Discussion

The number of different fungal and bacterial species that can be found in the indoor environment is variable, depending on the sampling methods and on the peculiarities of the examined environments. In most of the studies[8] a great variation in samples taken at a few weeks of distance or using different isolation media was observed. The fungal component of dust biodiversity is strongly underestimated, both because only a few studies to date have provided thorough mycological characterizations of indoor dust,[9] and because some of the fungi that colonise the indoor environments are easily overlooked due to their peculiar growth requirements. However, data obtained sampling the FAO library at time zero (before A-Bios system operating) indicate that the environment considered is poorly contaminated by fungal spores. i.e. about 40 units/m^3, as shown in Figure 3 (and comparable with that of a class B clean room[10]). The average values of CFU obtained in the control is even under the fixed limit for fungal contamination of museum environments (150 CFU/m^3) as reported in the Italian Official Document for Conservation of Indoor Cultural Heritage (Atto di indirizzo sui criteri tecnico-scientifici e sugli standard di funzionamento e sviluppo dei musei, G.U. n.244, 19 ottobre 2001). The A-Bios device was tested in a not completely isolated part of a huge library space and demonstrated its potential utility in lowering and maintaining low the concentration of the spores of airborne fungi in such an environment. After 3 h of the device running an abatement of about 70% (and 90% after 6 h) of viable airborne spores was observed (Figure 3). Moreover the diminished concentration of viable spores was observed almost uniformly in all tested points. The sampling points were chosen in a way to verify the effect on spores present in the air on different distances from the A-Bios outlet; the first point (0.2 m height from the floor) was more than 1 m below the instrument's outlet, the second one (1.5 from the floor) around the same height of the outlet and the third one (2.5 m from the floor) was about 1 m higher than outlet. The absence of significant differences, concerning sampling points, in the concentration of fungal spores after 3 h of functioning of the A-Bios device, indicates that the airflow provided by instrument was sufficient to move the air in the whole room and to affect the viability of almost all the spores present in the air. The row selected for this experiment was only partially separated from the rest of the library room; there was no separation between the room where the experiment was conducted and the corridor that connects all the shelf rows between them. Even if all the human activities were absent during the experiment, the air-cooling system was on. The outlets of the air-cooling system are positioned in different points of library's ceiling and the one nearest to the experimental space was about 2.5 m far. This, together with the lack of the total separation, could have provided some airflow and incoming of new spores in the experimental row. Nevertheless the A-Bios showed very good and significant results indicating that its application could be useful in libraries even during a normal use of these spaces. Spores of all fungi present in the experimental environment demonstrated similar sensibility to UV irradiation by A-Bios as indicated by comparable results obtained by sampling on different cultural media.

5 Conclusions

In conclusion the A-Bios device seems to be a promising tool to lower, and maintaining low, the risk of microbial contamination in closed spaces, like libraries and other exposing spaces for cultural heritage. To optimize the results of A-Bios running, an evaluation of the potential microbiological risk in relation to the architecture of the treated space is needed to establish the position and the time for a better A-Bios operation. The absence of any influence on the air composition or production of dangerous chemical species, like ozone (data not shown) guarantees that A-Bios is harmless for cultural heritage to be conserved and that it is suitable for use also in the presence of humans.

6 Acknowledgements

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