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Proposal for a biological environmental monitoring approach to be used in libraries and archives

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Abstract

In cultural-heritage-related indoor environments, biological particles represent a hazard not only for cultural property, but also for operators and visitors. Reliable environmental monitoring methods are essential for examining each situation and assessing the effectiveness of preventive measures. We propose an integrated approach to the study of biological pollution in indoor environments such as libraries and archives. This approach includes microbial air and surface sampling, as well as an investigation of allergens and pollens. Part of this monitoring plan has been applied at the Palatina Library in Parma, Italy. However, wider collections of data are needed to fully understand the phenomena related with biological contamination, define reliable contamination threshold values, and implement appropriate preventive measures.

Key words

Aerobiology, microbial contamination, air sampling, surface sampling, microorganisms, pollen, fungi, cultural heritage, environmental, monitoring

INTRODUCTION

Cultural property preserved in indoor environments, such as libraries and archives, is subject to the deterioration caused by physical, chemical and biological agents, and can result in heavy economic and cultural losses. Particularly, materials made of organic compounds are subject to spoilage by bacteria, fungi, insects and rodents [1, 2, 3]. Furthermore, certain classes of airborne particles contain allergens and are potentially toxic, and may pose a danger to operators and visitors [4, 5, 6, 7]. The main goal of any preventive approach should be to limit the biodeterioration of cultural property and to prevent diseases in operators and visitors. Monitoring the biological contamination of air and surfaces is essential to assess contamination levels and to evaluate any potential risk to the preservation of the cultural property, and represents the first step to a successful preventive strategy. An appropriate monitoring, carried out using standardized methods and non-destructive surface sampling techniques, is essential to obtain results that can be interpreted and compared.

Different methodologies and measuring techniques have been adopted to date [3, 4, 6, 7, 8, 9, 10, 11, 12], but a standardized and universally accepted methodology that can guarantee reliability and reproducibility, allowing results to be compared, has yet to be found. To our knowledge, no study so far has adopted an integrated approach to investigate biological environmental pollution; the risks for cultural heritage and those for operators and visitors have been dealt with separately. Based on experiences gathered in other fields characterized by high risks of contamination and infection [13, 14, 15, 16, 17] and on the microbial environmental monitoring method for cultural heritage applied during the Correggio exhibition in Parma [18], we advocate a broader approach to the study of biological pollution in libraries and archives that also includes the assessment of allergens and pollens, as well as airborne particles.

The aim of this study is to present a biological environmental monitoring plan for archives and libraries, and describe its partial implementation at the Palatina Library in Parma. The Palatina Library was built in 1761 and contains over 700,000 volumes, including manuscripts, correspondence, incunabula, prints and drawings, as well as the largest collection of Jewish manuscripts outside Israel.

MATERIALS AND METHODS

Biological environmental monitoring plan

Air sampling. Microbial air sampling is carried out both as active sampling to measure the concentration of microorganisms in the air, and passive sampling to measure the rate at which viable particles settle on surfaces [19]. Active sampling is performed using a DUO SAS 360 sampler (International PBI, Milan, Italy), with a flow rate of 180 litres per minute (L/min). The sampler is placed in the monitored room 1-1.5 m above the floor and about 1 m away from any major physical obstacle. To sample the air coming from the heating, ventilation and air conditioning (HVAC) system, the

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sampler is placed at a distance of 30 cm from the air grille. The results are expressed as colony forming units per cubic metre (CFU/m^3). A sampling volume of 500 L is considered adequate. In extremely contaminated environments, a lower sampling volume may be sufficient. Petri dishes with a diameter of 9 cm are used in passive sampling to determine the Index of Microbial Air Contamination (IMA) [20]. This value corresponds to the number of CFU counted on a Petri dish left open to the air according to the 1/1/1 scheme (for 1 h, 1 m above the floor and about 1 m away from walls and any major obstacles). The IMA can be expressed either as CFU/plate/h or as CFU/dm^2/h. Tryptic Soy Agar is used for bacteria isolation, with incubation at 36±1°C for 48 h, and Sabouraud Dextrose Agar with chloramphenicol is used for fungi isolation, with incubation at 22±1°C for 120 h.

Particles are counted with a laser particle counter. This instrument is used extensively in the pharmaceutical and electronic industries to measure the cleanliness of an environment, and can provide information on the concentration of airborne particles of different size [21].

A Hirst spore trap with a flow rate of 10 L/min is also used for the direct detection of microscopic fungal spores, both viable and non-viable, and for evaluation of the temporal distribution of particulates. The count is performed according to the method suggested by the Italian Association of Aerobiology (AIA), based on the Italian Organization for Standardization (UNI) norm number 11108/04. This approach also allows the operator to assess the presence of pollen in the air, which can result from improper behaviours (for example, opening windows in an air conditioned room).

Allergen sampling is performed using volumetric traps with a flow rate of 20 L/min. Air passes through 25-mm-wide PTFE (Polytetrafluoroethylene) air sampling filters for at least one hour. An immunoassay test is used to determine the concentration of some allergens, including Der p1 (*Dermatophagoides pteronyssinus*), Der f1 (*Dermatophagoides farinae*), Fel d1 (cat), Bla g2 (cockroach), Rat n1 (rat), Mus n1 (mouse), Asp f1 (*Aspergillus* spp.) and Alt a1 (*Alternaria* spp.) [22].

Surface sampling. Microbial surface sampling of cultural objects is carried out in a non-destructive way using nitrocellulose membrane filters (Sartorius AG, Gttingen, Germany) with a diameter of 47 mm. Microbial Buildup (MB) and Hourly Microbial Fallout (HMF) are measured [23, 24]. The MB represents the number of microorganisms that have collected on a given surface during an indefinite period of time prior to the sampling. Samples are collected by pressing a nitrocellulose membrane on the selected surface for 30 s, with finger tips protected by sterile gloves. The HMF corresponds to the number of microorganisms that fall on a given surface during the period of 1 h. Samples are collected by leaving a nitrocellulose membrane on the selected surface for 1 h. After the samples are collected, the nitrocellulose membranes are transferred to Petri dishes containing Tryptic Soy Agar for bacteria isolation, and Sabouraud Dextrose Agar with chloramphenicol for fungi isolation, with incubation at 36±1°C for 48 h and 22±1°C for 120 h, respectively. MB and HMA are expressed in CFU/dm^2.

Surface sampling for allergens is carried out using a vacuum cleaner equipped with MITEST filters. Surface-born allergens, of the same type as airborne allergens, are detected by means of immunoenzymatic assays [22].

Recording of microclimatic parameters. Microclimatic parameters – temperature (°C), relative humidity (%) and ventilation – are recorded.

Experience at the Palatina Library in Parma

Methodology. Active and passive microbial air sampling was carried out in 10 different rooms, for a total of 10 sampling points. A HIRST spore trap (Burkard) was used in the reading room.

Surface samples were collected on a table inside the reading room and on the pages of books and newspapers to assess the Microbial Build-up (MB) and the Hourly Microbial Fallout (HMF). All samples were collected during opening hours.

RESULTS AND DISCUSSION

Libraries and archives are subject to a particularly high risk of biodeterioration. We applied the same environmental monitoring plan that had been proposed and implemented during the Correggio exhibition in Parma [18], thus showing its feasibility. Some interesting aspects have emerged. Table 1 shows the single values and the descriptive statistics of microbial air contamination in the monitored rooms. Microscopic examination of slides from the Burkard spore trap revealed a prevalence, among fungal spores, of *Cladosporium* spp.; *Fusarium* spp. and *Ustilago* spp. were also detected. The following families or genera of pollens were isolated: *Poaceae, Platanaceae, Betula, Quercus*. On Saturday and Sunday (closing days) neither spores nor pollens were detected (Tab. 2). MB and HMF values are shown in Table 3.

A wide range of bacterial and fungal contaminants has been detected in the distinct environments, suggesting the need for a study on the specific characteristics of every environment. In some cases, substantial discrepancies between the results obtained by active and passive sampling methods were recorded. For example, the microbial counts obtained with the active sampling were significantly lower than those obtained with passive sampling (e.g. bacterial contamination in the cellar: 2 *vs* 127). Possibly, an event that was not detected with a punctiform active sampling,

Table 1. Microbial air contamination values in the monitored rooms. Passive sampling (IMA, CFU/dm^2/h) and active sampling (CFU/m^3)

	[a] IMA (CFU/dm^2/h)			CFU/m^3		
	[b]B	[c]F	[d]T	B	F	T
Cellar 1	127	72	199	2	156	158
Cellar 2	175	63	238	190	334	524
Storeroom	2	2	4	76	191	267
Incoronata Gallery	2	2	4	98	68	166
Reading room	49	3	51	383	132	515
De Rossi Room	2	2	4	20	14	34
Gallery 1	2	2	4	0	38	38
Gallery 2	0	0	0	18	38	56
Gallery 3	4	4	8	22	110	132
Gallery 4	2	2	4	140	85	225
Min-Max	0-175	0-72	0-199	0-383	14-334	34-524

[a] IMA : index of microbial air contamination
[b] B: bacteria
[c] F: fungi
[d] T: total microbial charge

Table 2. Spores and pollens values over a week period

	Tue April 7 2009	Wed April 8 2009	Thu April 9 2009	Fri April 10 2009	Sat April 11 2009	Sun April 12 2009	Mon April 13 2009
Spores							
Cladosporium spp.	19	11	9	10	0	0	2
Fusarium spp.	1	1	0	2	0	0	0
Ustilago spp.	0	1	0	1	0	0	0
Pollens							
Poaceae	2	2	0	1	0	0	1
Platanaceae	2	1	0	2	0	0	2
Betula	1	0	0	1	0	0	0
Quercus	1	0	0	0	0	0	0

Table 3. Microbial surface contamination values: MB and HMF (CFU/dm^2)

Sampled surface	[a]MB (CFU/dm^2)	[b]HMF (CFU/dm^2)
Newspaper *Gazzetta di Parma,* 1 April 1877	6	-
Newspaper *Il Giornale,* April 1975	0	-
Book CV 4211, Vol. 2, p. 115	0	-
Book MS PARM 2202, map 183V	0	-
Table in the reading room	75	-
Table in the reading room	-	35

[a]MB : microbial buildingup
[b]HMF: hourly microbial fallout

was detected with passive sampling. The absence of CFU's in some passive samples could be explained by particular ventilation conditions acting against the deposition of particles, or by the presence in the air of a high number of non-settling particles. In the latter case, the particle count could provide useful information on the relative quantity of different-sized particles. It is important to perform both sampling methods, since they provide different types of information: active sampling measures the concentration of microorganisms in the air, while passive sampling provides a measure of how the biocontamination of air contributes to the biocontamination of surfaces. Several studies have found a significant correlation between active and passive sampling methods, while others have failed to find such a correlation [25]. It is therefore questionable to assume that a predefined correspondence between active and passive sampling exists, as some authors do when using specific formulae to obtain the number of CFU/m^3 from the number of CFU/settle plate [8].

Pollens were isolated every day of the week except on Saturday and Sunday. The presence of pollens in indoor air shows an exchange of air between the inside and the outside. Pollen isolation could then be useful to detect unwanted indoor-outdoor air exchange.

As for surfaces, the highest value of microbial contamination was recorded, as expected, on the reading table, while in some cases no microorganisms were found on the paper. TSA was the only medium used for the total microbial count of surface samples, since the aim was to evaluate the applicability of the method. It is possible that fungal contamination might have been present as well, suggesting that a specific medium for fungal isolation should always be used.

CONCLUSIONS

The study performed at the Palatina Library in Parma reveals the importance of an integrated approach to microbial environmental monitoring in a cultural heritage. Our results only provide a 'snapshot' of the situation and therefore must be viewed as indicative rather than conclusive. The limited number of samplings does not allow us to draw general conclusions, nor to propose threshold values. A larger collection of data covering a wider variety of sites (both old and modern structures), periods of time, operational conditions, and climatic and microclimatic conditions will provide the basic knowledge to study the phenomena associated with biological environmental contamination. Such data will allow researchers to determine threshold values for biological contamination, with target and action levels, and to devise preventive measures that will protect both cultural heritage materials and the health of operators and visitors.

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