



Aerobiology applied to the preventive conservation of cultural heritage

Giulia Caneva · Paola De Nuntiis  · Marco Fornaciari · Luigia Ruga · Paola Valenti · Giovanna Pasquariello

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Abstract This work aims to provide an historical overview on aerobiology applied to the preventive conservation of cultural heritage. Bioaerosol represents a potential risk to cultural artifacts since in favorable nutritional and microclimatic conditions the settled biological particulate matter can develop and grow, thus triggering the biodeterioration. Aerobiology has become an important discipline for developing prevention and control strategies for the biological deterioration of cultural heritage. The most used equipment and methods for sampling in both indoor and outdoor environments (passive-sedimentation plates and active impactor for air, contact plates and

membranes for surfaces) will be described. The aerobiological monitoring, always combined with microclimatic monitoring, along with information on the artifact and its conservation status, allows to defining situations of potential biologic risk. All the information and data gathered create the baseline for setting up management protocols, defining tailored corrective strategies aimed at preventing damage to cultural heritage and reducing risks to the health of operators and users. New perspectives for this discipline could arise thanks to (a) the development of user-friendly technologies and instrumentations for aerobiological monitoring and sampling of surfaces; (b) the definition of threshold levels of biological risk to the different types of cultural heritage; (c) the creation of a card of “biodeterioration risk” (international database).

G. Caneva
Department of Science, University Roma Tre, Rome, Italy

P. De Nuntiis (✉)
Institute of Atmospheric Sciences and Climate (CNR-ISAC), National Research Council of Italy, Bologna, Italy
e-mail: p.denuntiis@isac.cnr.it

M. Fornaciari · L. Ruga
Department of Civil and Environmental Engineering,
University of Perugia, Perugia, Italy

P. Valenti
Central Institute for Restoration and Conservation of
Archival and Book Heritage, Ministry of Cultural
Heritage and Activities, Rome, Italy

G. Pasquariello
Central Institute for Graphic Arts, Ministry of Cultural
Heritage and Activities, Rome, Italy

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1 Introduction

Aerobiology applied to the cultural heritage sector has become an elective discipline for the preventive conservation of historical-artistic and documentary artifacts. Preventive conservation is any measure that aims to prevent or slow down deterioration (physical, chemical and biological) of cultural heritage,

operating on the environment surrounding the artwork and never on the artwork itself. In Italy, preventive conservation is included in long-term planning and aerobiological analysis is indicated for determining the concentration of airborne biological pollutants (MIBAC 2001).

A brief historical overview is presented below. The International Aerobiology Working Group was constituted in 1968 within the International Biological Program to coordinate all the national aerobiological programs. However, in Italy the first study that used an aerobiological approach was carried out in libraries located in monumental buildings (Camposano 1950) and date back to the 1950s. Subsequently, other researches were performed in the National Library of Rome, using instruments, methods and measurement techniques used in that assess air quality for environmental health purposes (Gallo 1993).

Similar studies have been conducted in libraries and archive repositories in Warsaw (Poland), in museums in Madrid (Spain), Rome and other Italian cities, in the National Archive of Havana (Cuba), in National Library of Paris (France) (Marcone et al. 2001; Mandrioli et al. 2003). The results obtained, besides being fairly similar from a quantitative point of view, also revealed correspondence between the airborne microflora of libraries and archives, and the biodeteriogens of books and documents (Valentin 2003; Borrego et al. 2010).

Aerobiological research has also often involved the sanitary sector, concerning the protection of the health of operators, especially as regards the confined environments such as museums, libraries, archives (Tarsitani et al. 1996; Apetrei et al. 2009). In fact, bioaerosol might represent a biodeteriogenic for cultural heritage but also a pathogenic agent for humans.

Bioaerosol is dispersed through the air and settles on all surfaces, and under favorable conditions for growth (water, temperature, nutrients, etc.), it reproduces and colonizes the substrate of cultural heritage, which can be used as food or as a support, triggering the phenomenon of biodeterioration. The study of biodeterioration has historically been focused on artworks and the analysis of types of their alterations. Recently, it has been focused on understanding the interaction between the artifact and the environment. Aerobiological studies aim to qualitatively and quantitatively characterize the bioaerosol dispersed in the

environment, to assess the biological risk and identify targeted preventive and corrective strategies aimed at preventing biodeterioration (Ruga et al. 2015). For this kind of study, the following parameters are taken into account: natural (such as soil) and artificial (such as human activity) sources; the deposit surfaces (such as shape, exposure, inclination); the chemical–physical characteristics of materials (e.g., organic and inorganic); microclimatic conditions; human presence (visitors, operators); air conditioning systems, air filtration systems and their maintenance and cleaning.

2 Overview of the sampling methods and techniques

In aerobiological investigations, sampling methods and techniques of analysis vary depending on the purpose of the sampling, but also the size and kind of particles (Caneva et al. 2007). For instance, the sampling of *viable* bioaerosol requires special attention for keeping organisms alive for a subsequent cultivation and analysis. In this case, microorganisms are collected in a solid or liquid culture medium before they are transferred into a culture medium.

Active sampling method uses volumetric samplers that aspire a known volume of air onto a collection surface that may consist of a solid or liquid culture medium for *viable* bioaerosol, or inert surfaces such as a microscope slide or tape, in the case of non-viable bioaerosol. It measures the concentration of the airborne microorganisms.

The most used equipments for *viable* particles are: Andersen Microbial Air Sampler (flow rate of 28.3 l/min) (Fig. 1) and Surface Air System Sampler (flow rate of 90–180 l/min) (Fig. 2). The results are expressed as colony-forming units per cubic meter (CFU/m³). The traps of the Hirst Sampler and Burkard are used for the collection of *non-viable* bioaerosol (i.e., fungal spores and pollen), which should subsequently be identified morphologically through microscopy.

Passive sampling consists in the exposition of Petri dishes containing suitable culture medium for a specific period of time, and it is used to measure the rate at which microorganisms settle on surfaces. The results are expressed as the number colony-forming units per dm² of the surface (CFU/dm²). Two culture media are suggested for the cultivation of viable



Fig. 1 Andersen Microbial Air Sampler in the Art Gallery of Perugia, Italy

bioaerosol: Tryptone Soya Agar (TSA) and Sabouraud Dextrose Agar (SDA) + chloramphenicol for bacteria and fungi isolation. Polymerase chain reaction (PCR) is suggested for detecting microbial species (Palla and Barresi 2017).

Following the air sampling, researchers proceed with the quantitative evaluation and with the identification of the microorganisms, using different methodologies: cultivation, microscopy and molecular analysis (PCR, etc.).

The surface of artworks of organic materials is assessed using sterile nitrocellulose membranes or nylon membranes (Fig. 3). Two parameters are usually measured: the Microbial Build-up (MB) and the Hourly Microbial Fallout (HMF), and the results are expressed as CFU/square decimeter (CFU/dm²). After sampling, nitrocellulose membranes are transferred to Petri dishes containing the identical culture media incubated at the same conditions of the air sampling

(Pasquarella et al. 2012). The surface of artworks of inorganic materials is assessed using contact plates (RODAC).

The aerobiological monitoring integrated with microclimatic monitoring allows to obtain information on the environmental conditions and to choose and implement targeted prevention strategies also through the use of biological risk maps (Skóra et al. 2015; Bonazza et al. 2017).

3 Conclusions

Many investigations analyze the biological damage of cultural heritage, but only a few consider aerobiological analyses in preventive conservation. In this specific issue, the working group “Aerobiology and Cultural Heritage,” activated in the AIA (Italian Aerobiology Association) in 1992, has produced



Fig. 2 SAS Sampler in the Crypt of Cappuccini, Rome, Italy



Fig. 3 Sampling with nitrocellulose membrane on artworks on paper

scientific papers, manuals and reports at national and international congress (e.g., ICA), supporting also the drafting of technical standards (UNI and CEN) for both the preservation of artifacts and of the health of operators.

New perspectives for the aerobiology in the field of cultural heritage could arise thanks to development of instrumentations and technologies for biological monitoring of air and surfaces; the definition of thresholds

for biological risk to the different types of artworks; the creation of a card of “biodeterioration risk.”

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