Biodeterioration of Cultural Heritage in Italy: State of Art

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1. Introduction

The problem of deterioration of works of art is particularly relevant in Countries like Italy that are rich in Cultural Heritage. In fact, following UNESCO data, in Italy are located 2/3 of the Cultural Heritage known in the World. Archeological areas, statues, buildings, museums, churches and items there located, hypogean environments, are subjected to different stresses due the geographical position, different degree of pollution, great variety of typology of materials and consequent status of conservation. All together these factors contribute to the different modality of biological attack.

Biodeterioration can be defined as the irreversible loss of value and/or information of an object of art following the attack by living organisms (Urzì and Krumbein, 1994).

Biodeterioration of stone monuments is one of the principal field of interest of Italian researchers. However, other groups are also concerned with the biodeterioration of other materials as books, glass, wood textile and other materials.

2. Factors affecting the biological deterioration of works of art

For the colonization and establishment of any biological community on the organic and inorganic materials, composition of materials used and its status of conservation, favorable environmental and climatic factors (temperature, humidity, rain and other precipitation, sun exposure, shadowing and inorganic and organic pollutants) can create good and sometimes even optimal conditions for the development of organisms on the often richly sculptured outer surfaces, (aesthetic damage), and/or in deeper layers (physic/mechanical and chemical damage), causing some typical biogenic alterations well described in the Italian NORMAL Lexicon (Commissione Normal, 1991) (Table 1).

Tab. 1 Factors influencing colonization and biodeterioration

Climatic and environmental factors	**➔ Sun, shadow, rain, Temperature**
Inorganic and organic pollutants	**➔ as C, N, S source and/ore/o growth inhibitors**
Surface bioreceptivity	**➔ Nature of material, conservation, length of exposition**
Treatments	**➔ Biocides/ Surfactants/ Hydrophobic compounds**

However, the mere presence of macro- and microorganisms does not make it sufficient to consider them as cause of decay, because only in particular conditions and when also other factors occur as well, they can cause and/or enhance deterioration mechanisms.

Each monument located in a given climatic area can be considered as a specific habitat. In addition, in each monument, different micro-niches also occur considering outdoor or indoor environments or different expositions (direct exposed zones, sheltered areas, soil proximity, vertical or horizontal surfaces, etc.).

3. Main groups of organisms responsible of biodeterioration

Macroorganisms

Birds and, in particular, pigeons cause a remarkable amount of aesthetical and chemical damage trough the deposition of guano. Guano, moreover, can provide a good growth medium for chemoorganotrophic microorganisms which, in turn, will cause a corrosive action on materials by releasing acid metabolites (Bassi and Chiatante, 1976). There is a multitude of other, smaller animals that live on and in mineral mixtures. The most important among them, in common terms, are spiders, flies, mosquito, stone wasp, ants, mites and beetles. Insect and artropodes are the groups most frequently involved in rock dwelling and rock decay and wood decay.

Among macroorganisms, plant with roots or climbing and adhering parts of leaves and stems create great problems for conservators because they cause obvious aesthetic damage and alterations to stone due to (a) the mechanical action of the roots and fixing parts, (b) chemical action through ionic exchange between roots and alkali or earth alkali cations of the stone constituents, or (c) vegetation shadowing, which slows down water evaporation.

Mosses and lichens are macroscopically evident because they cover the material surfaces with visible films of growth. Consequently, an aesthetic alteration is initially noticed. In addition, they have a corrosive effect on the substrate because they release acid metabolites, some of which are chelating agents that determine a solubilizing and disintegrative action on the constituents. Lichens provoke physical as well as chemical damage; acid metabolites solubilize and disintegrate the substrate (Nimis et al., 1992). One of the most prominent effect of lichens is the formation of pits or crater shaped holes.

In literature are reported many papers dealing with the studies of flora diversity in archeologic areas in Italy (Altieri et al., 1999, Caneva et al., 1995). Ecological studies of vegetation are the first step to individuate the main factors that enhance their unwanted grow and to develop specific techniques and /or new chemicals for their control and elimination.

Microorganisms

Microbially induced or accelerated decay processes of art objects are often underestimated.

Cyanobacteria are usually present in association with green and red algae and diatoms. The dominance of one or another of these groups varies both locally and regionally. Cyanobacteria and green or red algae growing on surfaces within buildings (e.g., churches or grottos) are well adapted to survive at very low light levels. Cyanobacteria and algae can form biofilms and crust on rock surfaces that are deep or bright green under humid conditions and deep black when dry. Apart from the evident aesthetic damage on the surfaces, there is much evidence of significant physical and chemical deterioration of the material by excretion of chelating organic acids and sugar-derived carbonic acids, which initiate the perforating activity.

Epilithic cyanobacteria and microalgae have been studied in a number of Roman Catcombs and Necropolis in Rome (Italy) to understand the eco-physiology and structural mechanisms that allow colonization and cause deterioration of archeological surfaces (Albertano, 1998) as well as the interactions between phototrophic and heterotrophic microflora (Albertano and Urzì, 1999).

Chemoorganotrophic bacteria - In recent years a constant growing number of contributions have been made about the impact of chemoorganotrophic microbiota also on the deterioration and biotransfer of materials of inorganic composition.

However, recent studies have shown there is not a close relationship between high number of bacteria and biodeteriorative potential, due to the fact that often microflora well adapted to live on the rock has a very slow growth pattern and it is not easy to detect with normal laboratory procedures.

Most of them are associated with different geomicrobiological processes among which are the abilities:

- to bound to clay and crystals particles and thus to be more persistent on the rock surfaces and pores spaces;
- to solubilize $CaCO_3$ through the release of acid metabolic products and/or through respiratory processes and release of CO_2 (weak acid activity);
- to oxidise metallic compound like Fe, Mn and lead to precipitation of orange to black layers or spots;
- to precipitate passively or actively carbonate, oxalate and other minerals and thus to contribute to the patina formations.

On monuments strains belonging to the vast order of Actynomycetales are found very often on rock substrate such as *Geodermatophilaceae* strains (Urzì et al., 2001) and also some *Micromonospor*a strains (Zezza et al., 1995; Urzì and Realini, 1998). In hypogean environments, *Streptomyces* strains are very often found (Urzì et al., in press). These bacteria are characterized by some features that allow them to survive in very hard conditions.

In fact, they possess:

- a high pleomorphism (changing from single cell to a cluster);
- a wide variety of pigments, from carotenoid to dark phenolic compounds;
- a low water demand for the growth;
- high resistance to dryness and high temperatures.

Fungi – Fungi are among the most harmful organisms associated to biodeterioration of organic and inorganic materials. It is well known, in fact, the metabolic versatility of this group of microorganisms that enhance their efficiency to colonize a very different kind of substrata (wood, glass, stone, book). In the last decade more evidences have been shown that in rock material, the most common fungal colonizators are the so-called black meristematic fungi. They are commonly isolated from the sun exposed surfaces in Mediterranean as well as from dry and cold climates (Anagnostitidis et al., 1992; Urzì et al., 2000a). Their occurrence on the stones is reported to be combined not only with aesthetical spoiling of the monuments, due to color changes and black spots, but also with a strong evidence that these organisms are causing crater shaped lesions, chipping and exfoliation of the rock surfaces combined with the loss of materials (Urzì et al. 1995, Urzì et al., 2000b).

They represent a wide and heterogeneous group of black pigmented fungi having in common the presence within the cells (swollen cells, hyphae and/or spores) of melanin. For this group of microorganisms is also used the term of rock-inhabiting fungi to underline the exclusive isolation of many strains from rock surfaces. Recently many strains were described as new species (Wollenzien et al., 1997; Sterflinger et al., 1997; De Leo et al., 1999). Ecological and taxonomic studies on this group of fungi are still in progress.

4. Ongoing researches and main thematics

At present, in Italy researches on biodeterioration are carried out in the frame of different National and European projects.

The Italian National Council for Researches (Consiglio Nazionale delle Ricerche, C.N.R.) has prepared and financed a “Finalized Project for the Safeguard of Cultural Heritage” active since 1996. The main aims of this project are:

- The protection of Italian Cultural Heritage
- The enhancement of its value through conservative strategies
- The public fruition of the Cultural Heritage.

To reach these three objectives the project has foreseen different steps summarized in the different themes (see web page http://www. culturalheritage.cnr.it).

Concerning the main thematic on the biodeterioration of works of art, they can be summarized in studies finalized to the:

a) Ecology of biotic community interacting with works of art;

b) Biosusceptibility and biodeterioration of organic and inorganic constituents;

c) Control of microorganisms and their utilization for conservative purpose.

The ecological studies were carried out on different class of organisms (higher plants, lichens, mosses, algae, microorganisms). Concerning microorganisms (bacteria, fungi and cyanobacteria) the importance of molecular methods to complement microscopical and cultural procedures is considered by many scientists and many projects are involved.

The interaction between organisms and material is studied applying different techniques including microscopy and/or new instruments.

Methods to control the growth of biodeteriogens are at present tested in several laboratories in order to reduce risks for the manufacts, the environment and the operators.

Studies aiming to use bacteria for conservative purpose (e.g. calcite precipitation for the reinforcement of calcareous materials in bad status of conservation) are also proposed.

These thematics are included in the following national and international projects:

1. Finalized project for the Safeguard of Cultural Heritage, Subproject n° 2 “Artistic and Architectural Heritage: analysis, diagnosis and restoration, Objective 2.2 “New diagnostic system for the characterization of the state of conservation of works of art on mobile support” and Objective 2.4 “ New methodologies for the treatment and protection of artifacts”. Web page: http://www.culturalheritage.cnr.it
2. EC Program Environment ENV4-CT98-0707 1998-2001 “SILICON”. Web page: http://www.sci.port.ac.uk/ec/
3. EC Program Environment ENV4-CT98-0704 1998-2001 “HERMES”.
4. EC Program Environment EVK4-2000-00028 2000-2003 “CATS”. Web page under construction
5. CA 1999-2002 Concerted action on molecular microbiology as an innovative conservation strategy for indoor and outdoor cultural assets, EVK4-1999-00061”COALITION”. Web page: http://www.genomic.uni-oldenburg.de/projekte/coalition

6. EC Program Environment EVK4-CT-2000-00037 “BIOREINFORCE”. Web page: http://www.area.cnr.it/cscoa/Bioreinforce.html.
7. Progetto di Ricerca di Ateneo PRA 2000-2001 “Studio delle comunità microbiche presenti negli ambienti ipogei: interazioni tra microflora autotrofa ed eterotrofa e tassonomia di ceppi di Streptomyces”.
8. Murst Parnaso Project. Web page: http://www.cnrbozza.polimi.it
9. Progetto di Ricerca di Ateneo Microbial degradation of silk.

5. Main institutions and groups operating in the field of biodeterioration of cultural heritage in Italy

Different institutions in Italy exist in which operate scientists concerned with problems of biodeterioration. A list of the main principal institution is shown in the Table 2:

Table 2. List of the principal Institution operating in the field of biodeterioration of Cultural Heritage in Italy

Institution/Organization	Centre/Department	Contact person	Main Field of interest
Consiglio Nazionale delle Ricerche (CNR, Florence) http://www.area.fi.cnr.it	Center for Scientific Conservation of Art Works	Dr. P. Tiano tiano@cscoa.fi.cnr.it	Conservation of stone monuments
Centro Nazionale delle Ricerche (CNR, Milan) http://www.cnrbozza.polimi.it	Centro “Gino Bozza”	Dr. M. Realini marco.realini@polimi.it	Conservation of stone monuments
Centro Nazionale delle Ricerche (CNR, Rome)	-	Dr. M. Monte monte@micanet.it	Study of Thiobacillus strains isolated from stone monuments
Istituto Centrale per il Restauro (ICR, Rome)	-	Dr. M. P. Nugari, mariapia.nugari@tiscalinet.it	Study on biodeterioration of inorganic and organic objects, Control of biodeterioration
Soprintendenza per il patrimonio Storico Artistico e Demoetnoantropologico di Venezia http://www.artive.arti.beniculturali.it	Scientific Laboratory	Dr. O. Salvadori orsalva@tin.it	Ecology of lichens and their implication on deterioration of stone monuments and methods of controls
Soprintendenza Beni Artistici (Bologna)	Scientific Laboratory	Dr. D. Pinna sbas-bo@iperbole.bologna.it	Ecology of lichens and their implication on deterioration of stone monuments
University of Pavia http://www.unipv.it/	Centro Interdipartimentale di Studi e di Ricerche per la Conservazione dei Beni Culturali	Prof. O. Ciferri ociferri@pillo.unipv.it	Microbial degradation of silk, wooden and stone
University of Milan	Dpt. of Food and Microbiological Sciences and Technologies	Prof. C. Sorlini csorlini@mailserver.unimi.it	Ecology of microbial communities on stone monuments
II University of Rome “Tor Vergata”	Dpt. of Biology	Prof. P. Albertano albertano@uniroma2.it	Ecology of phototrophic microorganims on stone monument in hypogean environment
III University of Rome http://www.bio.uniroma3.it/biologia	Dpt. of Biology	Prof. G. Caneva caneva@bio.uniroma3.it	Phytosociological studies of vegetation in archeological areas
University of Messina http://ww2.unime.it/mbio/urzi/clara.htm	Dpt. of Microbiological, Genetic and Molecular Sciences	Dr. C. Urzì urzicl@unime.it	Ecology and taxonomy of microbial communities on stone monuments

6. Some references related to the Biodeterioration of works of art.

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