The interaction between environmental pollution and cultural heritage: from outdoor to indoor “MetroArcheo2020”

Paola Fermo¹ · Valeria Comite¹ · Mauro Francesco La Russa²

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This special issue deals with the chemical techniques and tools for application in the field of cultural heritage. In particular the articles here presented deals with the topics of interest for the international conference on metrology for archeology “MetroArcheo2020”.

In the field of research related to the characterization, conservation, and restoration of cultural heritage, as well as the techniques of manufacture of objects, it is essential to use diagnostic methods that often are named as archeometric techniques. Archeometry (which measures what is ancient) deals with the scientific study with laboratory analyses of the materials employed.

The characterization of the material is essential both to acquire information on the fabrication technique (allowing to advance even hypothesis on the identity of the artist, if there were doubts about the attribution of the work) and to allow the preservation over time. The lack of a thorough knowledge of these aspects can lead to improper choices of methods or materials during the restoration. In fact, the diagnostic approach applied to cultural heritage allows assessing the state of conservation of a work allowing the experts to adopt the best techniques available for the conservation, also monitoring over time the effectiveness of the materials and the treatments used.

In this area, collaboration between experts from various disciplines is essential. It will therefore be necessary for the chemist to work with the physicist, geologist, archeologist, conservator, etc. Moreover, the diagnostics applied to cultural heritage is a very complex discipline from the technical

point of view because we are always faced with different problems and because artistic techniques are hardly “standardized.” The range of materials used in the past is wide and consequently also the conditions of conservation and the products of degradation that have been generated over time can be very variable.

The analytical techniques that can be used in archeological studies are different depending on what you want to investigate and the information you want to obtain. First of all, it is important to follow an operational protocol, consisting of several points. The first point is the choice of the sample that must be representative of what you want to investigate. In the case in which a sampling must be carried out, micro-samples will be taken in particular areas (for example, in the case of a vase for which we want to investigate the chemical composition of the ceramic body or of the coating, the sampling will be carried out in an already damaged zone that may present some chipping; in the case of a painting, the sampling is even more problematic and delicate and must be carried out under the supervision of the art historian). It is also possible to obtain important information about the works using some properties of light: the investigations in grazing light, or in ultraviolet and infrared light, can in fact show details otherwise not visible such as repainting or afterthoughts of the artist.

Depending on the information to be obtained and the type of analysis to be performed, the method of sampling may be different (solid, powder, or liquid).

The analytical techniques applicable to the study of cultural heritage are different and allow to obtain both information on the chemical composition of the artifact and useful information to plan a proper restoration. The analysis can be aimed at the study of morphology, molecular composition, chemical composition at the elementary level, crystalline or amorphous structure. Obviously, all these methodologies will provide complementary results that will be combined within a sort of puzzle. In the

✉ Paola Fermo
paola.fermo@unimi.it

Valeria Comite
valeria.comite@unimi.it

Mauro Francesco La Russa
mauro.larussa@unical.it

¹ Università degli Studi di Milano, Milan, Italy

² Università della Calabria, Rende, Italy

following, the main techniques applied in these filed are mentioned and briefly described.

- Morphological analysis: involves the observation of the fragment as it is or as a cross section that can be observed by optical microscopy (OM) or scanning electron microscopy (SEM), a technique that allows to reach very high magnifications allowing the observation of particles that have a size up to a few microns.
- Elemental analysis: these are methodologies that allow to identify and quantify the chemical elements present in the sample. The information obtained allow, for example, to identify the nature of the material used. Sometimes it is fundamental to acquire information on the entire chemical composition of the sample, not limiting to a single element: in particular, in this case it is possible to carry out studies on the origin of the materials used. For example, by analyzing a rather large number of ceramic samples, on the basis of the elemental compositional data it is possible to reconstruct a sort of “fingerprint” of materials coming from the same area: it will therefore be possible to distinguish objects produced in a certain site, starting from a common raw material that has a very precise characteristic composition, from objects that have been imported and therefore show a different fingerprint. Sometimes it is possible to highlight the origin by analyzing trace elements. Among the techniques of elemental analysis we can mention atomic absorption spectroscopy (AAS), atomic emission spectrometry with inductively coupled plasma source (ICP-OES), X-ray fluorescence spectroscopy (XRF), and analysis by microprobe EDS coupled to SEM analysis.
- Molecular spectroscopy techniques: in case you want to obtain information on the nature of the molecules present, infrared spectroscopy (FT-IR) and Raman spectroscopy can be used; these techniques do not necessarily require the collection of micro-fragments as there are very advanced and effective technologies for in situ analysis. These techniques provide important information not only about the chemical nature of inorganic pigments, but also allow to identify organic components such as binders used by artists as a means of dispersion for pigments (oils, resins, protein materials, etc.).
- Chromatographic techniques: these techniques allow to highlight the presence of different molecules even in very complex mixtures. These methods are widely used in the field of cultural heritage, for example, in the identification of organic substances. Among the most widely used techniques we can mention gas chromatography coupled to mass spectrometry (GC-MS) or liquid chromatography coupled to mass spectrometry (LC-MS).
- X-ray diffraction analysis: it provides information about the crystalline phases of minerals in a sample. A widely used technique is X-ray powders diffraction (XRPD) that

allows to discriminate, for example, between the different phases present in an ancient mortar or in a ceramic. In the specific case of ceramics it is possible to associate the presence of certain phases to the achievement of a certain firing temperature.

- Dating techniques: these techniques are aimed at determining the date of manufacture and origin such as isotopic analysis, dating by thermoluminescence or carbon. A correct analytical protocol allows to carry out several analyses even with small quantities of sample.

All these methodologies, often applied in a synergic way, allow to carry out a complete investigation of the works of art of interest.

A further important topic is represented by conservation issues. The conservation of works of art, both outdoor and exhibited inside museums, is strongly influenced by the environmental quality. In outdoor environments atmospheric pollutants are responsible of different phenomenon including stone sulfation and black crusts formation while temperature and relative humidity are generally monitored in indoor environments, but they are not the only parameters to be kept under control. In order to get more detailed information on possible risk to which works of art are subjected, a deep knowledge of pollutant concentrations together with their chemical and physical characteristics is mandatory to study degradation and alteration of the works of art and to set up suitable conservation and restoration intervention.

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Paola Fermo graduated in chemistry in 1993; researcher in Analytical Chemistry, Chemistry Department, University of Milan since 1999; since 2015 associate professor of Analytical Chemistry; since 2022 full professor of Analytical Chemistry. The research topics are in the field of environmental analytical chemistry as well as analytical chemistry applied to cultural heritage. Principal investigator of national and international projects. Author of about 150 scientific publications on international peer-review journals; h-index (Scopus) = 38; 20 conference proceedings, 16 book chapters, more than 250 communications in national and international congresses. Invited speaker in international congresses and member of the editorial board of international journals (*AtmosphereApplied ScienceSustainabilityInternational Journal of Cultural Heritage*).

Valeria Comite graduated in Diagnostics, Conservation and Restoration of Cultural Heritage University of Calabria in 2010, PhD Earth Sciences at the University of Catania XXVI Cycle in 2014. Present occupation: research fellow at the Department of Chemistry, University of Milan. The research topics are in the field of environmental analytical chemistry as well as analytical chemistry applied to cultural heritage. Author of 63 scientific publications on international peer-review journals;

h-index (Scopus) = 15; 38 conference proceedings; numerous communications in national and international congresses.

Mauro Francesco La Russa was born in Lachen (CH) on September 30, 1977. He took an MSc in Geological Sciences at the University of Calabria (2002) and a PhD in Petrography and Petrology (2005–2008) at the University of Catania. Since December 2008, he has been a Researcher at the Department of Biology, Ecology and Earth Sciences, University of Calabria. He is involved in teaching activity on several courses in the fields of petrographic and mineralogical disciplines and geo-mineralogical

studies applied to the conservation and restoration of Cultural Heritage. He is the scientific representative responsible for several agreements with national and international research institutions and universities, as well as for diagnostic analysis carried out on the Trevi Fountain during the 2014/2015 restoration. He is the scientific representative responsible for several national and international research

projects. At present, his main research interests concern the field of Cultural Heritage and, in particular, the characterization of stone building materials, their decay and the experimentation of innovative protective products as well as the archeometric study of chronologically different ceramic remains. Some of the investigated sites include the Trevi Fountain (Italy), Herculaneum (Italy), cave churches (Tokaly in Cappadocia, Turkey), Pompei (Italy), the underwater site of Baia (Campania, Italy), the Val di Noto area (Sicily, Italy), and the non-catholic cemetery of Rome (Italy). He is author and co-author of 158 peer-reviewed publications, 3 book chapters, 115 abstracts and proceedings, and 2 patents.