AIR POLLUTION AND HISTORIC MONUMENTS

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Abstract

A research program to evaluate the effects of air pollutants on the outside of historic and artistic buildings has requested to carry out experiments in sites with different environmental conditions. We have selected two areas of the historic centre of Rome and two sites in the Latium region.

Moreover, in order to assess the damage caused by the deposit of air pollutants, the "greying level" measurement of some monuments selected areas has also been carried out and compared with the results obtained with travertine slabs used as reference.

Introduction

This research aims to study the decay rate of the historic monuments. In particular regards: a) the control of the specific environment; b) the quantitative and qualitative evaluation of stone artifacts superficial damage due to pollution.

Table 1 shows the location of the monuments studied and their environmental characteristics.

Such locations represent case-sites owing to the different proportion between methane gas and traditional fuel oil used in the heating-plants and to the different intensity of traffic. Furthermore, Villa Adriana can be regarded as a "blank", since it is considered a non-polluted area.

Table 1. Environmental characteristics and monuments location.

Site No.	Site name and location	Traffic	Methane plants %
1	Basilica di Santa Maria Maggiore, Rome	Heavy and fast	81
2	Teatro di Marcello, Rome	Heavy and fast	48
3	Chiostro di Villa d'Este, Tivoli	Heavy and stagnant	100
4	Villa Adriana, Tivoli	None	100

Characteristics of materials

The materials of the artifacts have been first studied from a chemical/mineralogical point of view by microscopic analysis.

Two stone samples have been removed from different close sheltered areas of the front-lodge, made of travertine, of Santa Maria Maggiore Basilica. In the travertine pores (2 mm maximum diameter) calcite crystals have been found; moreover, the outer surface shows lack of cohesion because of sulphate formation: this is a clear result of a chemical alteration process.

Three stone samples removed from different close sheltered areas under Teatro di Marcello arches, made of travertine, are characterised by pores (2 mm. maximum diameter) containing calcite crystals. Inside the corrosion gulfs chalk aggregates can be seen. On the samples surface a black thick crust containing carbon particulate, iron oxides, quartz and silicates can be noted.

Environmental measurements

In each of the four seasons, 20-30 days long, air pollution measurement campaigns have been carried out to establish the concentrations of the following four dangerous pollutants:

- sulphur dioxide (SO_2)
- nitrogen oxide (NO) and nitrogen dioxide (NO_2)
- total suspended particulate (TSP).

The measurements have been carried out using a mobile laboratory equipped with continuous automatic analysers. It comprises an analysing device and a computer with a software able to run the whole apparatus as well as to provide drift automatic correction and to effect periodic self-checks.

In Table 2 are showed the pollutants studied and the physical principles of the methods used for their determination: same are classified as "reference methods" by the Environmental Protection Agency (EPA).

Table. 2. Pollutants studied and physical principle of the used methods

Pollutant	Analysing device	Physical principle
SO_2	Automatic detector	UV fluorescence
NO	Automatic detector	Chemoluminescence
NO_2	Automatic detector	
TSP	TEOM automatic detector	Continuous microgravimetry

Greying level measurements

At the same time of the environmental measurements, a campaign has been started to study the greying level of vertical and horizontal travertine slabs (80 x 110 cm) situated in sheltered areas of the four sites examined, in order to obtain an indirect monitoring of the deposition rate of suspended particulate and dust-fall.

Close to the samples studied under Teatro di Marcello arches, it has also been placed an experimental prototype (Electronic Industry Support - EIS) able to measure automatically the brilliance (inversely correlated to the greying level) of travertine reference samples (5 cm diameter disks). Measurements are also being carried out on some stone surfaces, close to the reference slabs. It is important therefore to set initial standard conditions of brilliance and consequently:

- travertine samples (slabs and disks) have been rubbed and cleaned first using a soft sponge wetted with distilled water, then they have been dryed up in open air for 24 hours and finally they have been stabilised as proved by the constant reference value obtained with a repeated series of brilliance measurements;
- original stone areas have been cleaned by applying pads wetted with a salt solution (250 g ammonium carbonate in 1 litre of distilled water) and then rinsed up and stabilised to a constant brilliance value.

Brilliance measurements on vertical and horizontal travertine surfaces exposed to air pollutants and protected against the rain, have been carried out with a Minolta CM-2002 spectrophotometric colourmeter. This instrument, complying with CIE (Commission International d'Eclairage) requirements, carries out 10 measurements and then automatically calculates the mean and the standard deviation.

The other apparatus (EIS) is similar to the Minolta colourmeter but is also provided with self-setting exposure and reading of samples: in this way the brilliance measurements on the "horizontal" travertine slabs can be compared with the colourmeter ones.

The above prototype, provided with a software that runs the whole apparatus, carries out measurements on four travertine disks after automatic resetting, before each measurement, on two reference disks (white and black) situated inside the instrument.

The travertine slabs and the stone monuments areas have been also analysed with a videomicroscope (Simitecno) equipped with an image processing program. This apparatus is very useful for the determination of the colour trichromatic components R, G, B (Red, Green, Blue) and for obtaining micromaps enhancing different greying level (using the "trace contour" program).

All the instruments and the samples analysed are listed in Table 3.

Table 3. Greying level measurements: employed equipments and samples.

1) Spectrophotometric colourmeter (mobile equipment) for measurements:
   - on travertine slabs (reference samples);
   - on stone monuments areas.
2) EIS equipment for automatic measurements:
   - on travertine disks (reference samples).
3) Image analysing videomicroscope (mobile equipment) for measurements:
   - on travertine slabs (reference samples);
   - on stone monuments areas.

Results and discussion

Considering the results obtained until now some conclusions can be pointed out:

1. Both Santa Maria Maggiore and Teatro di Marcello areas show maximum NO_x and TSP concentrations nearly in the same hours: early in the morning (8-9 a.m.) and late in the evening (between 20:30 and 23:00. and up to 00:30): such values are between 100 and 150 (as expressed in $\mu g/m^3$ for TSP and in ppb for NO_x) and on the average they appear to be greater in the summer and slightly higher for Teatro di Marcello.

   On average basis lower TSP concentrations (between 50 and 110 $\mu g/m^3$) can be found in the two Tivoli sites with the exception of the autumn campaign at Villa d'Este which shows different values at different times thus pointing out a particular situation likely due to the piling up of earth particles because of adjustment and re-arrangement works near to the site and of the blowing wind especially in the evening and at night.

   It has also to be underlined that the average TSP values found at Villa Adriana (unpolluted area), between 50 and 130 $\mu g/m^3$, are due to the peculiar site as well as to summer rain shortage. NO_x concentration values are low (between 10 and 40 ppb) in both Tivoli sites.
2. Sulphur dioxide concentrations are very low or near zero at night hours in all sites.
3. During the day NO_x and TSP concentrations depend chiefly on traffic whilst sulphur dioxide presence can hardly be noted because of its lower content in traditional fuel oil and of the progressive use of methane gas in the heating-plants (Lorusso[1]).
4. NO_x and TSP maximum and average values largely confirm the noxious quantity of these two pollutants in Rome areas. Their rather high values suggest to set pedestrian islands in order to reduce as much as possible the problems resulting from traffic pollution. TSP deposition in the cities give rise to more and more frequent cleaning and restoration of the monuments located in the historic centres, since the suspended particulate heavily affects outdoor stone materials, in particular all limestone monuments (Lorusso[2,3]).

Up to now however, no attempt has been made to check the damage using easy, quick, reproducible and cheap non-destructive methods. To that purpose in the present work two equipments, a prototype (EIS) and an image analyser videomicroscope, have been used to enable automatic measuring of surfaces progressive greying.

The main conclusions coming out from these studies are:

1. The decrease of brilliance values is continuous for all the surfaces under examination; moreover, the greying values of the horizontal travertine slabs, obtained with the spectrophotometric colourmeter, appear to be much higher than those of the vertical ones because of dust fall influence.
   Nevertheless it can be noted that:
   - some brilliance values related to the vertical slab at Santa Maria Maggiore (63.4% on March 1996 compared to 58.5% on November 1995) as well as to the horizontal slab at Teatro di Marcello (15% on March 1996 compared to 14.6% on November 1995) appear to have been originated by experimental and climatic circumstances;
   - as it has already been mentioned, the decrease of brilliance values in both Tivoli sites has been caused by earth particles coming from areas around the sites.
2. Comparing the horizontal slab values obtained from the spectrophotometric colourmeter with those coming from the EIS prototype concerning the travertine disks at the Teatro di Marcello site, it comes out that results are almost the same (figure 1). The EIS prototype, easy to use and provided with automatic resetting and reading of the stone surface greying level, seems to satisfy the need to assess automatically the degree of pollution caused by the so-called "black smokes" in the historic centres with heavy traffic.

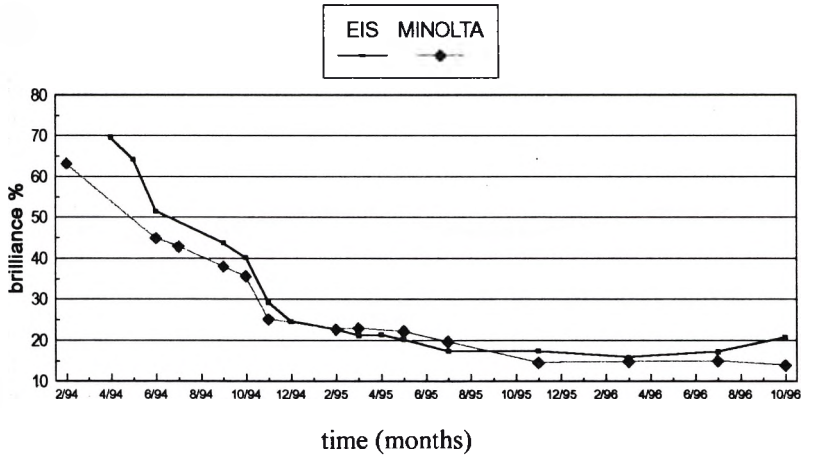

Figure 1. TEATRO DI MARCELLO - Rome
Pattern of greying measurements by EIS equipment on travertine disks and by spectrophotometric colourmeter on travertine horizontal reference slabs.

Elaboration of the R, G, B values obtained with the videomicroscope are still in progress; however, some images of the horizontal slab located at the Teatro di Marcello, before and after 7 months exposure, show differences in the colour enhanced using the image analysis program (trace contour): the most dirty parts (red) are easily compared with the best conserved ones (green-blue).

With regard to Teatro di Marcello site it is showed, in figures 2 and 3 correspondingly, the mean concentration values for SO_2, NO_x, TSP and the typical Monday through Saturday day; in figures 4-7 the photos and the successives elaborations obtained with the image analysing videomicroscope.

In conclusion, the use of the EIS equipment together with the image analysing videomicroscope in order to obtain reference micromaps of the examined surfaces, will permit to combine the concentration values of the airborne pollutants with the data concerning the effects of their deposition on areas of materials protected against the rain (the so-called effect of the dry deposition). This method could be a good reply to the need of an easy, cheap and non-destructive technique to keep under control the levels of the environmental pollution in the historic centres.

References

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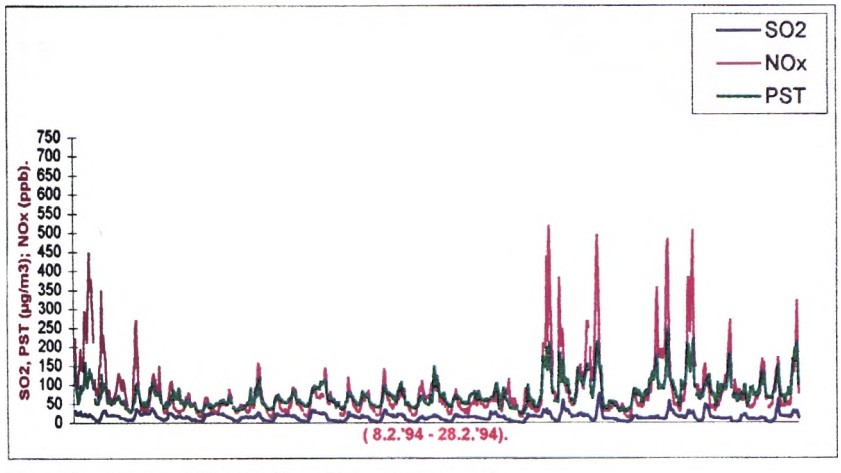

Figure.2. Teatro di Marcello - Winter Campaign
Mean Concentration values for SO_2, NO_x, TSP.

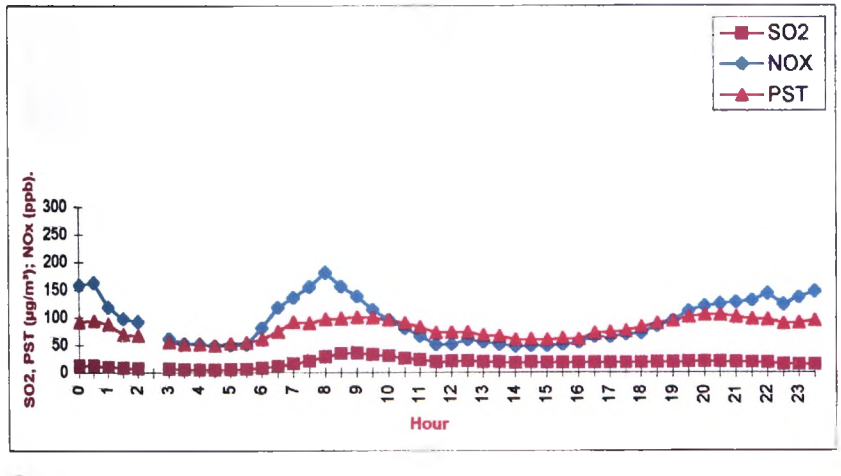

Figure.3. Teatro di Marcello-Winter Campaign
Typical Monday through Saturday day

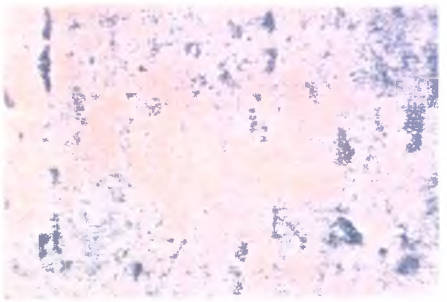

Fig.4. TEATRO DI MARCELLO - Rome
Horizontal travertine slab photographed by videomicroscope on 25.7.1995

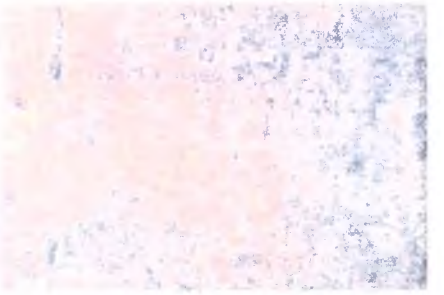

Fig.5. TEATRO DI MARCELLO - Rome
Horizontal travertine slab photographed by videomicroscope on 14.3.1996

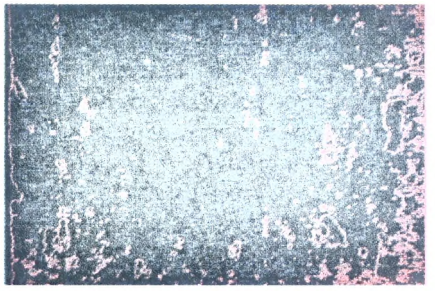

Fig.6. Slab showed in figure 4 processed by image analysing videomicroscope using "trace contour"

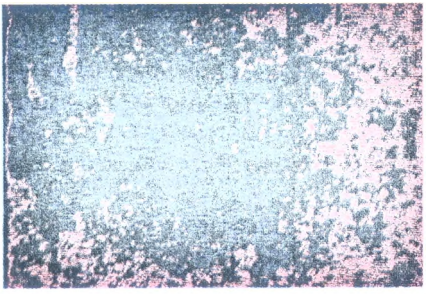

Fig.7. Slab showed in figure 5 processed by image analysing videomicroscope using "trace contour"