Methodologies and sensors for microclimatic monitoring in confined ambients

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The creation of indoor environmental conditions suitable for conservation is a complex problem.

These may be often the presence of numerous visitors, a number of related infrastructures (heating, lighting, etc.), or particular internal conditions inherent to the environment itself (e.g. caves or hypogea).

The study requires accurate and appropriate methodologies and analytical instrumentation, often built ad hoc, to identify both problems and interventions.
In the last 30 years, more sophisticated analyses were done to:

- identify the **precise causes** of environmental variations
- define the most suitable **conservation procedures**
- reach **practical solutions** to improve the environment

**WHAT ARE THE NUMEROUS PROBLEMS TO BE TAKEN INTO CONSIDERATION IN INDOOR ENVIRONMENTS??**

Some examples
through studies carried out or in progress as part of national and international projects
WHERE ITALY was or is involved
Management of the indoor environment

Doors & windows

Cleaning

Δ RH 20%

S. Croce Museum
Florence (Italy)

Max variation of T
6-7°C in 30 minutes

Max variation of SH
4 g/kg in 30 minutes

Max variation of RH
30% in 30 minutes
Heating & Cooling

Traditional systems

S. Croce Museum - Florence (Italy)

2 heating systems

- Highest differences of T: 20°C
- Highest difference of RH: 40%

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Difference in T of 2-3°C every 2-3 h

Modern sophisticated systems
Natural and artificial lighting

Effects on the tables
- Heating of the surface
  - Gradients of T and RH
  - Elongation
  - Variation of EMC in the material

S. Croce Museum Florence (Italy)

Deposizione della Croce of Francesco Salviati

Cimabue’s Cross

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Natural and artificial Lighting

- High and low levels (max. 1.5°C in May)
  - mainly due to artificial and natural lighting
- Front and back surfaces (max. 3.7°C in May)
  - mainly due to thermal inertia of the materials

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Capilla Mayor, Santiago de Compostela Cathedral (Spain)

Escursions due to:
- Lighting
- Solar radiation
- Heating of non isolated ceiling

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The number of visitors need to be controlled and regulated

Example:

Each person emits about: 150 Wh of energy 50 g/h of vapour

The Sistine Chapel (Rome)

- ~6000 ÷ 7000 persons/day with peaks to ~17,000 persons
- average time of visit ~30 minutes

Results: considering an average time of visit ~30 minutes every day the public emits in the Chapel

- 450 ÷ 1250 kWh
  (it corresponds to switching on of 1500 ÷ 4000 of 100-watt lamps for 3 hours)
- 180 ÷ 400 kg of vapour
The pollutants need to be controlled and reduced

The environmental/physical conditions strongly influence the absorption of gases and deposition of suspended particles

The deposition of pollutants depends on:

- their concentration in air that can be filtered
- velocity of deposition: depending on the environmental parameters (T, RH, surface T, concentration of vapour, wind, dimension of particulate, physical conditions of the surface, etc.) so the indoor microclimate needs to be correctly managed

Sistina Chapel - Rome (Italy)
VIDRIO

Determination of conditions to prevent weathering due to condensation, particle deposition and micro-organism growth on ancient stained glass windows with protective glazing

Coordinator: CNR-ISAC
http://www.isac.cnr.it/~vidrio

Multidisciplinary research to:

- study the effects of the indoor and outdoor environment on the ancient glass and on the grisaille
- evaluate the efficiency of the protective glazings combining the effects of microclimatic conditions, pollutants and microbiological growth

Cologne Cathedral
Sainte Chapelle-Paris

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Technologies and tools to prioritize assessment and diagnosis of air pollution impact on immovable and movable Cultural Heritage

Coordinator: CNR-ISAC
http://www.teachproject.eu

Objectives:

The pollutants responsible for the weathering of cultural heritage are changing. It is necessary to identify the pollutants which will play the most important role in the future and to monitor their effects by means of new and appropriate devices and tools.
Energy consumption & Energy saving

During the last years other priorities are emerging:

- A greater energy efficiency
- An increase of the use of energy conservation technologies and renewable energy sources
- A reduction of atmospheric pollution, in particular CO$_2$

Approximately 80% of the buildings and structures of the future cities are already constructed.

About 20% of existing buildings are Historical Buildings (HB) corresponding to more than 3.5 million HB in urban areas.
Cultural & Historical Buildings are **highly energy demanding**

We need to achieve “**Energy Efficiency**” but....
We **must conserve works of art** &
We must reach comfort for visitors and staff...

So ... "possible" applications in Cultural & Historical buildings (*e.g.* incorporation of new materials) need to be identified & **technologies** need to be **adapted** to overcome the barriers

During the **7FP**, some projects were focused on the **reduction of energy** in the Cultural & Historical buildings...

Three running projects where Italy is participating:

- 3ENCULT
- MESSIB
- EFFESUS
It is devoted to demonstrate that in Historical Buildings the Energy Efficient retrofit is useful for structural protection as well as for comfort reasons - for users and for heritage collections.

3ENCULT aims also to demonstrate the feasibility of a “Factor 4” to a “Factor 10” reduction in energy demand, depending on the case and the heritage value.
Multi-source Energy Storage System Integrated in Buildings

WP8 Leader: CNR-ISAC

1. S. Croce Museum in Italy, Florence
2. Archeological museum in Spain, Alicante, Novelda

New materials for the conservation of works of art:

Phase Change Materials (PCM)

Analysis in S.Croce Museum in Florence
The main goal is to develop and demonstrate a methodology for assessing and selecting energy efficiency interventions, based on existing and new technologies compatible with heritage values.

A multi-scale data model for the management of energy to control the environment in historic buildings and urban districts controlled differently from modern cities.

New non-invasive, reversible yet cost-effective technologies for significantly improving thermal properties.

Regulations and building policies.
Today more sophisticated analyses need more accurate devices and tools.

Insufficiently precise and accurate instrumentation and an incorrect use and knowledge can lead to a wrong evaluation of the environmental dynamics and/or to an incorrect interpretation of physical or chemical processes which cause weathering.

e.g. microclimatic monitoring at the Lascaux caves

<table>
<thead>
<tr>
<th>Parameter/phenomenon</th>
<th>Required accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature air &amp; surface</td>
<td>0.01 °C</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>0.1 - 0.2 %</td>
</tr>
<tr>
<td>Condensation on the surface</td>
<td>new dew sensor</td>
</tr>
</tbody>
</table>

Coordinator: CNR-ISAC
Technology transfer

SPIN OFF of the Italian Ministry (CNR is a shareholder)

Research project “Development of new meteorological and microclimatic instruments to measure physical parameters in extreme environments”

Dew Sensor
- Temperature of the air (accuracy ~0.01 °C)

Psychrometer
- Contact temperature (accuracy ~0.01 °C)
- Relative Humidity (accuracy ~0.02 % RH)

Research & Environmental Devices
www.red-srl.com

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European Directive and Standards

- **CEN/TC346**: “Conservation of Cultural Property”

Italy is strongly involved in numerous WPs devoted to indoor conservation.

In particular in:

- **WG 4**: Protection of the collections
- **WG 6**: Exhibition lighting of CH
- **WG 7**: Specifying and measuring indoor/outdoor climate
- **WG 8**: Energy efficiency in Historical buildings

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Conclusions

Needs to reach a sustainable indoor environment to preserve works of art are:

- to obtain a clear picture of the “specific” environment and materials
- to use the most suitable instrumentation
- to understand the environmental causes of weathering of CH
- to find the most suitable solutions

and...

- to respect the new environmental demands in particular to save energy and reduce the pollution
Many thanks for your kind attention

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