Evaluation of environmental conditions of the Museo del Ejército (Toledo, Spain) by means of Sol-Gel optical sensors

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INTRODUCTION

- Gaseous pollutants enhance most of degradation processes of materials due to high acidity (low pH).
- No device in the market is able to measure acid-basic chemical species in the air.
- TechnoHeritage groups C02 and IC2 have developed pH optical sensors to measure acidity/basicity.
- Evaluation of environmental pH levels of the Museo del Ejército.
MUSEO DEL EJÉRCITO (Army Museum)

- It is a state-owned museum attached to the Spanish Ministry of Defense.

- Wide variety of items and materials from 15th century AD, distributed over 8,000 m².

- Installed currently in the Alcázar of Toledo since 2010. (Stronghold palace rebuilt on overlapping Arabian, Medieval and Renaissance castles).

- Different kinds of materials (metals, textiles, paper documents, woods, leathers, paints, and so on).

- Interesting challenge: studying their preventive conservation.
• LED – Photodiode combination.
• Temperature sensor also inside.
• Portable, low power consumption, temperature compensated.
• User-friendly application to handle and store data recorded.
SYNTHESIS OF SENSORS

• Synthesized by the Sol-Gel method:
  – A thin coating from a sol deposited by dipping upon common glass slides.
  – Soft thermal treatment to transform the sol into a gel.

• Organic dye sensitive to pH encapsulated in the thin coating.

• Coated slides cut and polished to the size required.

Acid pH

\[
\begin{align*}
\text{pH} = 3 & \quad \text{Yellow} \\
\text{Basic pH} & \quad \text{pH} = 9 \quad \text{Purple}
\end{align*}
\]
INSTALLATION OF SENSORS

- Inside of representative showcases of different sizes and content.
- Non-visible places to do not disturb exhibition.
INSTALLATION OF SENSORS

- Air from the environment of the exhibition rooms selected.
- Outdoor façades of the building.
<table>
<thead>
<tr>
<th>Position</th>
<th>Room</th>
<th>Sensors</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vexilia</td>
<td>2</td>
<td>Inside two different showcases containing flags</td>
</tr>
<tr>
<td>2</td>
<td>Artillería</td>
<td>1</td>
<td>Behind a cannon exposed to the room air</td>
</tr>
<tr>
<td>3</td>
<td>Etnografía</td>
<td>1</td>
<td>Inside a showcase containing a Japanese armour</td>
</tr>
<tr>
<td>4</td>
<td>Pla Dalmau</td>
<td>1</td>
<td>Under a showcase exposed to the room air</td>
</tr>
<tr>
<td>5</td>
<td>Condecoraciones</td>
<td>1</td>
<td>Inside a showcase containing medals</td>
</tr>
<tr>
<td>6</td>
<td>Miniaturas</td>
<td>1</td>
<td>Inside a showcase containing miniatures</td>
</tr>
<tr>
<td>7</td>
<td>Uniformidad</td>
<td>1</td>
<td>Under a support inside a showcase containing uniforms</td>
</tr>
<tr>
<td>8</td>
<td>Medinaceli</td>
<td>4</td>
<td>Inside four different showcases containing armours and weapons</td>
</tr>
<tr>
<td>9</td>
<td>Monarquía Hispánica</td>
<td>2</td>
<td>Inside two showcases containing textiles</td>
</tr>
<tr>
<td>10</td>
<td>Monarquía Ilustrada</td>
<td>1</td>
<td>Beside a showcase exposed to the room air environment</td>
</tr>
<tr>
<td>11</td>
<td>Liberales-Absolutistas</td>
<td>4</td>
<td>Inside showcases containing several materials and to the room air</td>
</tr>
<tr>
<td>12</td>
<td>Estado Liberal</td>
<td>7</td>
<td>Inside an Arabian tent and showcases containing distinct materials</td>
</tr>
<tr>
<td>13</td>
<td>Restauración</td>
<td>6</td>
<td>Inside showcases containing weapons, flags and paper documents</td>
</tr>
<tr>
<td>14</td>
<td>Siglo XX</td>
<td>5</td>
<td>Inside showcases containing textiles, metallic and wooden pieces</td>
</tr>
<tr>
<td>15</td>
<td>Outdoor</td>
<td>4</td>
<td>Four outdoor positions at the museum façades</td>
</tr>
</tbody>
</table>
RESULTS

After 8 months of continuous monitorization (October 2011-April 2012)

Average of environmental pH

- Indoor pH: from 6.2 to 8.2 (nearly neutral condition)
- Outdoor pH: from 3.0 to 6.9

Barely noticeable variations recorded inside showcases due to their ventilation system.

No clear influence from materials exhibited in showcases.

Pla Dalmau (room 4)
Medinaceli (room 8)
RESULTS

After 8 months of continuous monitorization (October 2011-April 2012)

- Stabilization period is established as much as 1 month (low RH indoor, ~35%)
- Later, pH recorded varied in a narrow range at about neutral conditions.

pH evolution in positions of room 11

- Showcase with items of wood and metals
- Air from a room with many visitors
RESULTS

After 8 months of continuous monitorization (October 2011-April 2012)

Temperature evolution

- Indoor: from 19.2 to 25.9°C
- Outdoor: from 2.5 to 22.0°C

Bars indicate maximum and minimum values.
CONCLUSIONS

- pH sensors based on Sol-Gel technology together with a portable electronic measurement device have been successfully applied.

- 8 months of continuous monitorization (October 2011-April 2012):
  - Outdoor average values ranged around a very acid pH (5.0) due to urban gaseous pollutants.
  - Average values of indoor pH were close to theoretical neutral conditions (7.2). Building materials (such as stone, bricks, mortars, etc.) may have played as active absorbent surfaces of gaseous pollutants.

- Control systems of this Museum have been good enough to exclude outdoor and even indoor acid pollutants.
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