Understanding Microclimates in Museums, Historic Houses, and Churches and their Impact on Heritage Materials

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Topic 4

Analysis and Interaction of Air Pollutants and Objects

Themes are monitoring in museum environments (Microclimate Studies) and the impact of these environments on selected heritage materials (Damage Assessment).

In the PROPAINT project “Improved protection of Paintings during Exhibition, Storage and Transit”, the aim was to monitor the air quality within microclimate frames, in the SENSORGAN project “Sensor System to Detect Harmful Environments” the aim was to monitor within lead-based organ pipes in contact with wooden parts of the organ.

Impact on Heritage Objects

Studies of the effect of pollutants were made on parchment in the IDAP Improved Damage Assessment of Parchment” project, and on varnished strips exposed in frames for paintings in the PROPAINT project.
Microclimate Studies

Parameters which affect microclimatic conditions

RH, T, light, pollutants (inorganic and organic)

Monitoring

Methods for monitoring air quality in museums have not yet been standardised and are not extensively used. For microclimates it is more difficult due to limited volume for air sampling.

Limitations

High cost of some techniques
No clear correlation between level of pollutants and impact on collections have discouraged monitoring on a large scale.

Dosimetry for Microclimate Studies

Dosimeter has enhanced sensitivity to the main cause of damage and the synergistic effect of contributing factors.

The PQC-dosimeter responds to the cumulative dose received and can be responsive to (1) volatile organic acids or (2) photooxidising effects.

The change monitored is of a chemical nature and is irreversible. The larger the change monitored the greater the degradation of the material in the particular environment.

Impact on Heritage Materials

Damage Assessment

Courtesy D. Thickett English Heritage published in ICOM-CC Proceedings
“Refitting old display cases” Vol 2 773 -782 (2008) Corrosion of lead tin solder
(forms lead formate) in jet brooch in showcase Iveagh Bequest, Kenwood House, London English Heritage
Atomic Force Microscopy (AFM) images of modern parchment (goat) after exposure to selected levels of acetic acid vapour

5µmx5µm

Exposed 15 days to 0.6ppm (c1500ug/m3) HAc at 74%RH

D. Bradshaw M.Sc Analytical Chemistry Thesis Birkbeck 2009

5µmx5µm

Exposed 33 days to 0.6ppm HAc at 74%RH

Extreme wrinkling, loss of D-banding occurs

Impact on Parchment Damage Assessment

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Quantification of AFM images gives parameter (peak area) used to measure extent of intactness of D-band of collagen.

Correlates with Ts (shrinkage T) for some historical samples and change in mechanical properties on exposure to programmed RH of pre-dried samples.

R. Larsen “Improved Damage Assessment of Parchment” EC (2007)
Effect of pollutant ageing: AFM images of exposure of modern parchment (calf) to SO2 (50ppm) for 2, 4, 8 and 16 weeks

Sample B (4 weeks)
Extension (2%) on increase in RH

Sample C (8 weeks)
Extension (1.1%) on increase in RH

“Manuali del Senato” State Archives of Genoa, Italy (end of XIVth-beginning of XVth) sample from water damaged bookbindings re-used in 1557

Extension (0.8%) on increase in RH

CHATELAIN’S FINANCIAL ACCOUNTS (CASTELLANIE)
State Archives of Turin

ASTO 4-1: 1467-1469 (goat) sample from sewing border on the recto part
Extension (1.6%) on increase in RH
Impact on Artists’ Varnishes

EC PROJECT PROPAINT

Sample preparation for pollutant ageing

"IMPROVED PROTECTION OF PAINTINGS DURING EXHIBITION, STORAGE & TRANSIT"

Varnishes selected
1. Resin Mastic
2. Dammar
3. Dammar and Tinuvin
4. MS2A
5. MS2A and Tinuvin
6. B72

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Microclimate Studies
Impact of pollutants on properties of varnishes

Measured NO$_2$ concentrations ($\mu$g/m$^3$) in rooms

Tg values of resin mastic coated strips in museums

Tg

Site exposure

Tate Store
National Museum Germany
National Museum Cracow
N.Museum Oslo
Statens (Dk)
English Heritage (K)
Museum Fine Arts Valencia
Tate Britain
English Heritage (Apsley)
Museum Mexico

Measured NO$_2$ concentrations ($\mu$g/m$^3$) in rooms
Resin Mastic Tg of strips in museums within frames (F) and in rooms (R) and measured NO$_2$, O$_3$, HAc values in frames and in rooms

<table>
<thead>
<tr>
<th>Location</th>
<th>Tg / °C</th>
<th>NO$_2$</th>
<th>O$_3$</th>
<th>HAc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tate B (F)</td>
<td>66</td>
<td>2</td>
<td>1</td>
<td>543</td>
</tr>
<tr>
<td>Tate B (R)</td>
<td>90</td>
<td>36</td>
<td>3</td>
<td>106</td>
</tr>
<tr>
<td>Cracow NF (F)</td>
<td>62</td>
<td>0</td>
<td>1</td>
<td>502</td>
</tr>
<tr>
<td>Cracow NF (R)</td>
<td>72</td>
<td>10</td>
<td>2</td>
<td>175</td>
</tr>
<tr>
<td>Valencia ES (F)</td>
<td>83</td>
<td>0</td>
<td>3</td>
<td>435</td>
</tr>
<tr>
<td>Valencia ES (R)</td>
<td>86</td>
<td>27</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>DK (F)</td>
<td>90</td>
<td>4</td>
<td>1</td>
<td>1070</td>
</tr>
<tr>
<td>DK (R)</td>
<td>78</td>
<td>13</td>
<td>13</td>
<td>43</td>
</tr>
</tbody>
</table>

Resin mastic in frame in Statens Museum (DK) shows Tg varnish in frame greater than Tg varnish in room. Levels of HAc in frame are higher. Frame offers no protection.

For Tate Britain Tg of varnish in room higher than in frame, possibly due to higher NO$_2$ in room. So protective action of frame containing painting.
L-PQC dosimeters exposed in Frames and Rooms.

Highest value is given by a prepared model painting in a mc-frame HAc (red)

Above red line values are considered to be above acceptable values
PROPAINT “Improved protection of Paintings during Exhibition, Storage and Transit”
SSPI - 044254

Lead coated PQC Dosimeters for continuous monitoring for volatile organic acids.

PQC dosimeter (battery powered) exposed at the Statens Museum for Art, Copenhagen
**Difference in dosimeter response between front and back of painting in microclimate frame**

![Graph showing temperature and relative humidity changes over time for Behind the painting and In front of the painting.](image-url)

- **Slupecki frame** 20.12.09-30.01.10
- **% change**
- **Time [days]**
- **Temperature [°C], Relative humidity [%]**
- **Behind the painting**
- **In front of the painting**

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Dosimetry for Microclimate Studies  PQC Dosimeter

Change (%) is calculated from the frequency shift $\Delta f$(Hz) relative to the original frequency of the crystal ($F_0$(kHz) after coating.

Change (%) (left) or Rate of change in lead (right) coated L-PQC crystal dosimeter on exposure to 596ppb HAc at 70%RH.

Piezoelectric Quartz Crystal dosimeter developed in MIMIC project (EVK4 -CT- 2000-00040) and adapted to microclimate monitoring in the SENSORGAN project (Birkbeck)
Atomic Force Microscopy of lead coating on L-PQC Dosimeter

before exposure 30 min. after exposure in oak cabinet

roughness: 18 roughness: 28

3.5 µm x 3.5 µm
Miniaturisation for continuous monitoring in organ pipes

Monitoring of organic acids


URL: http://www.goart.gu.se/sensorgan
Wood (pine and oak) is used in the palette boxes of historical organs.

Emission of volatile organic acids is influenced by increases in relative humidity and T.

In SENSORGAN lead coated piezoelectric quartz crystal dosimeters (right) are used to monitor the volatile organic acids.

http://www.goart.gu.se/sensorgan
Site testing using small holder
(a) St Botolph without Aldgate and (b) Örgryte

In St Botolph response is lower for period (8-10-2008 to 12-10-2008)

In Örgryte New Church (newly built baroque organ) response is much higher for period 11.07.08 and 15.07.08
Continuous monitoring in organ pipes at St Botolph without Aldgate, London

07-02-08 to 24-04-08
Pipe over new wood
RH 35-40% 15-20C
Rate of change 1%/day first 8 days

08-10-08 to 23-10-08
Pipe over old wood
RH 50-65% 17-20C
Rate of change 2.75%/day for first 2 days and slows down for 3 days
Miniaturisation of dosimeter

SME QuartzTec and Dr.S.Jakiela ICSC Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Poland
Miniaturisation of dosimeter for use within paint frames

Holder and control box

Measures crystal f, RH, T, light

Control box contains

2 switches for power and USB download of data

Dr. S. Jakiela ICSC Institute of Catalysis and Surface Chemistry Poland
Conclusions

1. PQC L-dosimeter provides an assessment of the quality of the microclimate. A coating of lead on PQC crystals is responsive to volatile organic acids. Accelerated ageing and exposure at sites where volatile organic acids have been measured has demonstrated that the response is proportional to the dose received.

2. PQC L-Dosimeter can be used to rapidly test volatile organic acid levels in enclosures. Where air exchange values are low and acetic acid concentrations exceed c.1500ug/m3 then response occurs within a few hours.

3. If response in enclosure is rapid then this acts as an early warning signal. Ageing studies on parchment show that levels of this magnitude affect collagen structure and there are implications for mechanical properties and response to RH. For varnishes Tg values are also affected.

4. AFM provides information on changes in (1) surfaces of materials and DMA on glass transition temperatures of varnishes.

5. Correlation was found between changes in parchment structure (at nanoscale level) and shrinkage temperature and mechanical properties on response to programmed RH of pre-dried samples.
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