A Little Background

A previous study* of air quality in European museums had compiled reactivity monitoring data for the period 1990 – 1999.

Presented data from analysis of environmental reactivity coupons (ERCs).

- 8 countries; 60 museums, libraries, and archives; mostly silver coupons

Indoor Air Quality Measurements
(1990-1999)
A Little More Background

The “cause-and-effect” relationship between levels of gaseous pollutants and the damage caused to materials and artifacts remains elusive.

There is no real agreement on what actually constitutes an acceptable environment with respect to airborne gaseous pollutants.
### Museum Air Quality Standards

<table>
<thead>
<tr>
<th>Contaminant/Parameter Measured</th>
<th>Concentration</th>
<th>Reactivity Level, Å/30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppb</td>
<td>µg/m³</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>&lt;4</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Chlorine</td>
<td>≤1 - 3</td>
<td>≤3 - 9</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>&lt;4</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Hydrogen chloride</td>
<td>≤1 - 3</td>
<td>≤1.5 - 4.5</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>≤2.65</td>
<td>≤5</td>
</tr>
<tr>
<td>Ozone</td>
<td>≤0.94 - 12.5</td>
<td>≤1.8 - 24.5</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>≤0.35 - 1.0</td>
<td>≤1 - 2.85</td>
</tr>
<tr>
<td>Silver Corrosion</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Copper Corrosion</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

These are still the most commonly cited specifications for gaseous pollutants, although H₂S and COS are beginning to show up as well.

a - with no chloride corrosion evident, b - with no sulfur corrosion evident
## ERC Sensitivities

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Chemical Types</th>
<th>Detection Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic chlorine compounds</td>
<td>Cl₂, HCl</td>
<td>&lt;1 ppb</td>
</tr>
<tr>
<td>Halogen acids</td>
<td>F₂, HF, HBr, HI</td>
<td>&lt;1 ppb</td>
</tr>
<tr>
<td>Strong oxidants</td>
<td>O₃, ClO₂, HNO₃</td>
<td>&lt;2 ppb</td>
</tr>
<tr>
<td>Active sulfur compounds</td>
<td>H₂S, COS, elemental sulfur, mercaptans</td>
<td>&lt;3 ppb</td>
</tr>
<tr>
<td>Sulfur oxides</td>
<td>SO₂, SO₃ (sulfuric acids)</td>
<td>&lt;10 ppb</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>NO, NO₂, N₂O₄</td>
<td>&lt;50 ppb</td>
</tr>
<tr>
<td>Ammonia and derivatives</td>
<td>NH₃, NMP, amines</td>
<td>200-500 ppb</td>
</tr>
</tbody>
</table>
Reactivity monitoring is a standard for all Dutch government archives.

“Advisory guideline air quality archives”

(March, 1995)

“The chemical pollution of the air in the archives should meet the air purity class DELTA 1, extremely pure, with a maximum corrosive value of the air of 40 Å (Ångstroms) per 30 days.”
### Air Quality Standards for Copper and Silver Reactivity*  

<table>
<thead>
<tr>
<th>Copper Reactivity</th>
<th>Corrosion Amount</th>
<th>Silver Reactivity</th>
<th>Corrosion Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
<td><strong>Air Quality Classification</strong></td>
<td><strong>Corrosion Amount</strong></td>
<td><strong>Class</strong></td>
</tr>
<tr>
<td>C1</td>
<td>Extremely Pure</td>
<td>&lt;90Å / 30 days</td>
<td>S1</td>
</tr>
<tr>
<td>C2</td>
<td>Pure</td>
<td>&lt;150Å / 30 days</td>
<td>S2</td>
</tr>
<tr>
<td>C3</td>
<td>Clean</td>
<td>&lt;250Å / 30 days</td>
<td>S3</td>
</tr>
<tr>
<td>C4</td>
<td>Slightly Contaminated</td>
<td>&lt;350Å / 30 days</td>
<td>S4</td>
</tr>
<tr>
<td>C5</td>
<td>Not Acceptable</td>
<td>≥350Å / 30 days</td>
<td>S5</td>
</tr>
</tbody>
</table>

*Reactivity monitoring is being drafted as an ISO standard (ISO/CD 11844).
Air Purity Recommendations

- **Class S1/ C1**: Archives, Metal Collections, Rare Books
- **Class S2/ C2**: Museums, Museum Storage, Libraries
- **Class S3/ C3**: Historic Houses
- **Class S4/ C4**: Indoor Short Term Acceptable
- **Class S5/ C5**: Not Acceptable
ERC Data Analysis

Corrosion on copper is nonlinear.
- Main corrosion products are sulfides and oxides.

Silver corrosion is essentially linear.
- Main corrosion products are chlorides, sulfides, and oxides.

Outdoors: **Copper** > **Silver** due to RH effects and higher pollutant concentrations than indoors.

Indoors: **Silver** > **Copper** if temperature/RH controlled.
- Silver is much more sensitive to low levels of pollutants.
Worldwide

- 19 countries
- 282 different locations
  - 228 museums
  - 30 archives – including 8 national facilities
  - 24 libraries – including 10 national facilities
- More than 4,000 ERCs, more than 75 ERMs

USA

- 31 states and the District of Columbia
Europe
- 12 Countries
- 41 Cities
- 74 Museums / Archives / Libraries
- 559 ERCs

Asia – 4 countries, 7 cities, 9 locations, 98 ERCs

Australia – 5 cities, 14 locations, 106 ERCs
Indoor levels of corrosion average ~50% of outdoor levels – indicating interior sources of pollutants.

Where air cleaning is employed, indoor corrosion levels are less than 10% the corresponding outdoor levels.

25% of copper coupons show sulfide corrosion, again indicating interior sources of pollutants.

Sulfur dioxide pollution is ubiquitous and **EVERY** silver coupon shows sulfide corrosion.
Future Work

- Look at seasonal variations
  - Corrosion amounts vs. regional NO₂, SO₂, O₃ levels.

- Look at humidity effects – especially indoors.

- Compare location & comparable use categories.
  - Metal collections, film storage, paper archives, etc.

A lot more I cannot think of right now!
Conclusions

The use of reactivity monitoring in conservation environments is expanding as a tool for assessing the aggressiveness of outdoor and indoor environments with regards to gaseous pollutants.

A standard classification system is in place that provides a numerical risk index to convey this information to conservators.

Continued examination of this data will serve to refine this air monitoring technique.
THE END!

Thank you for your attention.

Questions?