An IAQ-index for cultural heritage applications
IAQ assessment

How to make a judgement?
Intuition

Expertise

Experience
Intuitive → rational
(IPI, dew point calculator with preservation evaluation - eClimateNotebook)

(M. Martens, TU Eindhoven, specific risk plot)
EPA Air Quality Index (AQI) - Krakow

<table>
<thead>
<tr>
<th>Air Quality Index (AQI) Values</th>
<th>Levels of Health Concern</th>
<th>Colors</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the AQI is in this range:</td>
<td>...air quality conditions are:</td>
<td>...as symbolized by this color:</td>
</tr>
<tr>
<td>0 to 50</td>
<td>Good</td>
<td>Green</td>
</tr>
<tr>
<td>51 to 100</td>
<td>Moderate</td>
<td>Yellow</td>
</tr>
<tr>
<td>101 to 150</td>
<td>Unhealthy for Sensitive Groups</td>
<td>Orange</td>
</tr>
<tr>
<td>151 to 200</td>
<td>Unhealthy</td>
<td>Red</td>
</tr>
<tr>
<td>201 to 300</td>
<td>Very Unhealthy</td>
<td>Purple</td>
</tr>
<tr>
<td>301 to 500</td>
<td>Hazardous</td>
<td>Maroon</td>
</tr>
</tbody>
</table>

O₃, SO₂, NO₂, CO, PM
IAQ-algorithm for heritage applications

- Key risk indicators
- Heritage-related thresholds
- Material-dependency
Key risk indicators (KRI)
KRI quantification: thresholds
Material dependency
Material dependency
## Material selection

<table>
<thead>
<tr>
<th>Material/Object Type</th>
<th>Subclasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>General collection *</td>
<td>Wood</td>
</tr>
<tr>
<td>Paintings</td>
<td>Cotton and rag paper</td>
</tr>
<tr>
<td>Paper</td>
<td>Restrained</td>
</tr>
<tr>
<td>Wood</td>
<td>Vegetable fibers</td>
</tr>
<tr>
<td>Textile</td>
<td>Restricted silk</td>
</tr>
<tr>
<td>Metal</td>
<td>Silver</td>
</tr>
<tr>
<td>Leather and parchment</td>
<td>Restrained</td>
</tr>
<tr>
<td>Glass</td>
<td>General</td>
</tr>
<tr>
<td>Ceramic</td>
<td>Terracotta/earthenware</td>
</tr>
<tr>
<td>Stone</td>
<td>Limestone</td>
</tr>
<tr>
<td>Ivory/ bone/ antler/ horn</td>
<td>Albumen</td>
</tr>
<tr>
<td>Feather/ insects/ stuffed animals</td>
<td></td>
</tr>
<tr>
<td>Photographs</td>
<td></td>
</tr>
<tr>
<td>Plastics</td>
<td></td>
</tr>
</tbody>
</table>

* The material/object type ‘general collection’ offers an option that is material unspecific as a generic approach. If a sensitive object is present in the collection, one should opt to continue with this specific material.
Material & KRI ranking

Key risk indicators (KRI)
Risk profile

Paintings

- Wood
- Canvas
- Copper

- Too high RH
- Too high dust
- Too high reduced sulfur
- Too high organic gases
- Too high oxidizing gases
- Too high UV
- Too high illuminance
- Too high T
- Too low RH
- Too low T
- Too large RH fluctuations
- Too large T fluctuations
### Algorithm

Data matrix

<table>
<thead>
<tr>
<th>Parameter, $X_1$</th>
<th>Parameter, $X_2$</th>
<th>Parameter, $X_3$</th>
<th>Parameter, $X_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data point 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data point 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data point 2</td>
<td></td>
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<td></td>
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</tbody>
</table>
Algorithm

1. Data matrix

<table>
<thead>
<tr>
<th>Parameter, $X_1$</th>
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<th>Parameter, $X_3$</th>
<th>Parameter, $X_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data point 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data point 2</td>
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<td></td>
</tr>
<tr>
<td>Data point 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Risk, $R_i$

- Parameter $X_1$
- Parameter $X_2$
- Parameter $X_3$
- Parameter $X_4$
Algorithm

1. Data matrix
   - Parameter, $X_1$
   - Parameter, $X_2$
   - Parameter, $X_3$
   - Parameter, $X_4$

2. Risk, $R_1$, $R_2$, $R_3$, $R_4$
   - Parameter $X_1$
   - Parameter $X_2$
   - Parameter $X_3$
   - Parameter $X_4$

3. $R_{\text{max}} = \max \{ w_1 R_1, w_2 R_2, w_3 R_3 \}$

4. $R_{\text{max}} = \max \{ w_1 R_1, w_2 R_2, w_3 R_3 \}$
Algorithm

1. Data matrix
   - Parameter, $X_1$
   - Parameter, $X_2$
   - Parameter, $X_3$
   - Parameter, $X_4$

2. Risk, $R_1$
   - Parameter $X_1$
   - $\times w_1$

3. Risk, $R_2$
   - Parameter $X_2$
   - $\times w_2$

4. Risk, $R_3$
   - Parameter $X_3$
   - $\times w_3$

5. Risk, $R_4$
   - Parameter $X_4$
   - $\times w_4$

$R_{\text{max}} = \max \{w_1 R_1, w_2 R_2, w_3 R_3\}$

$\text{IAQ}_{\text{general}} = 1 - R_{\text{max}}$
Algorithm

1. Data matrix
   - Parameter, $X_1$
   - Parameter, $X_2$
   - Parameter, $X_3$
   - Parameter, $X_4$

2. Risk, $R_1$
   - Parameter $X_1$
   - $\times w_1$

3. Risk, $R_2$
   - Parameter $X_2$
   - $\times w_2$

4. Risk, $R_3$
   - Parameter $X_3$
   - $\times w_3$

5. Risk, $R_4$
   - Parameter $X_4$
   - $\times w_4$

6. $R_{\text{max}} = \max \{w_1 R_1, w_2 R_2, w_3 R_3\}$

7. $\text{IAQ}_{\text{general}} = 1 - R_{\text{max}}$

8. IAQ-index
   - 23/07/2017 to 23/10/2017
<table>
<thead>
<tr>
<th>Time stamp</th>
<th>Temperature (°C)</th>
<th>RH (%)</th>
<th>Lux_AV (lux)</th>
<th>UV (mW.cm²)</th>
<th>PM 2.5 (µg/m³)</th>
<th>NO2 (ppb)</th>
<th>O3 (ppb)</th>
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<td>83.093182</td>
<td>225.46298</td>
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</tbody>
</table>
Conclusion

- IAQ-algorithm
- ↑ environmental parameters
- Practical tool with intuitive visualization
- Reproducible & quantitative IAQ-judgements