The assessment of air quality at the Accademia Gallery, Florence
Aim of the study

- Assessing of the air quality in different locations of the first floor where the statue is displayed;

- Testing the performances of HVAC (heating, ventilation, air conditioning system);

- Testing the effect of the public on the air quality inside the Gallery.
Outline of the study

- Three months of measurements of gaseous pollutants (for each of two consecutive years)
- Six weeks of measurements of particles (during the following year)
- One intensive campaign of measurement of particles (lasting two days)

- Measurements of gaseous pollutants at three internal sites;
- Measurements of particles by gravimetry at two sites (one external and the other near the statue);
- XRF determination of metallic components of PM10;
- Intensive measurements of particles at different heights at three sampling points (right, left and in front of the statue) by nephelometry.
Criteria for conducting an assessment of air quality aimed at the protection of marble made works of art

- **Measure** of pollutants affecting the conservation because of their harmful potential: SO₂ and other acidic gases for ex. HNO₃ and Particles;

- **Map** of the exhibition place especially along the possible infiltration ways;

- Taking into account the presence of **HVAC system test** its performances on protection from external pollutants and check for possible inhomogeneities of the distribution of pollutants inside.
Monitoring gaseous pollutants

Entrance

Prigioni’s Gallery

Michelangelo’s David Tribune
Monitoring gaseous pollutants
Working principle of Diffusive sampling

Fick’s first law

\[ \Phi = -D \frac{dC}{dx} \]

\[ \Phi = \frac{S}{A} \Delta t \]

\[ \frac{dC}{dx} = C_a - C_s \]

\[ C_a = \left( \frac{S \cdot L}{D \cdot A \cdot \Delta t} \right) + C_s \]
Monitoring particles
Monitoring gaseous pollutants

SO₂
Monitoring gaseous pollutants

NO₂
Monitoring gaseous pollutants

\[ \text{NO}_x \]
Monitoring gaseous pollutants

$O_3$

Graphs showing concentration levels of pollutants in different locations and months.
Monitoring gaseous pollutants

- **HNO$_2$**
  - Graph showing concentration (µg/m$^3$) for June, July, September, and October for different locations: David, Prigioni's Gallery, Entrance, and Outside.

- **HNO$_3$**
  - Graph showing concentration (µg/m$^3$) for June, July, September, and October for different locations: David, Prigioni's Gallery, Entrance, and Outside.
Evaluation of the influence of outside environment on indoor air quality

<table>
<thead>
<tr>
<th>Compound</th>
<th>Indoor/Outdoor</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur Dioxide</td>
<td>0.1–0.5</td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>1–3</td>
<td></td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>&lt;1</td>
<td>No internal sources of CO</td>
</tr>
<tr>
<td></td>
<td>1–5</td>
<td>With internal sources of CO</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>0.5–1</td>
<td>No internal sources of NO₂</td>
</tr>
<tr>
<td></td>
<td>2–5</td>
<td>With internal sources of NO₂</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.1–0.25</td>
<td>No internal sources of O₃</td>
</tr>
<tr>
<td>Particles</td>
<td>1</td>
<td>No smokers</td>
</tr>
<tr>
<td></td>
<td>&gt;2</td>
<td>Smokers</td>
</tr>
<tr>
<td>Radon</td>
<td>3–5</td>
<td>Smokers</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Aromatic Hydrocarbons</td>
<td>1–3</td>
<td></td>
</tr>
<tr>
<td>Polycyclic Hydrocarbons</td>
<td>0.5</td>
<td>No smokers</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>&gt;1</td>
<td>Smokers</td>
</tr>
</tbody>
</table>
# Indoor/Outdoor Ratio

<table>
<thead>
<tr>
<th></th>
<th>David (Tribune)</th>
<th>Uffizi/Leonardo (Room 15)</th>
<th>Uffizi/Dürer (Room 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{NO}_2$</td>
<td>0.82</td>
<td>0.55</td>
<td>0.51</td>
</tr>
<tr>
<td>$\text{O}_3$</td>
<td>0.37</td>
<td>0.11</td>
<td>0.08</td>
</tr>
<tr>
<td>$\text{SO}_2$</td>
<td>0.20</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>$\text{HNO}_3$</td>
<td>0.27</td>
<td>0.21</td>
<td>0.06</td>
</tr>
<tr>
<td>$\text{NO}_X$</td>
<td>0.85</td>
<td>0.84</td>
<td>0.89</td>
</tr>
<tr>
<td>$\text{HONO}$</td>
<td>6.03</td>
<td>8.02</td>
<td>12.03</td>
</tr>
</tbody>
</table>
Gravimetric Measurements of PM10

PM10 Concentration (µg/m³)

- Outdoor
- Indoor
- Traffic
- U. B. Bassi
- U.B. Boboli

Dates: 12/11, 14/11, 16/11, 18/11, 20/11, 22/11, 24/11, 26/11, 28/11, 30/11, 2/12, 4/12, 6/12, 8/12, 10/12, 12/12, 14/12, 16/12, 18/12, 20/12, 22/12

Days: Sat, Sun

Weekends show higher PM10 concentrations compared to weekdays.
Gravimetric Measurements of PM10

- Outdoor
- Indoor
- Traffic
- U.B. Bassi
- U.B. Boboli

PM 10 Concentration (µg/m³)

- 350
- 250
- 150
- 100
- 50
- 0

23/1 28/1 2/2 7/2 12/2 17/2

Sat Sun Sat Sun
Nephelometric Measurements of PM10

PM10 Concentration (ug/m³)

HVAC off/closed | HVAC on/closed | HVAC on/open | HVAC off/open

Left | Centre | Right | Left | Centre | Right | Left | Centre | Right | Left | Centre | Right
Conclusions

- Safe levels of SO$_2$ were found;
- HVAC system seemed to be effective (also in the worst conditions);
- No vertical gradients nor noticeable differences in concentrations were found in proximity of the statue.
Thank you!