Sources and Impact of
Urban Air Pollution
25-27 October 2004
Venice

Indoor Air Quality in Museums

Franco De Santis
CNR-IIA

Air quality and Cultural Heritage

- Pollutants contribute heavily to the deterioration of Cultural Heritage
- Gaseous pollutants such as ozone, sulphur dioxide and nitrogen dioxide are involved in chemical reactions with surfaces
- Controlling air quality is difficult and complex and depends on several interrelated factors

Recommended Standard Values for Museum Atmospheres

Pollutant	Recommended Standard
Ozone	1 ppb
Sulphur Dioxide	< 0.4 ppb
Nitrogen Dioxide	< 2.5 ppb
Particles (> PM2), SPM	Removal at 95% Efficiency

The search for a "Threshold"

- In opposition to people, materials accumulate deterioration from any attack, slowly decaying more and more
- Therefore even small exposures to pollutants will have an effect in the large perspective

Risk Management

THRESHOLD

NOAEL (No Observed Adverse Effect Level)

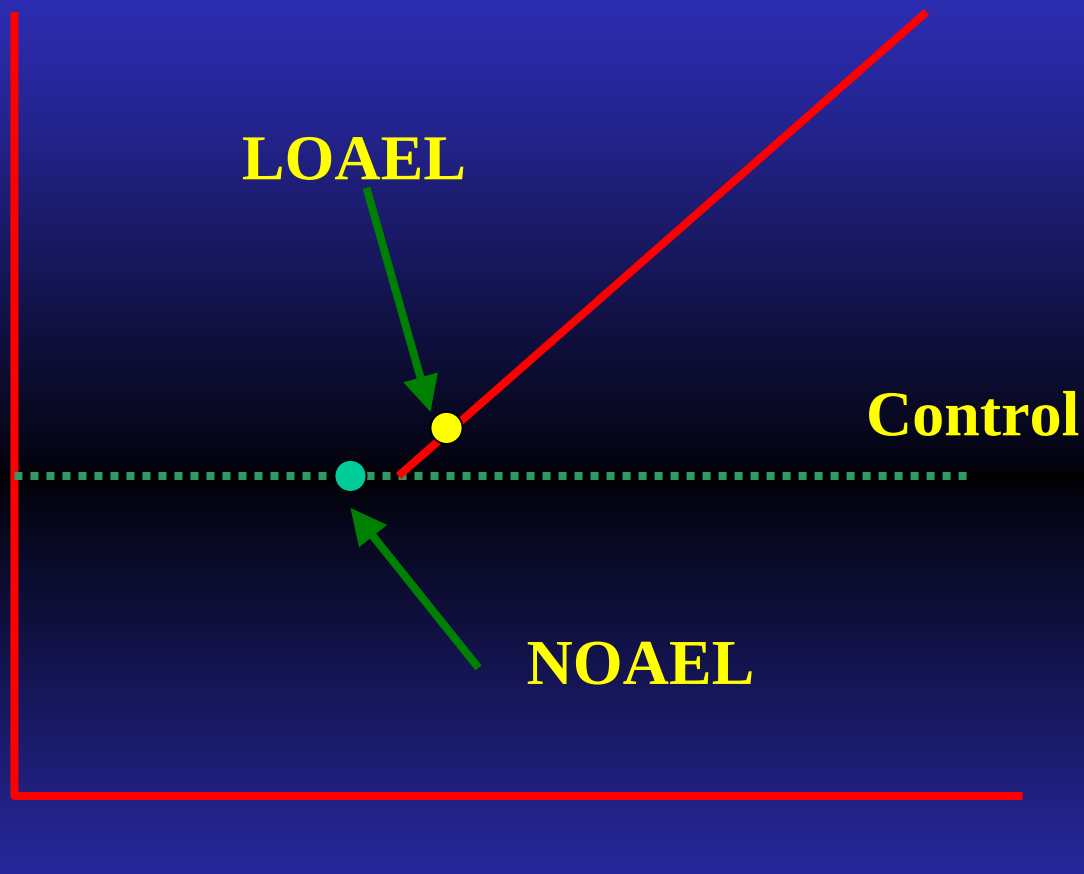
LOAEL (Lowest Observed Adverse Effect Level)

The parameter NOAEL is now becoming increasing popular in the conservation literature as a standard (e.g. Hatchfield and Tétreault)

From Health Protection we know that:

- NOAEL is a level that should be considered safe and requires no application of a safety factor to determine a safe intake, based on the most sensitive subgroup. It is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects.

- LOAEL is a level that should NOT be considered safe for everyone and may require the application of a safety factor to calculate a safe intake. It is the lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects.


RESPONSE
LOAEL
Control
NOAEL
DOSE

Which is the relevance of the NOAEL Concept?

Jean Tétreault has shown that the corrosion of lead surfaces occurs at concentrations of acetic acid above 300 ug/m3 *(Studies in Conservation 48, 273-250, 2003)*

However, Jens Glastrup of the National Museum of Denmark has demonstated that this result has been obtained because he was unable to measure a corrosion lower than 25 nm/year

The "No Observed Adverse Effect Level" concept

- The highest level of a pollutant that does not produce an adverse effect on a specific chemical or physical characteristic of a material

- But it should be added "in a particular experimental set-up"

CNR-IIA Projects funded by EC

Project	Title	Period
STEP	**Physico chemical parameters, including pollutant interactions affecting the rate of dry deposition of SO2 and other pollutants on CaCO3 surfaces**	1991-1994
ENVIRONMENT	Deposition of gases and particles and their corrosive effects on surfaces of cultural and artistic value inside Museums	1994 - 1997
MIMIC	Microclimate Indoor Monitoring in Cultural Heritage Preservation	2001 - 2004
MULTIASSESS	Model for multi-pollutant impact and assessment of threshold levels for cultural heritage	2002 - 2005

EVK4-CT-2000-00040 MIMIC:
Microclimate indoor monitoring in cultural heritage preservation

Microclimate Indoor Monitoring in Cultural Heritage Preservation

Funded by the European Commission Environment Programme

Coordinator

School of Biological & Chemical Sciences, Birkbeck College, University of London (Dr. Marianne Odlyha)

Partners

- **Institute for Atmospheric Pollution of the CNR (National Research Council of Italy).**
- **Institute of Applied Physics (IFAC) (National Research Council of Italy)**
- **National Trust (England, Wales and Northern Ireland).**
- **El Alcazar, Segovia, Spain**
- **National Museum of Denmark, Conservation Dept.**
- **FOM Institute for Atomic and Molecular Physics, The Netherlands**

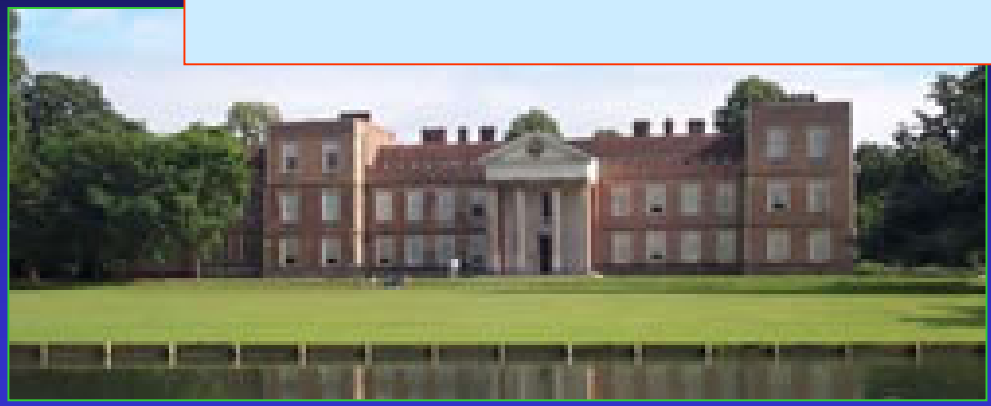
AIR POLLUTANTS and ARTWORKS

The main objective of MIMIC is to provide an early warning damage dosimeter to assess damage

In this framework the CNR-IIA aim was to collect pollutant data at several selected sites

A diffusive sampling technique was used to determine levels of NO_2, NOx, SO_2, O_3, HONO and HNO_3

EVK4-CT-2000-00040 MIMIC:
Microclimate indoor monitoring in cultural heritage preservation



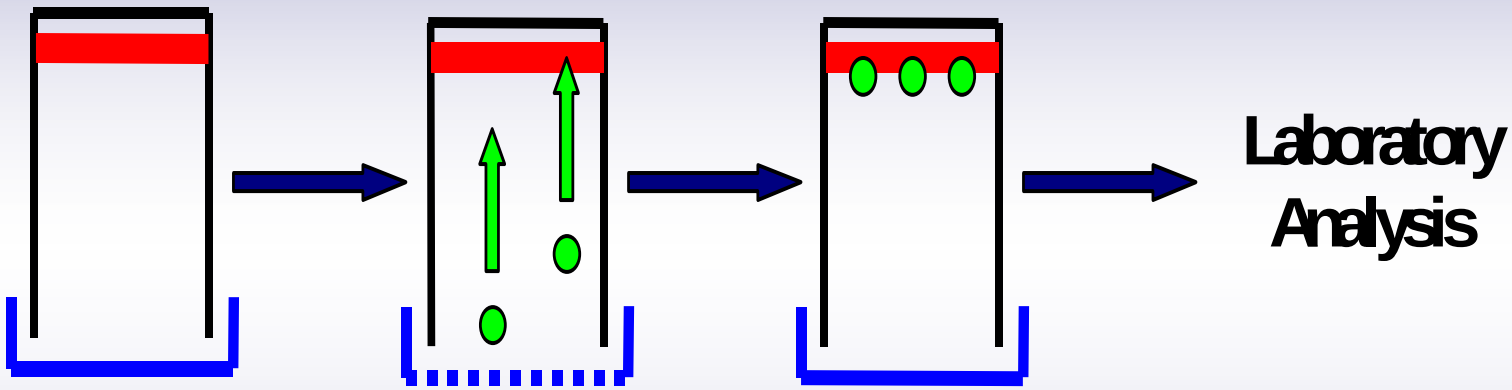
EVK4-CT-2000-00040 MIMIC:
Microclimate indoor monitoring in cultural heritage preservation

"Analyst"

Can be used for

- Indoor-outdoor evaluation
- Ambient air monitoring
- Monitoring of industrial sites

Diffusive sampling. How it works



A B C

The sampler consists of a tube, one end containing a sorbent which fixes the pollutant

After exposure the sampler is closed and returned to the laboratory for analysis

Diffusive Sampling

advantages:

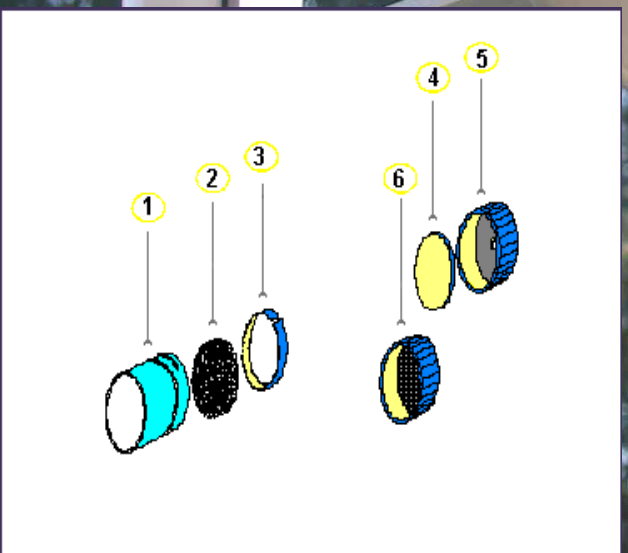
- No pumping systems
- No specialized people for handling
- High spatial resolution
- Low cost
- Little
- Silent
- Not influenced by meteorological parameters

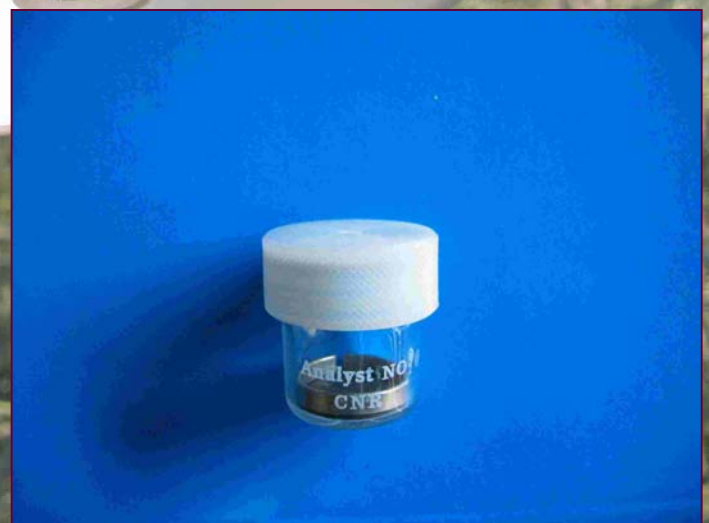
disadvantages:

- Low resolution time

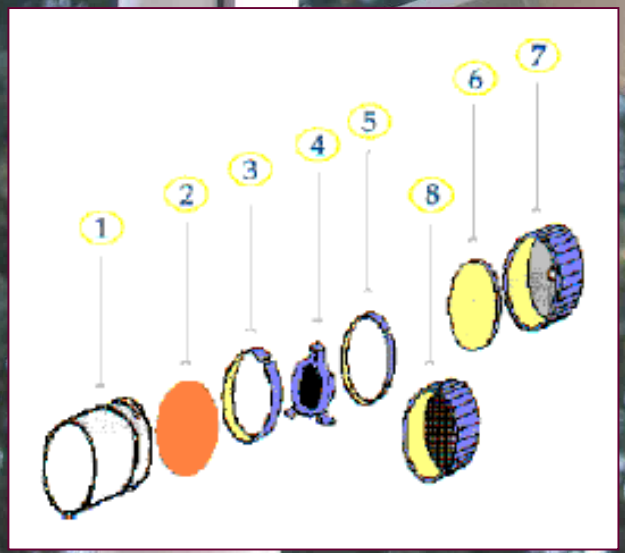
In the overall assessment of the pollutant impact on materials, time weighted averages are more useful than short-term concentrations as they reflect the long-term action of the pollutant

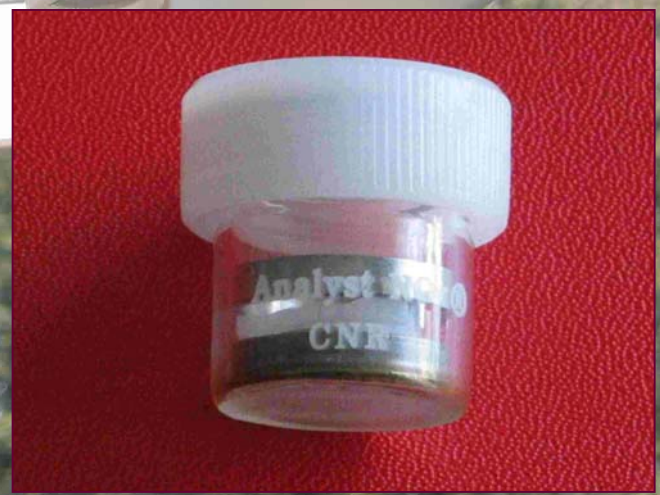
"Analyst" for Nitrogen Dioxide



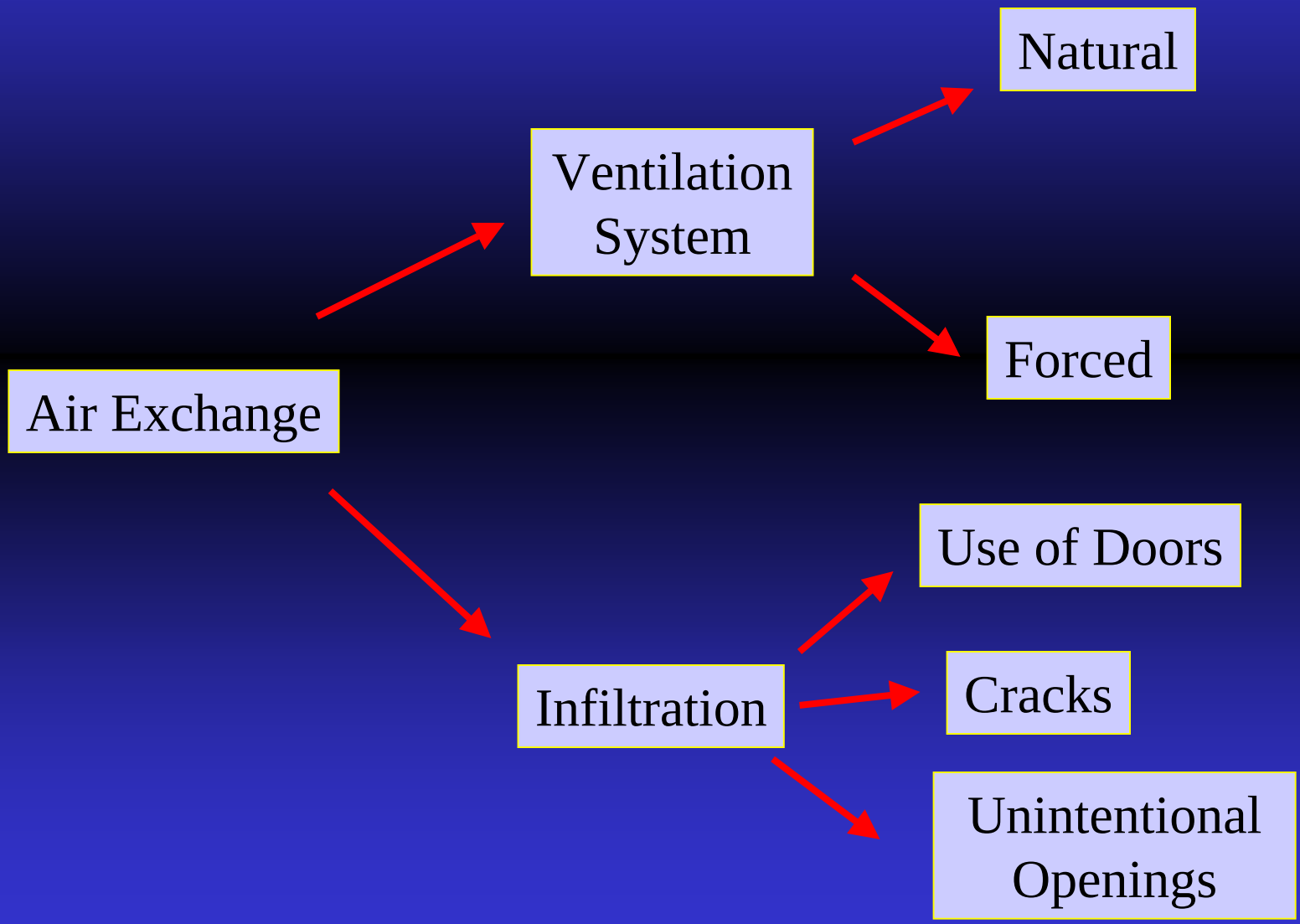


"Analyst" for Nitrogen Oxides





Sampling at the Uffizi


Air Exchange
Ventilation System
Natural
Forced
Infiltration
Use of Doors
Cracks
Unintentional Openings

$$\frac{dC_i}{dt} = mIC_o + S - mIC_i - \frac{R}{V}$$

Where:

C_i = *Indoor Concentration*
C_o = *Outdoor Concentration*
I = *Ventilation rate*
S = *Source strenght*
R = *Decay Rate*
m = *Mixing Factor*
V = *Volume of the room*

Assuming:

- $R = KVC_i$
- $m = 1$
- *Steady-state conditions*
- $S = 0$

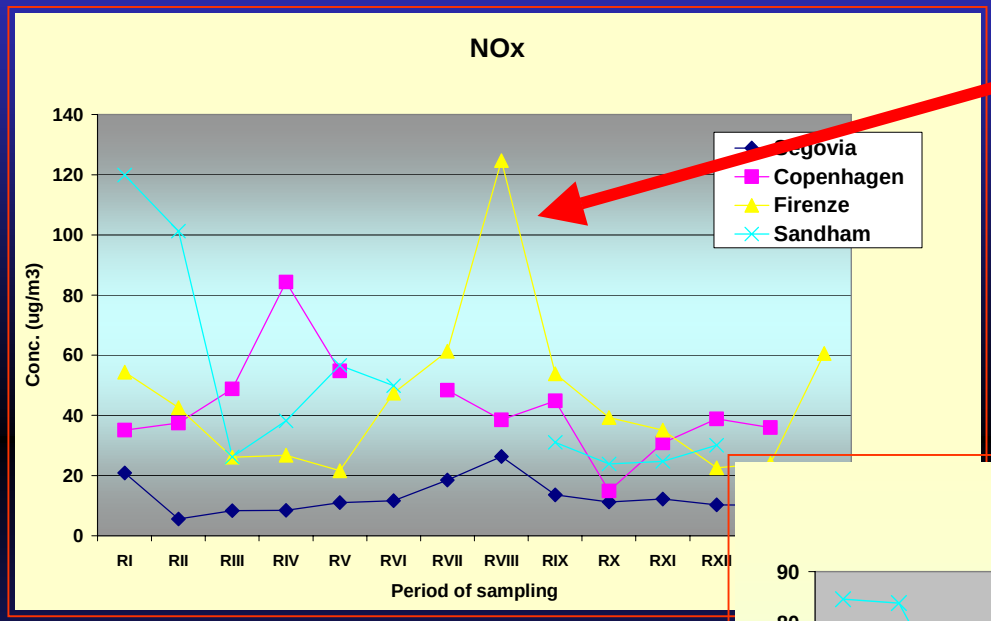
then:

$$C_i = \left(\frac{I}{I + K} \right) C_0$$

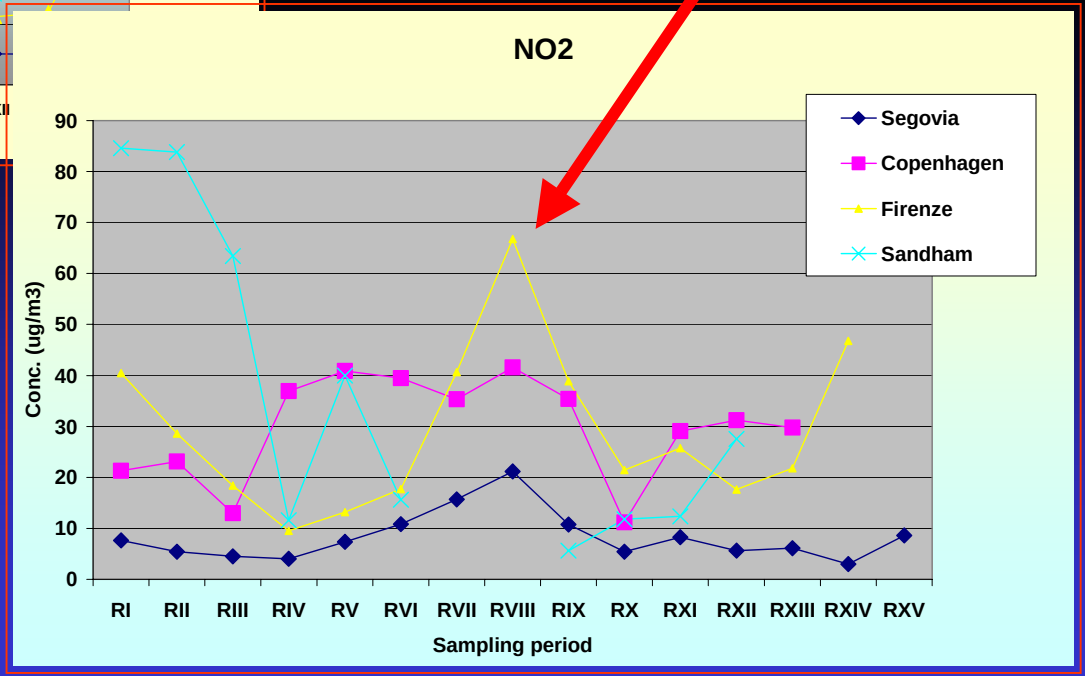
Uffizi Gallery

Outdoor Pollution at the Uffizi in comparison to the other sites

NOx



NO_2



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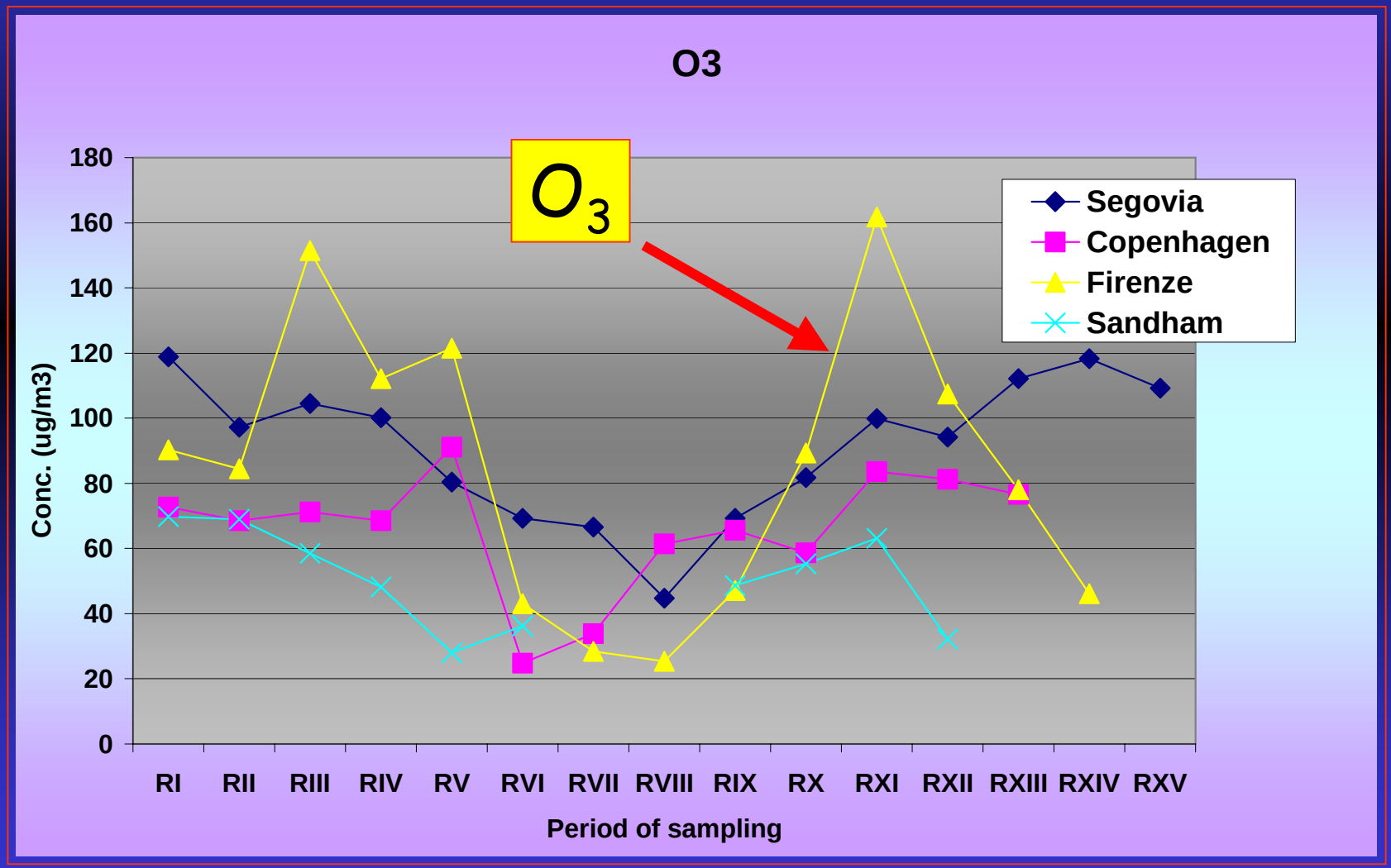

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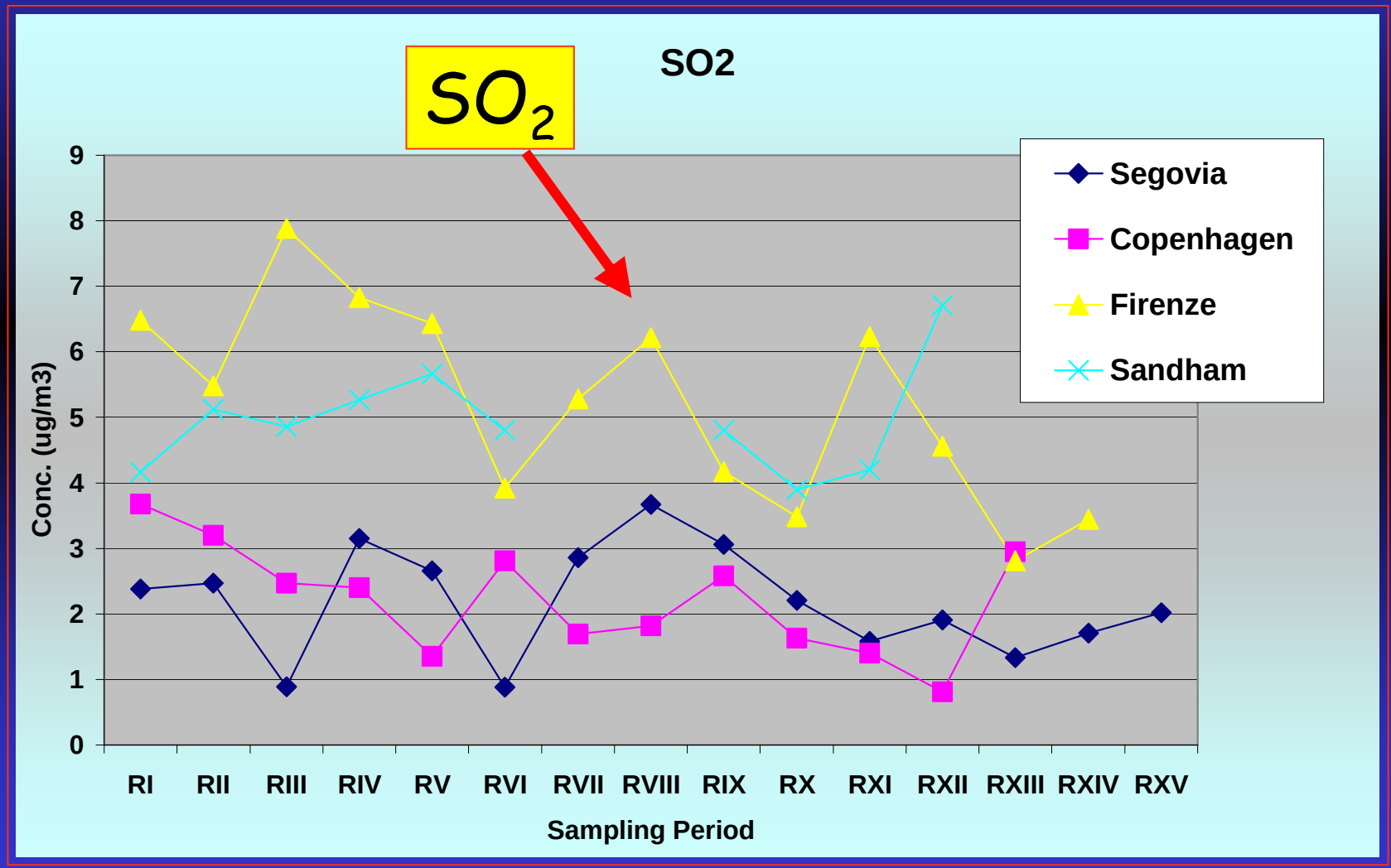

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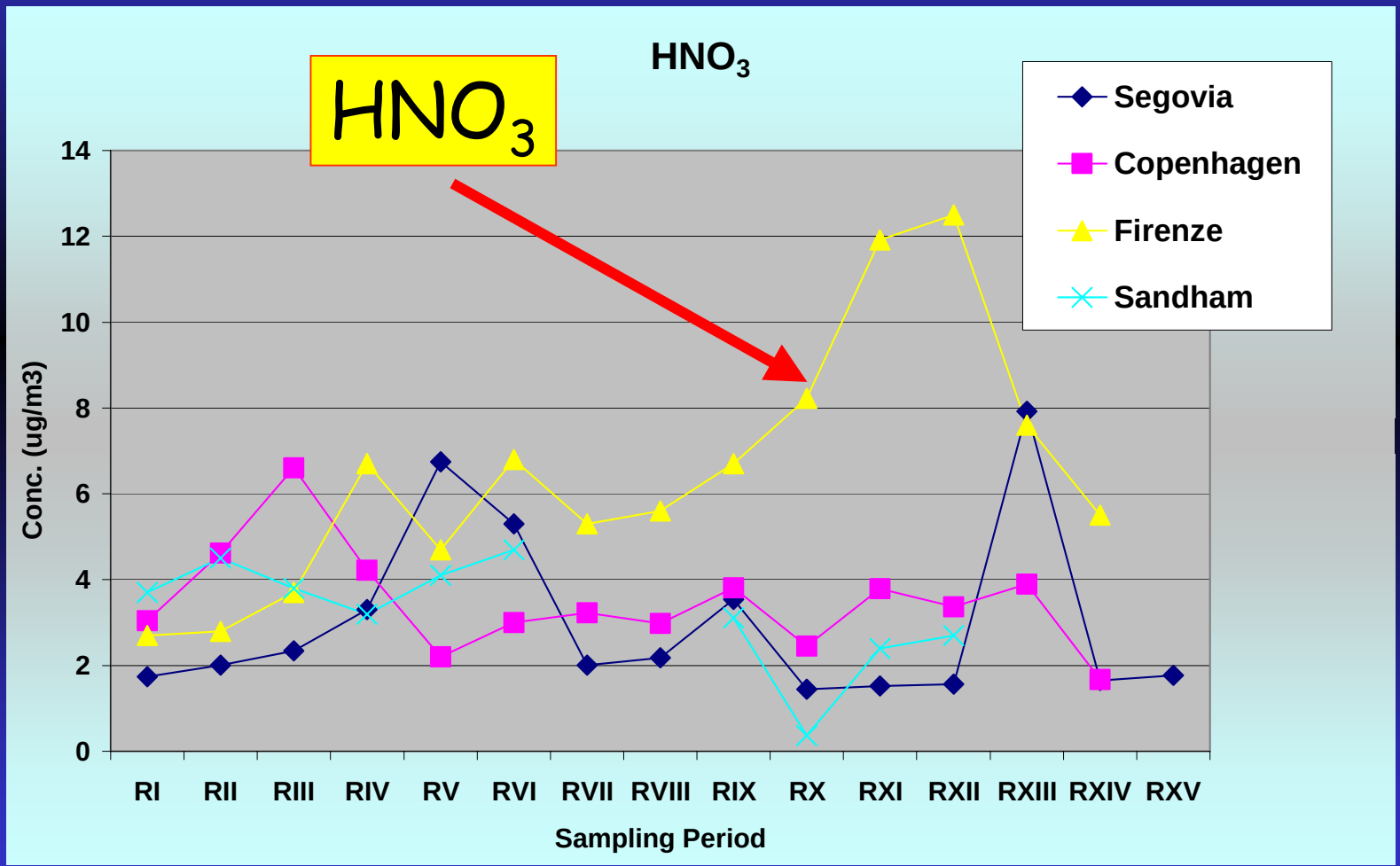
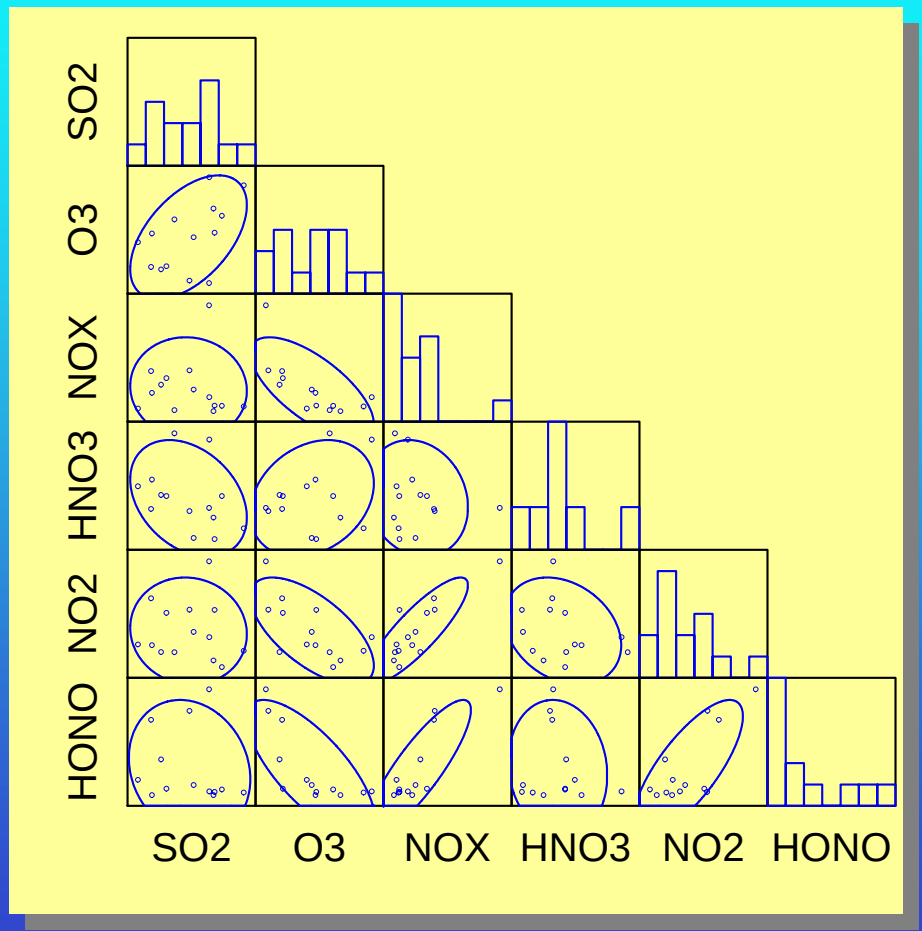
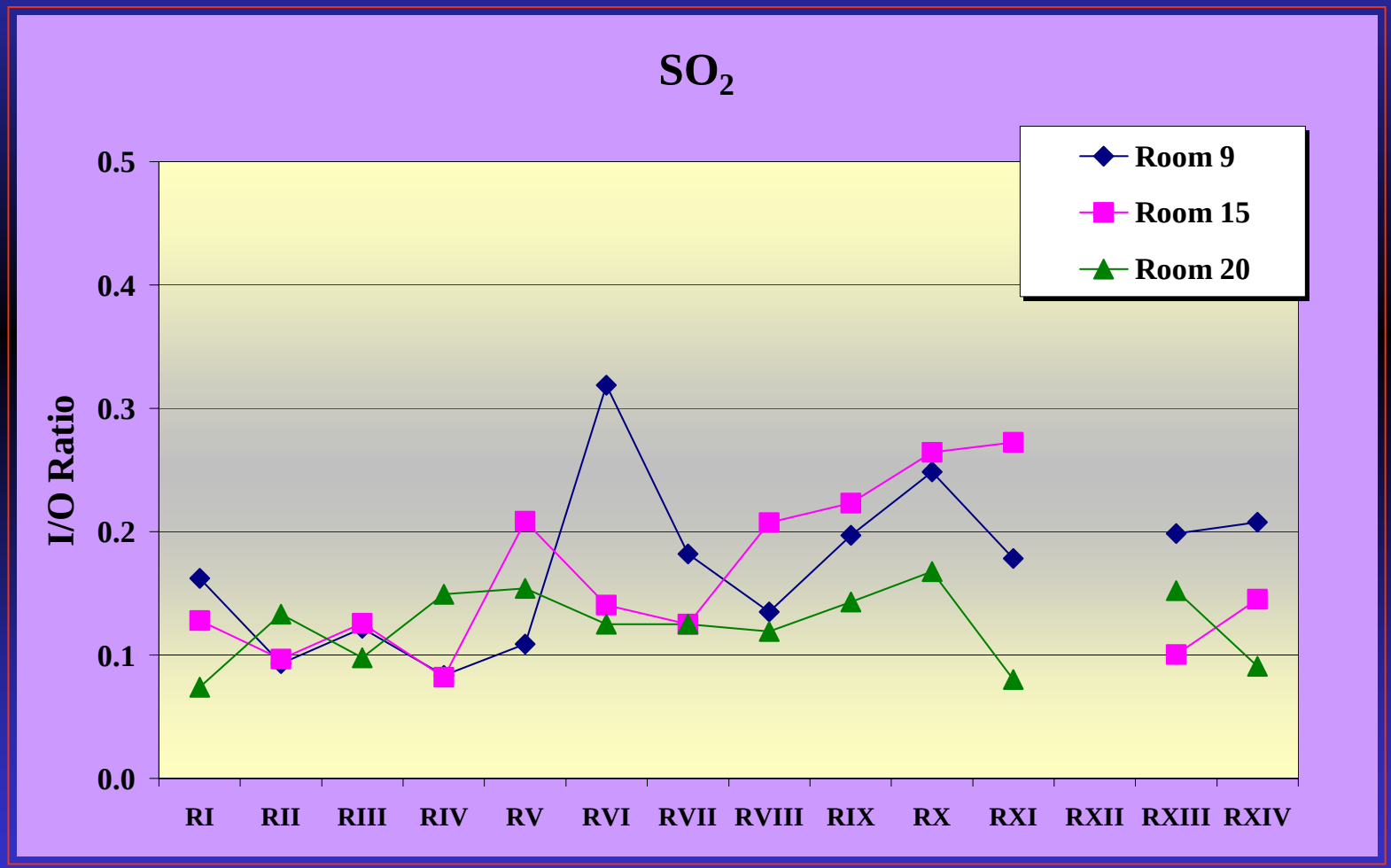


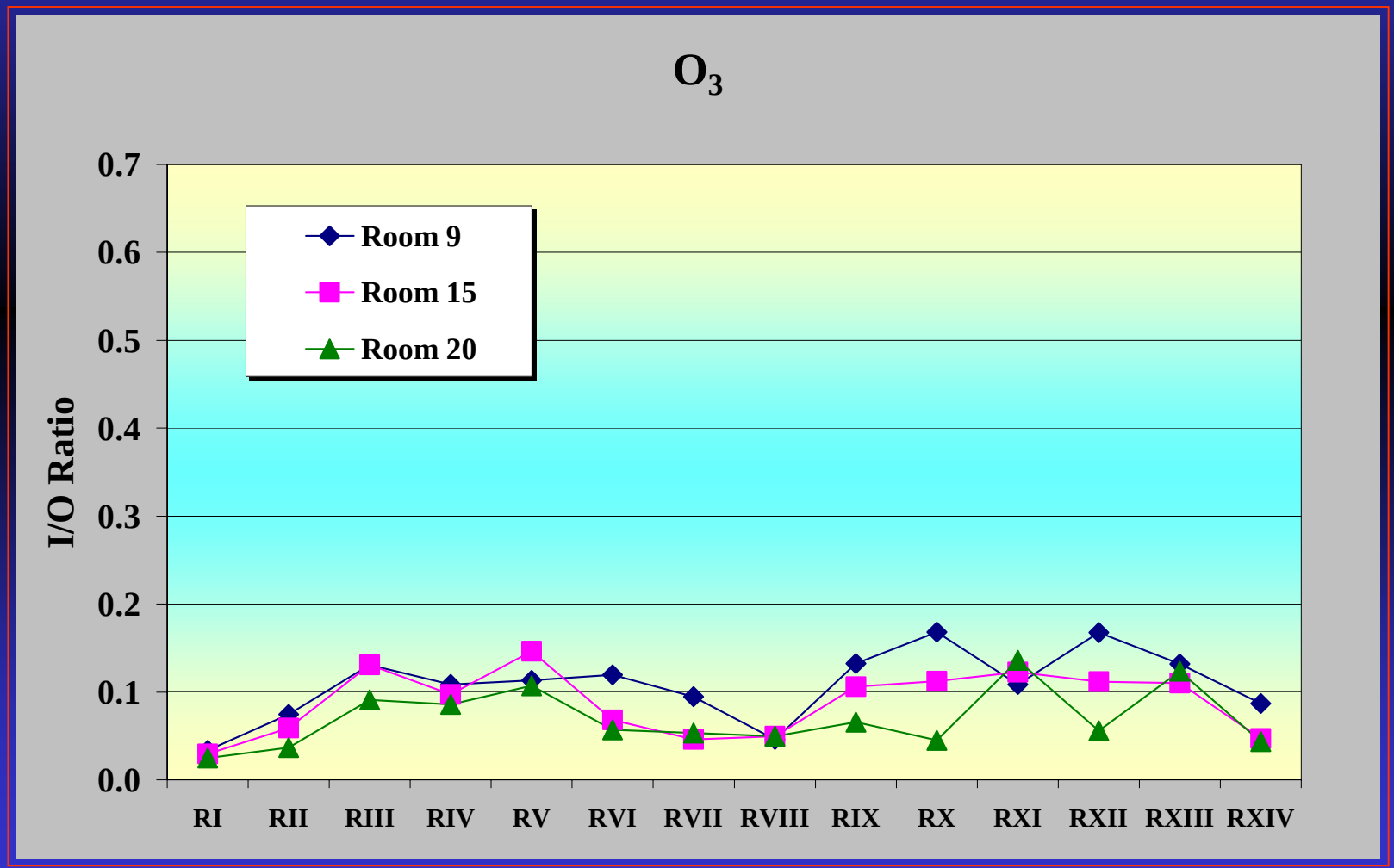
Pearson correlation matrix Outdoor



Indoor/Outdoor Pollution



Indoor/Outdoor Pollution



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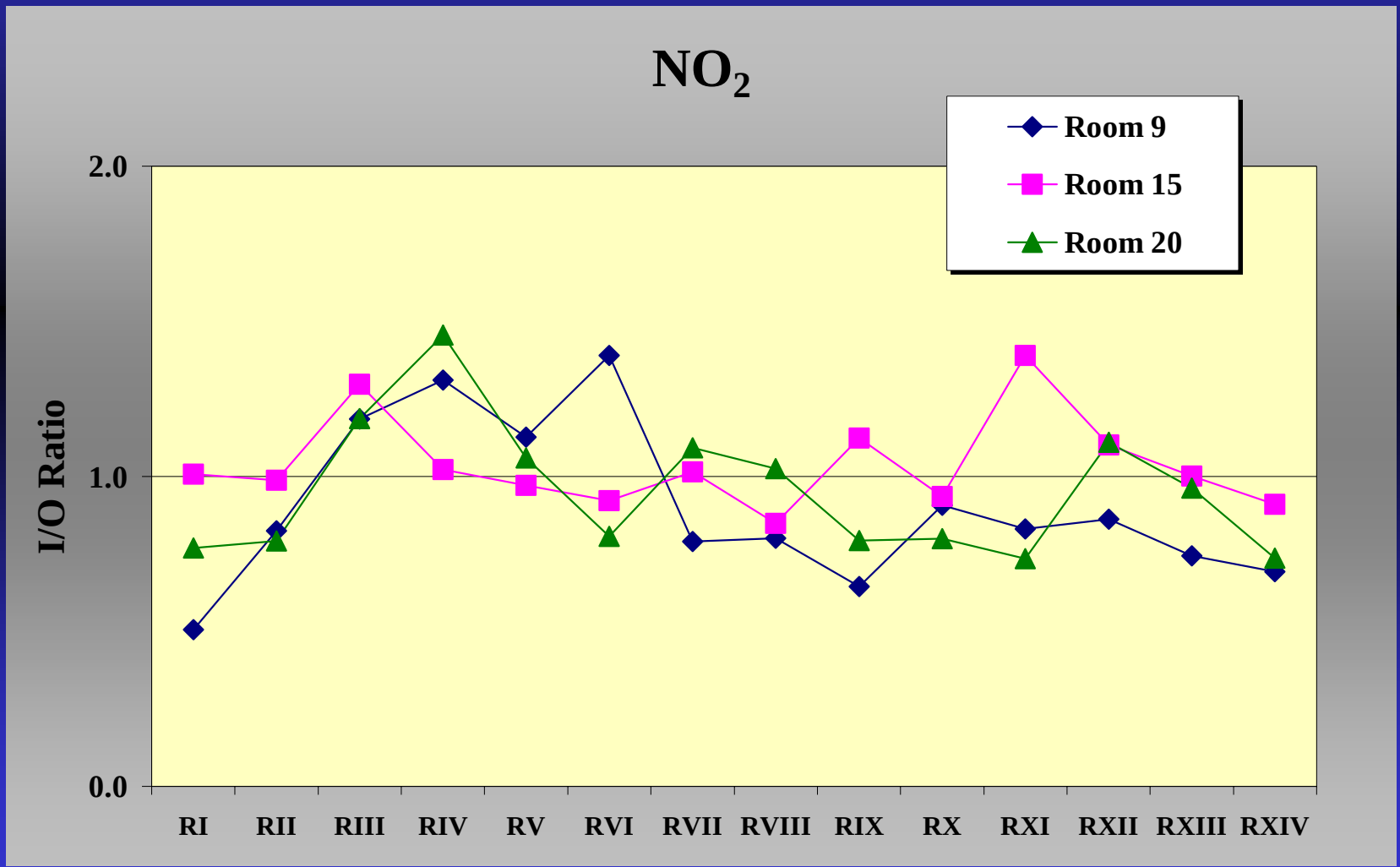

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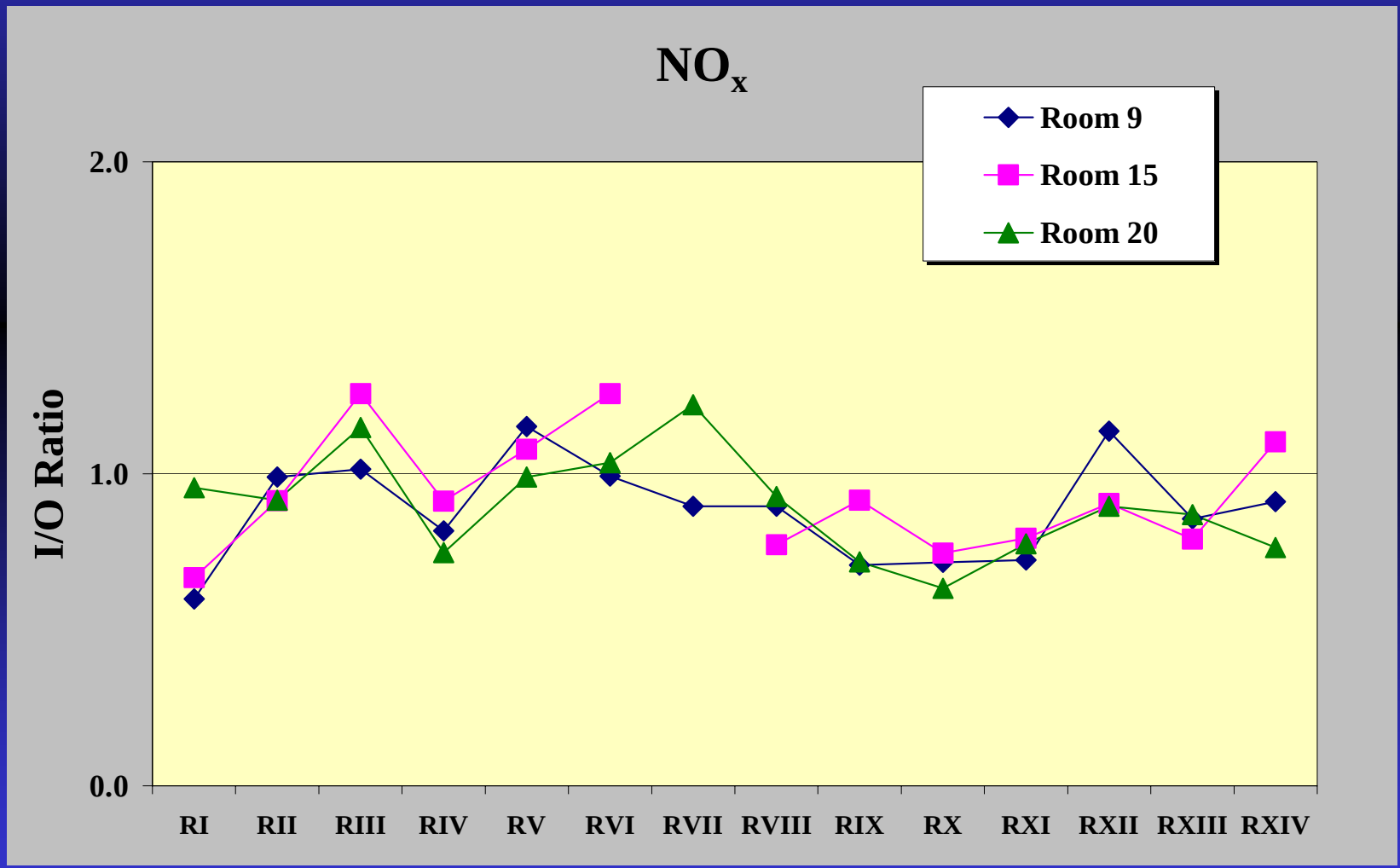
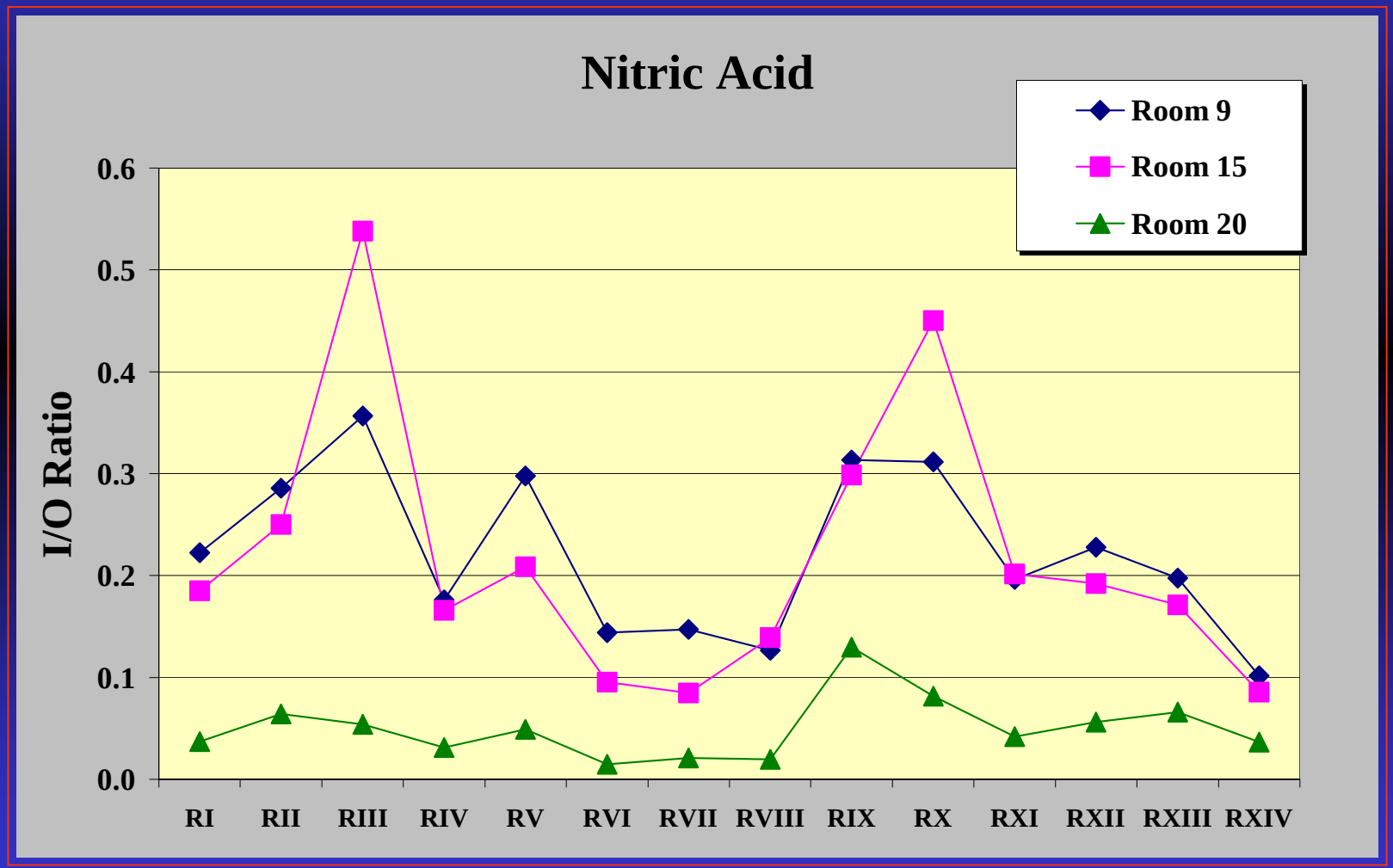
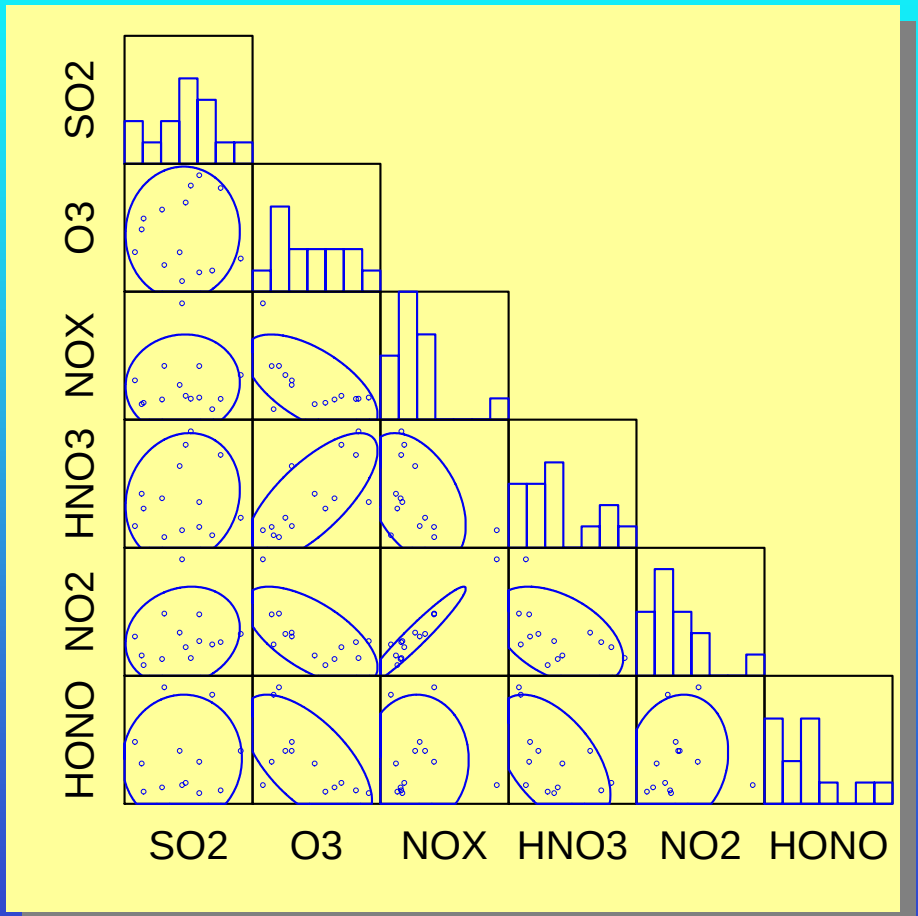


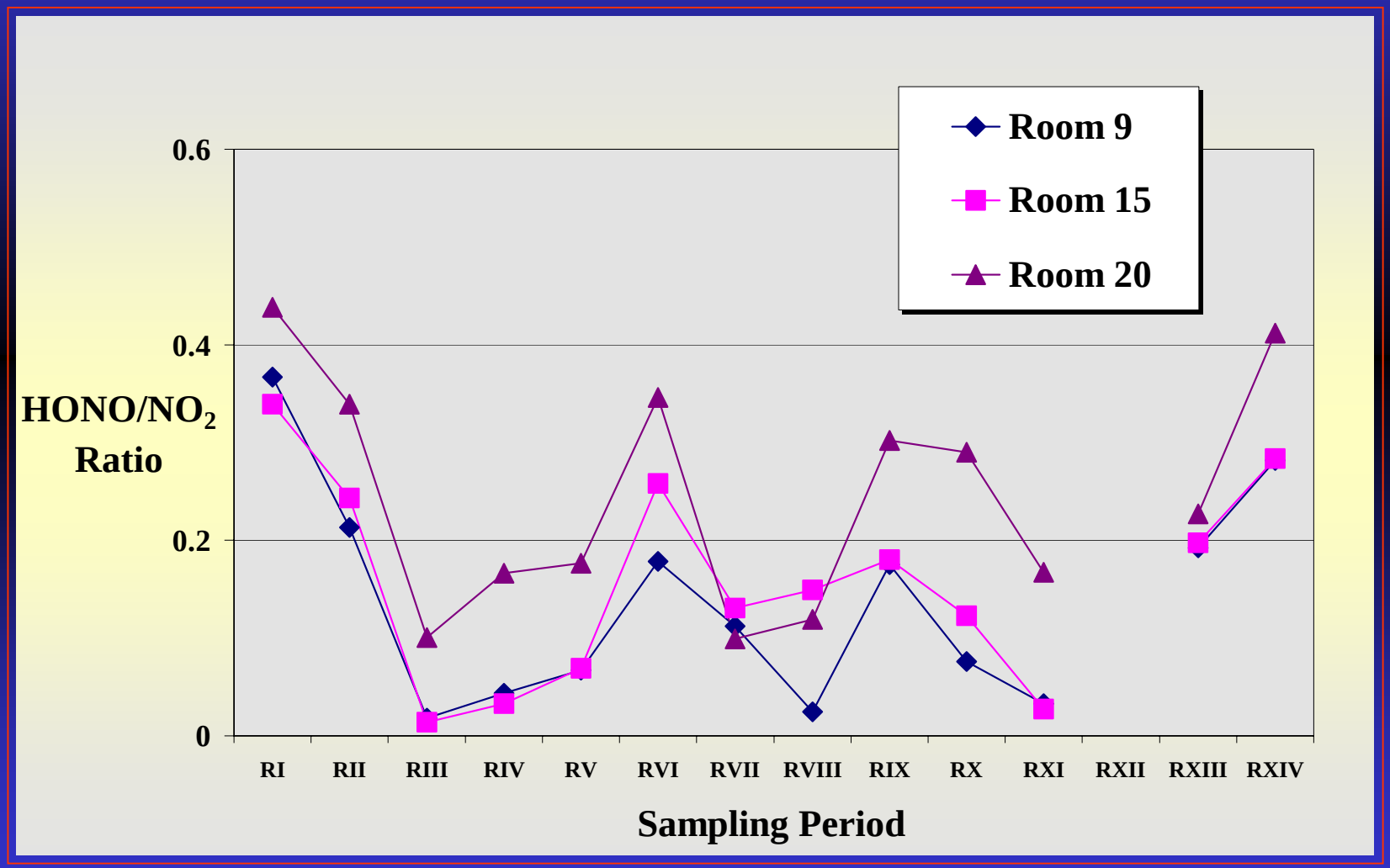
Indoor/Outdoor Pollution



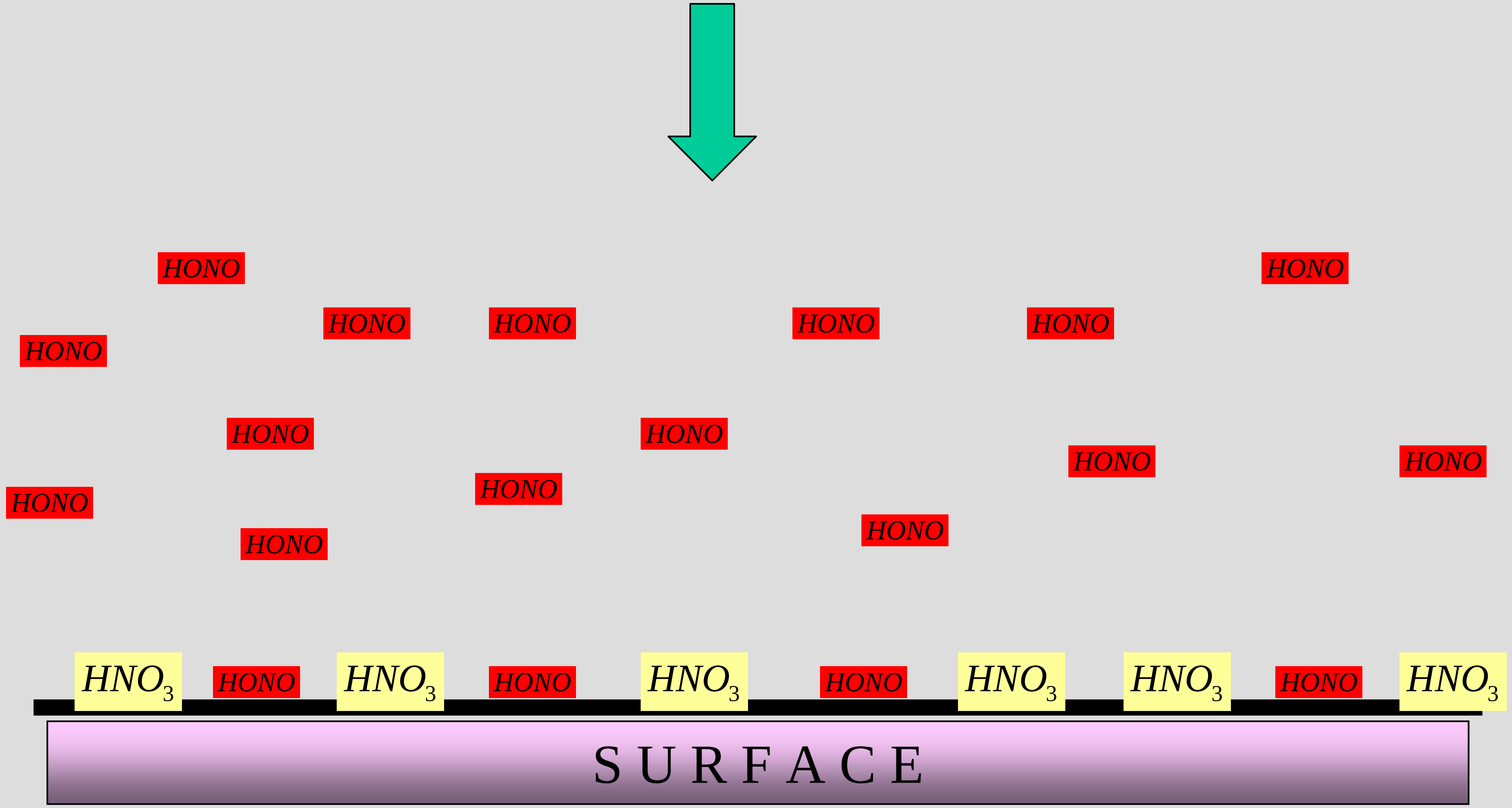
Pearson correlation matrix Lippi Room



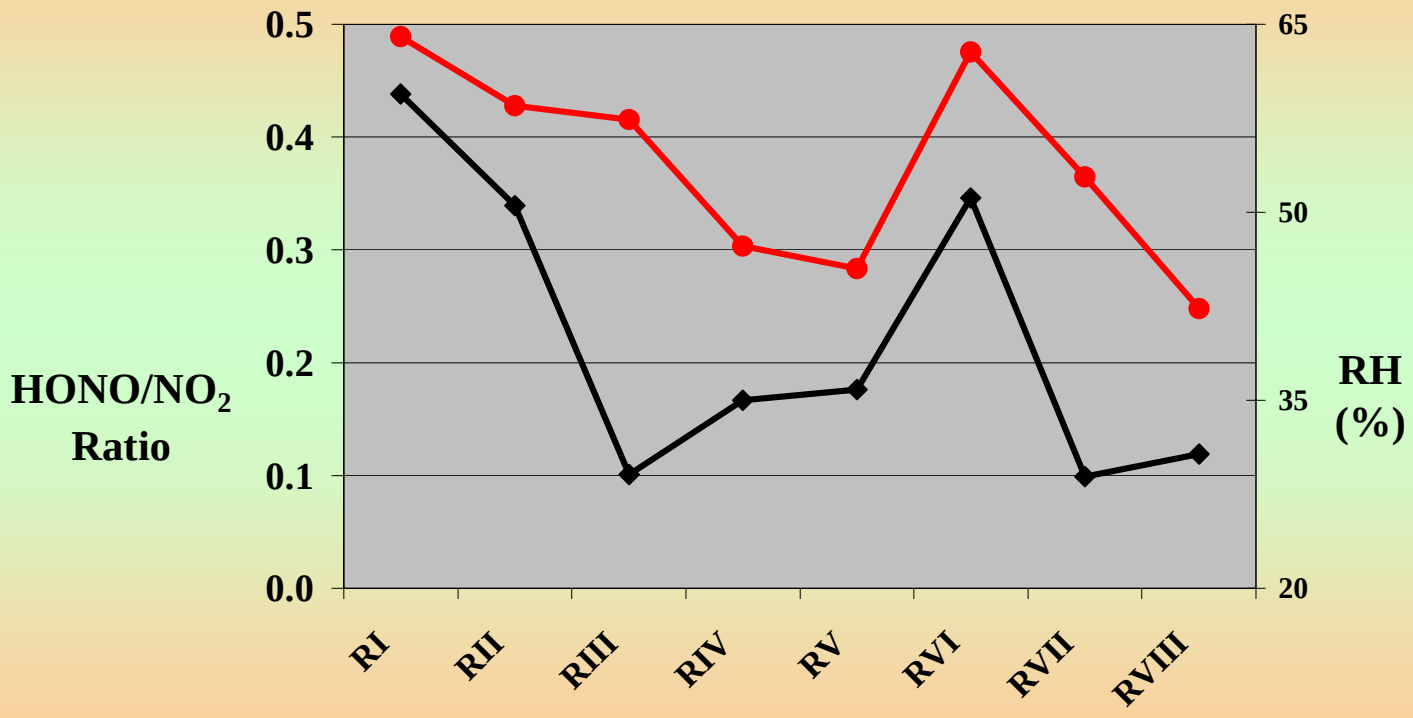
The formation of HONO in different rooms



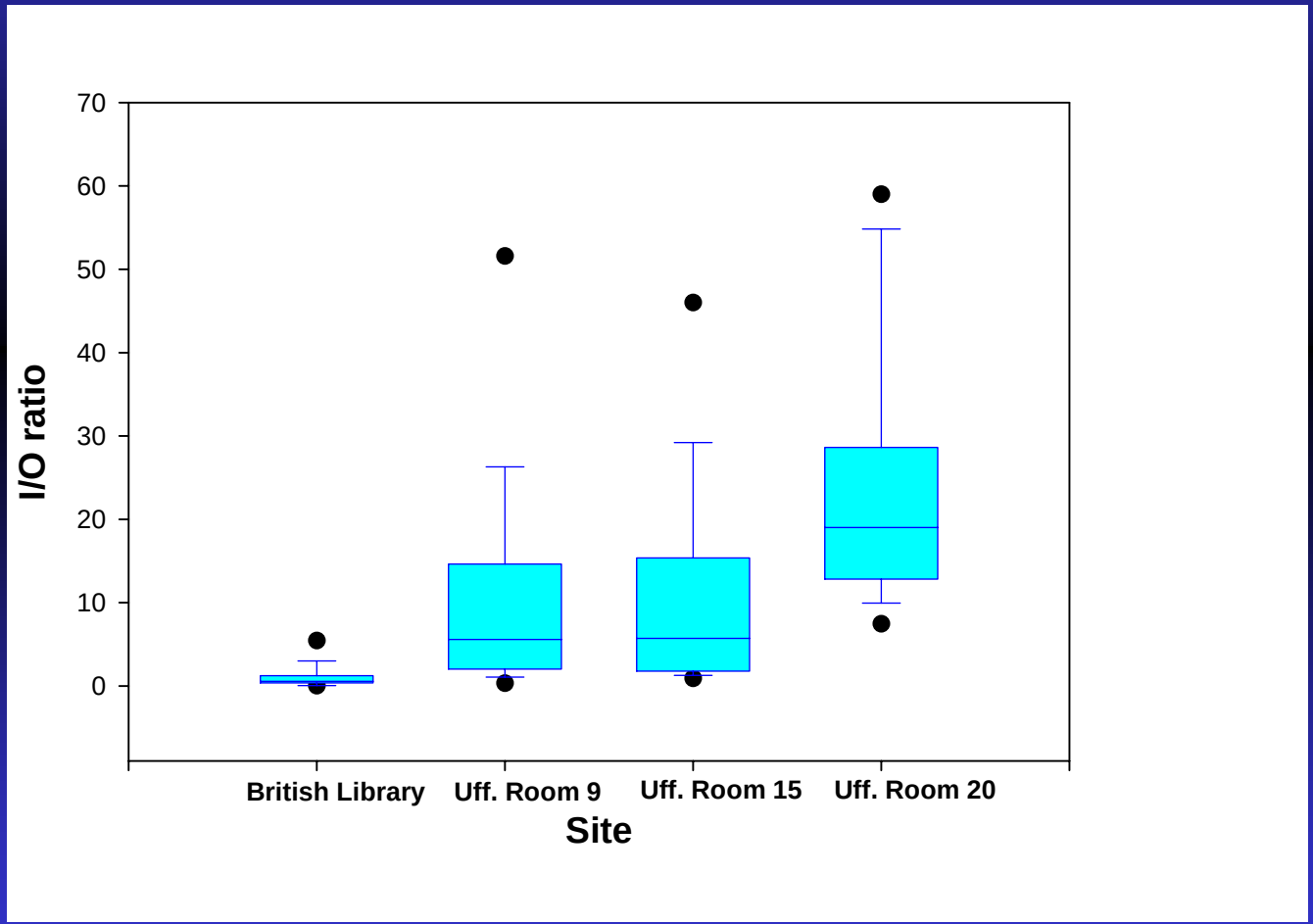
$$2NO_2 + H_2O \rightarrow HONO + HNO_3$$



HONO formation and relative humidity



The I/O ratio of HONO in different rooms of the UFFIZI vs British Library



CONCLUSIONS (1/2)

- The technique results suitable for carrying out concentration mapping of a Museum to study the impact of atmospheric pollution
- The concentrations found indoors for Ozone, Nitrogen Dioxide, Nitrous and Nitric acid represent a risk to the artworks

CONCLUSIONS (2/2)

- This work confirms that the surface catalysed heterogeneous reaction of water with NO_2 gives equimolecular amounts of HONO and HNO_3
- The concentrations of Nitrous and Nitric acids measured indoors are the result of homogeneous and heterogeneous chemistry combined with the characteristics of the surfaces involved

"The basic science of conservation of cultural materials is in its infancy"

(Ralph Mitchell)