Air Quality in stores, archives and exhibition spaces

Workshop on low energy climate control in museum and archives
Copenhagen, 7 October 2010

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The agenda

- On pollutants: compounds, sources, and their effects on materials
- How to measure
- Typical values observed in museum buildings

- Source control
- Control by ventilation
- Control by air cleaners
- Control by passive sorption

Compounds and sources

- Ozone
- Nitrogen dioxide
- Sulphur dioxide

- Organic acids (acetic + formic)
- Volatile organic compounds

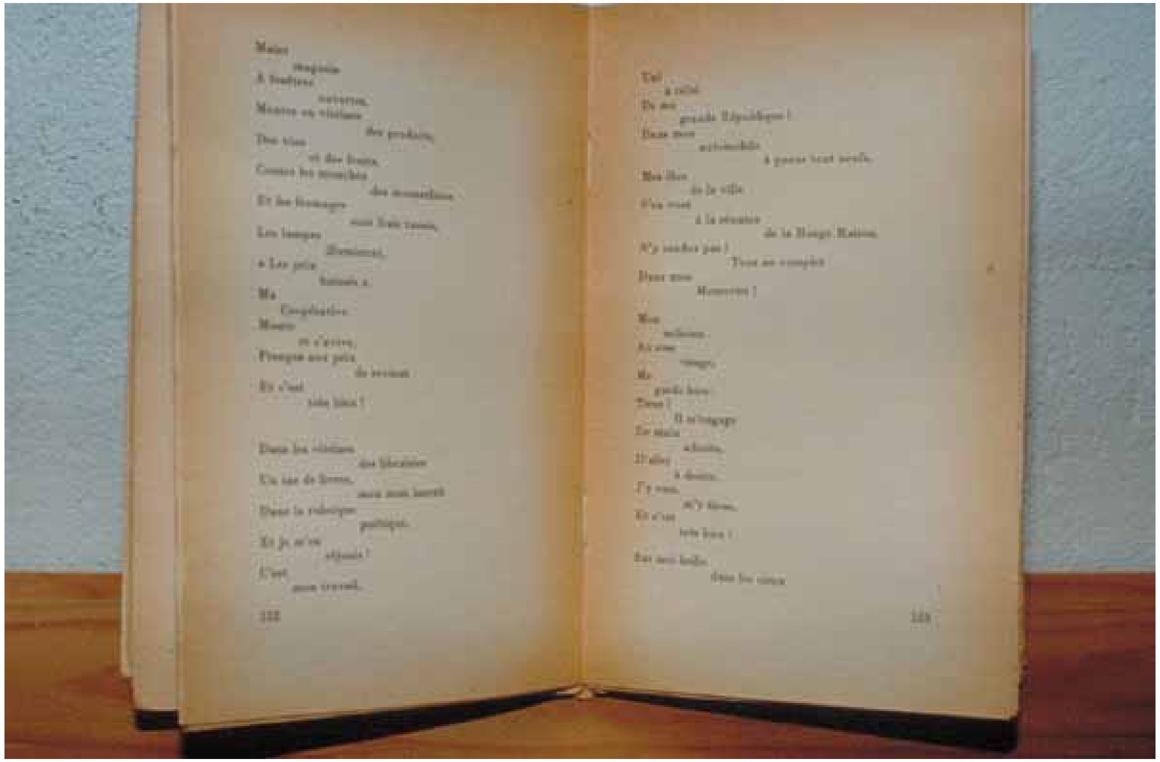
- Dust and particles

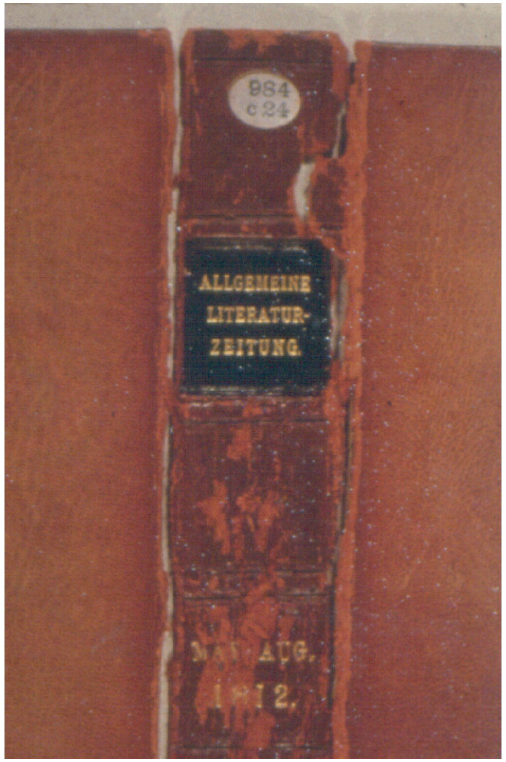
Damage caused by air pollution:
Lead corrosion

Damage caused by air pollution: *Silver tarnish*

Damage caused by air pollution:
Oxidized rubber

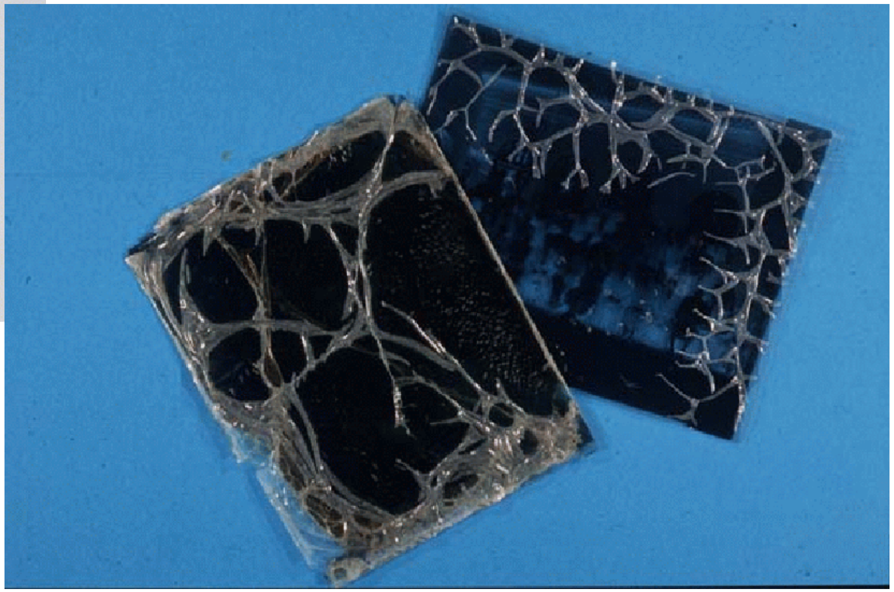
Damage caused by air pollution:
Paper and leather



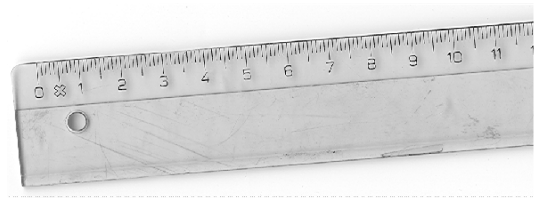


Damage caused by air pollution: *Soiling*

Damage causing air pollution:
Deterioration of plastics



Monitoring

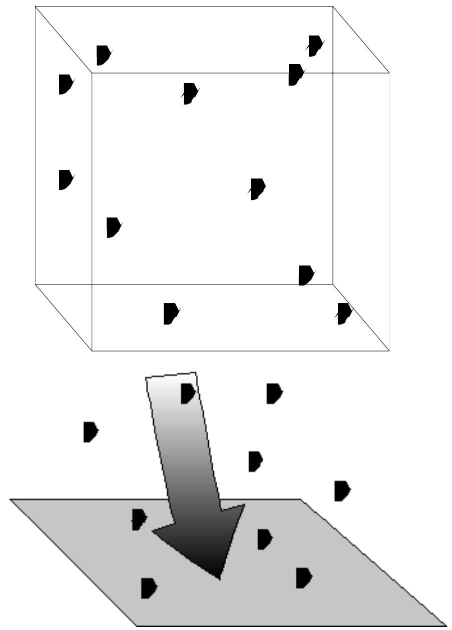


Concentration measurements

- passive sampling, diffusion tubes
- active sampling, real-time instruments

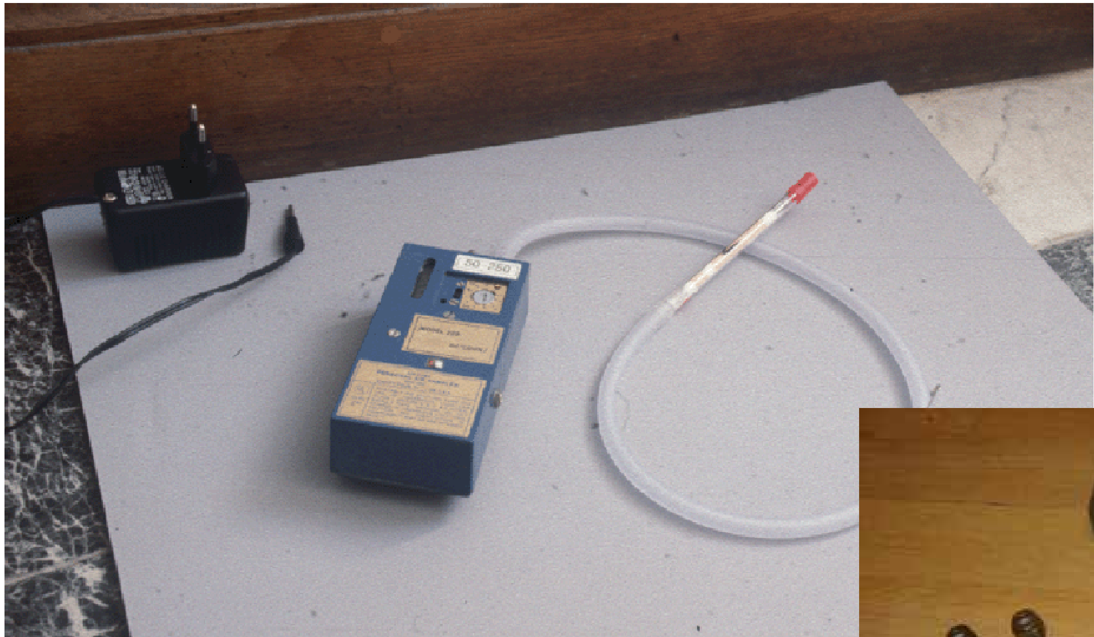
Dosimetry

- ”dummy” materials
- advanced dosimeters



Diffusion tubes (passive)

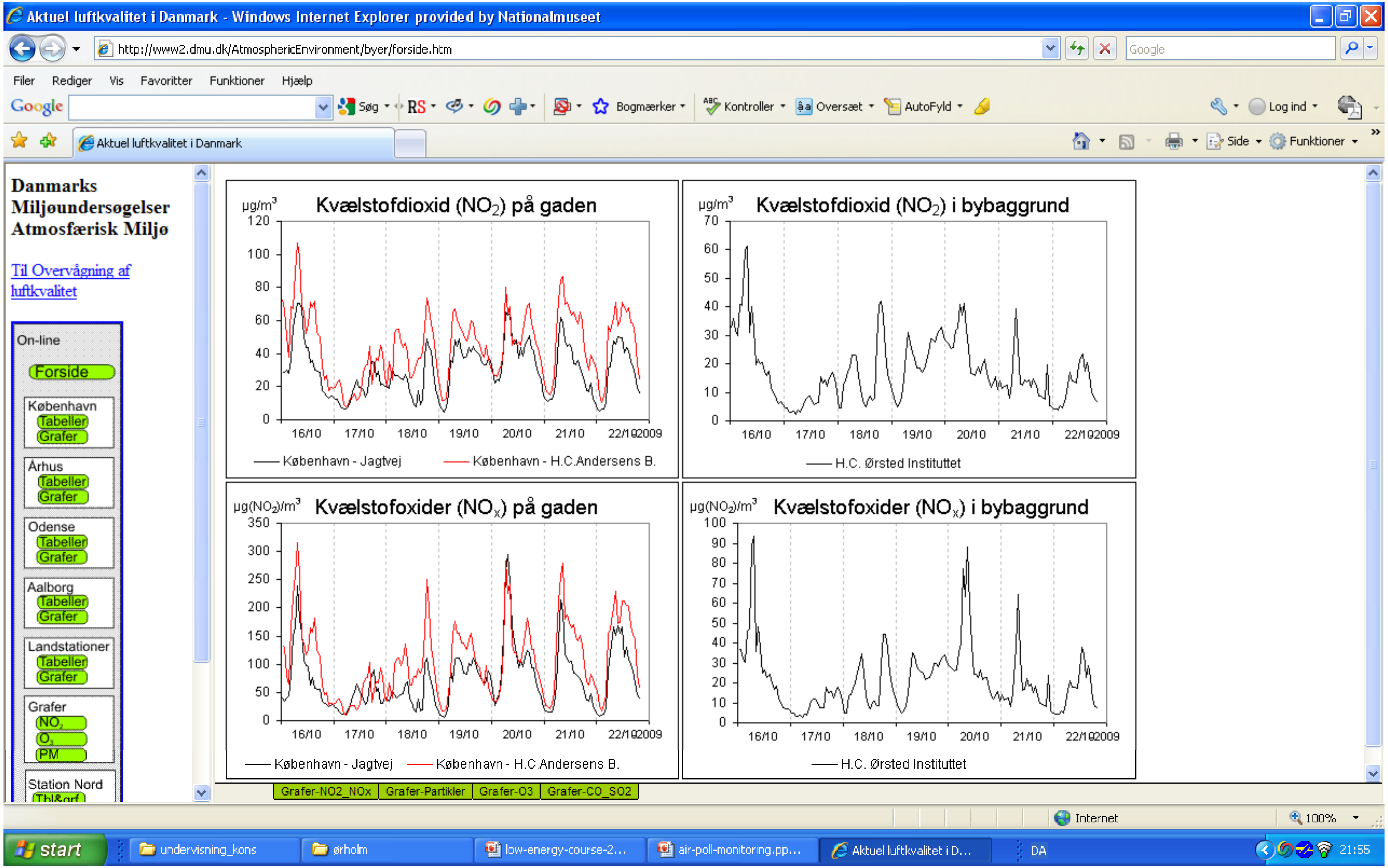
Active sampling



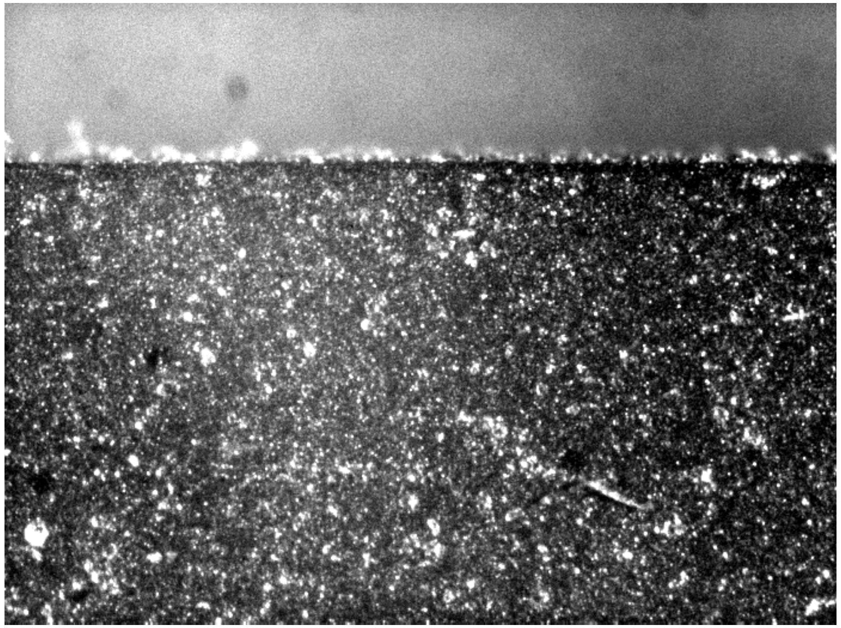
Real-time monitoring

Outdoor sampling

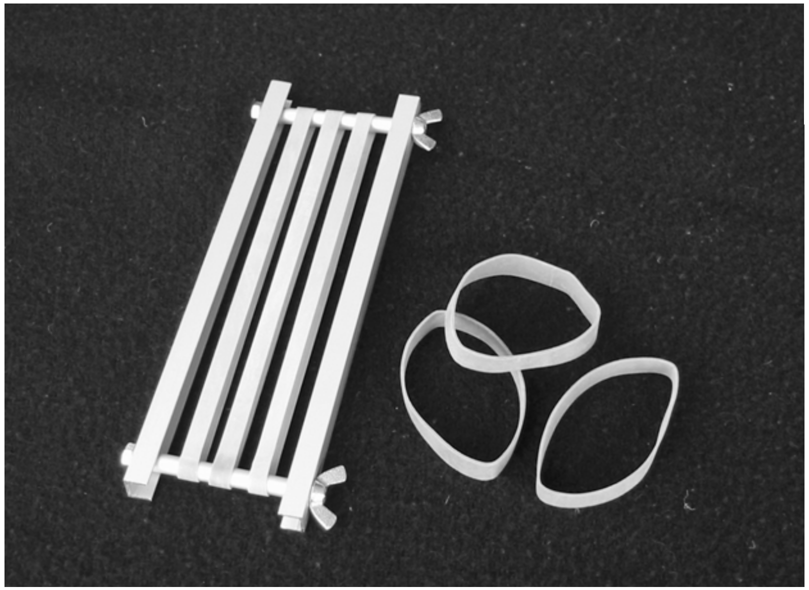
Online data

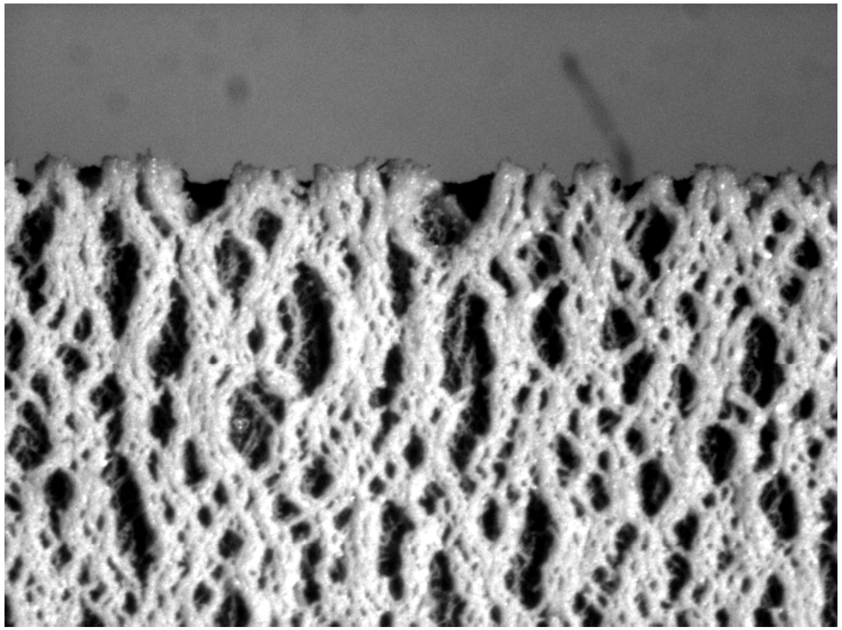


Aktuel luftkvalitet i Danmark - Windows Internet Explorer provided by Nationalmuseet
http://www2.dmu.dk/AtmosphericEnvironment/byer/forside.htm
Danmarks Miljøundersøgelser Atmosfærisk Miljø
Til Overvågning af luftkvalitet
On-line
Forside
København Tabeller Grafer
Århus Tabeller Grafer
Odense Tabeller Grafer
Aalborg Tabeller Grafer
Landstationer Tabeller Grafer
Grafer
Station Nord
Kvælstofdioxid (NO2) på gaden
Kvælstofdioxid (NO2) i bybaggrund
Kvælstofoxider (NOx) på gaden
Kvælstofoxider (NOx) i bybaggrund
København - Jagtvej
København - H.C.Andersens B.
H.C. Ørsted Instituttet
16/10 17/10 18/10 19/10 20/10 21/10 22/10 2009
Grafer-NO2_NOx Grafer-Partikler Grafer-O3 Grafer-CO_SO2



Dosimetry: oxidizing agents (ozone)





Dosimetry: corrosive environments

Commercial dosimeters

Commercial dosimeters

Purafil coupons

(silver & copper)

NILU EWO (polymer)

Examples of museum environments

Odense Chatedral
Urban environment
Natural ventilation with heating

Ozone outdoor: up to 45 ppb
Ozone inside church: about 5 ppb
LOW
Ozone inside coffin: below detection

Organic acids outdoor: 1-2 ppb
Organic acids inside church: 1-5 ppb
LOW

Organic acids inside coffin: > 400 ppb
VERY HIGH

Examples of museum environments

National Museum
Ørholm Store ”P”
Suburban environment

Dehumidified, little heating

low air exchange rate
(approx . 1 per day)

Ozone outdoor: up to 50 ppb
Ozone inside: below 5 ppb

Organic acids outdoor: 1 ppb
Organic acids inside: 50-100 ppb

LOW

HIGH

Examples of museum environments

National Museum
Brede Store "921"
Suburban environment

Full HVAC, high recirculation rate
Carbon filtration

Ozone outdoor: up to 50 ppb
Ozone inside: below 2 ppb

LOW

Organic acids outdoor: 1 ppb
Organic acids inside: 5-15 ppb

LOW

Examples of museum environments

Ozone outdoor: up to 70 ppb
Ozone inside: below 1 ppb
LOW

Organic acids outdoor: 1 ppb
Organic acids inside: 1-5 ppb
LOW

Vejle Storage Facility

Intenal re-circulation with dehumidification, no heating
Rural environment

Control measures

Outdoor pollutants: Block

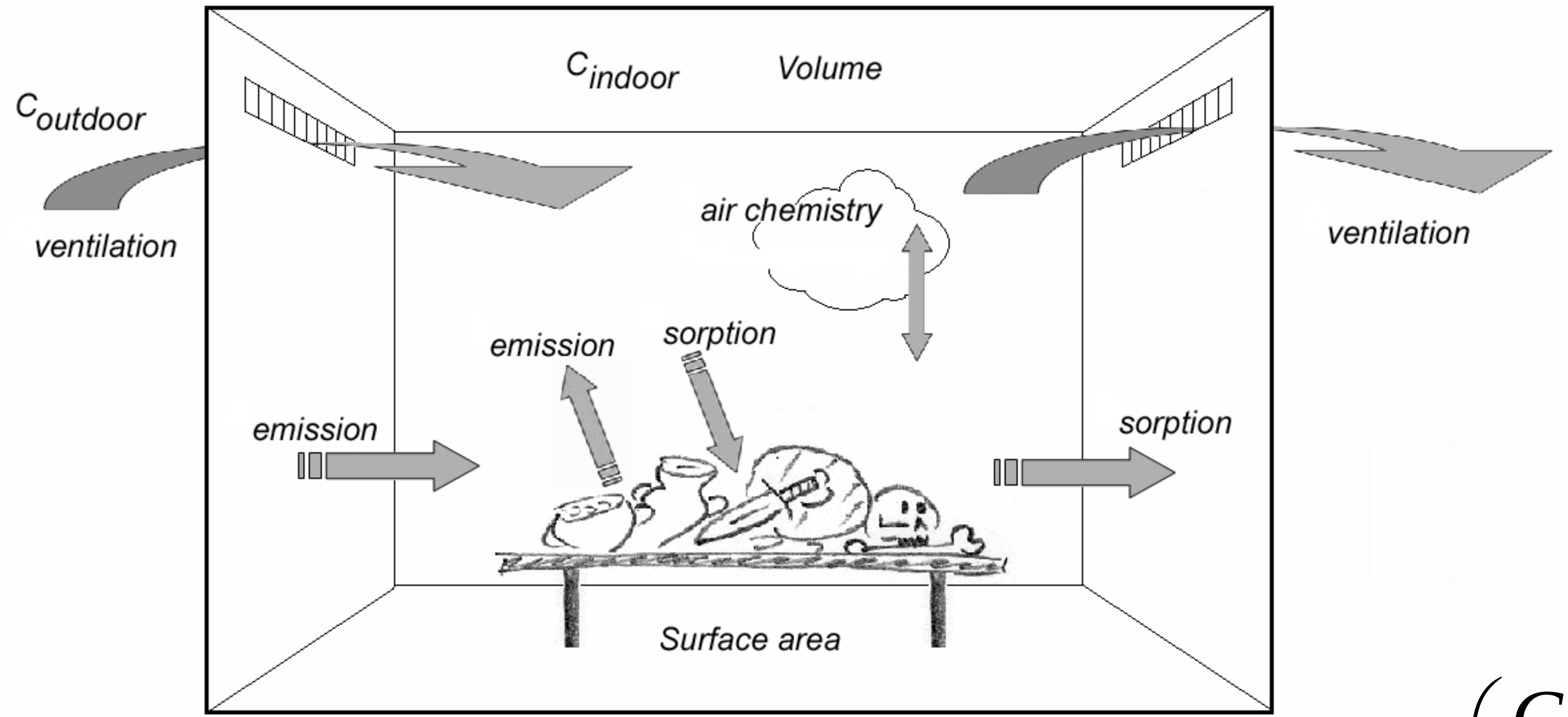
- Forced filtration
- Low air exchange
- Tortuous infiltration route

Indoor pollutants: Shift mass balance, remove from air

- Avoid/remove/reduce source
- Increase reactive surface area
- Forced filtration (internal)
- Increase ventilation

- Decrease reaction rate (low temperature, low RH)

Pollution pathways



$$C_i = \frac{C_o \times n}{n+S} + \frac{\left(\frac{G}{V}\right)}{n+S}$$

Ryhl-Svendsen, M., 'Indoor air pollution in museums: a review of prediction models and control strategies', *Reviews in Conservation* **7** (2006) 27-41.

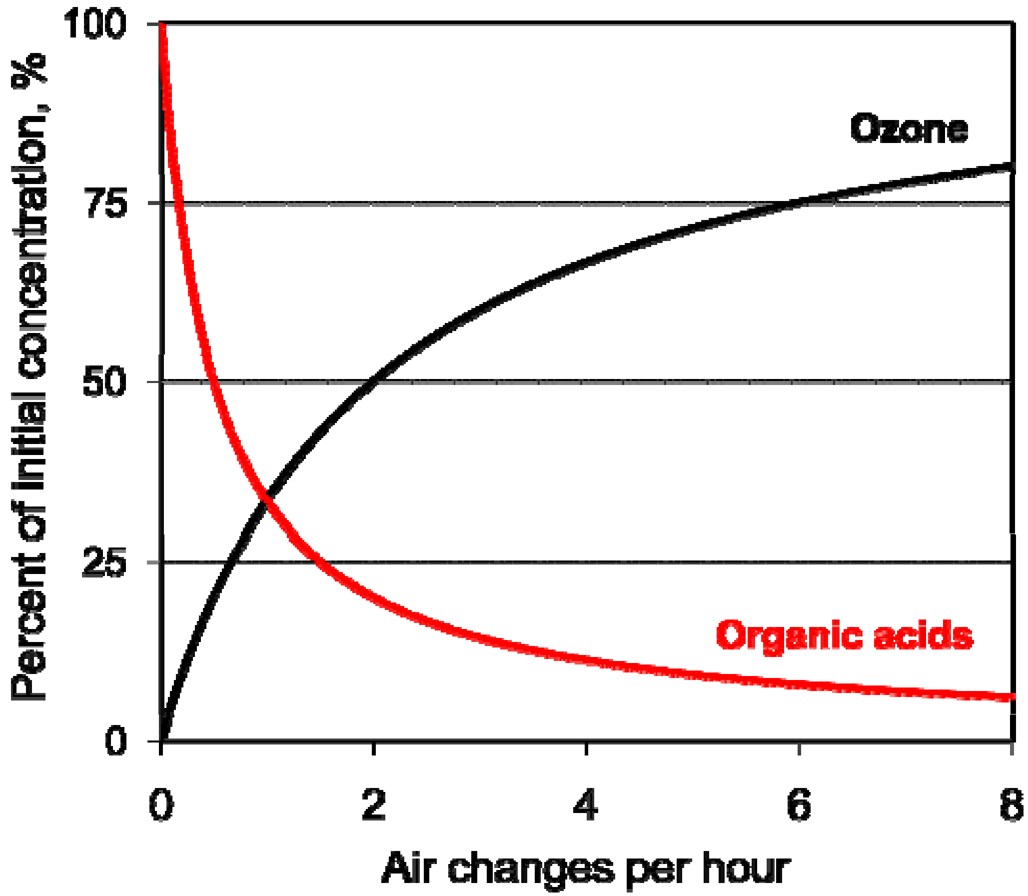
Block outdoor pollutants

Vejle Storage Building:
No windows, few doors
approx. one air exchange per day

Blocking pollutant's pathway: a double-edged sword

Ventilation

Dilution / infiltration



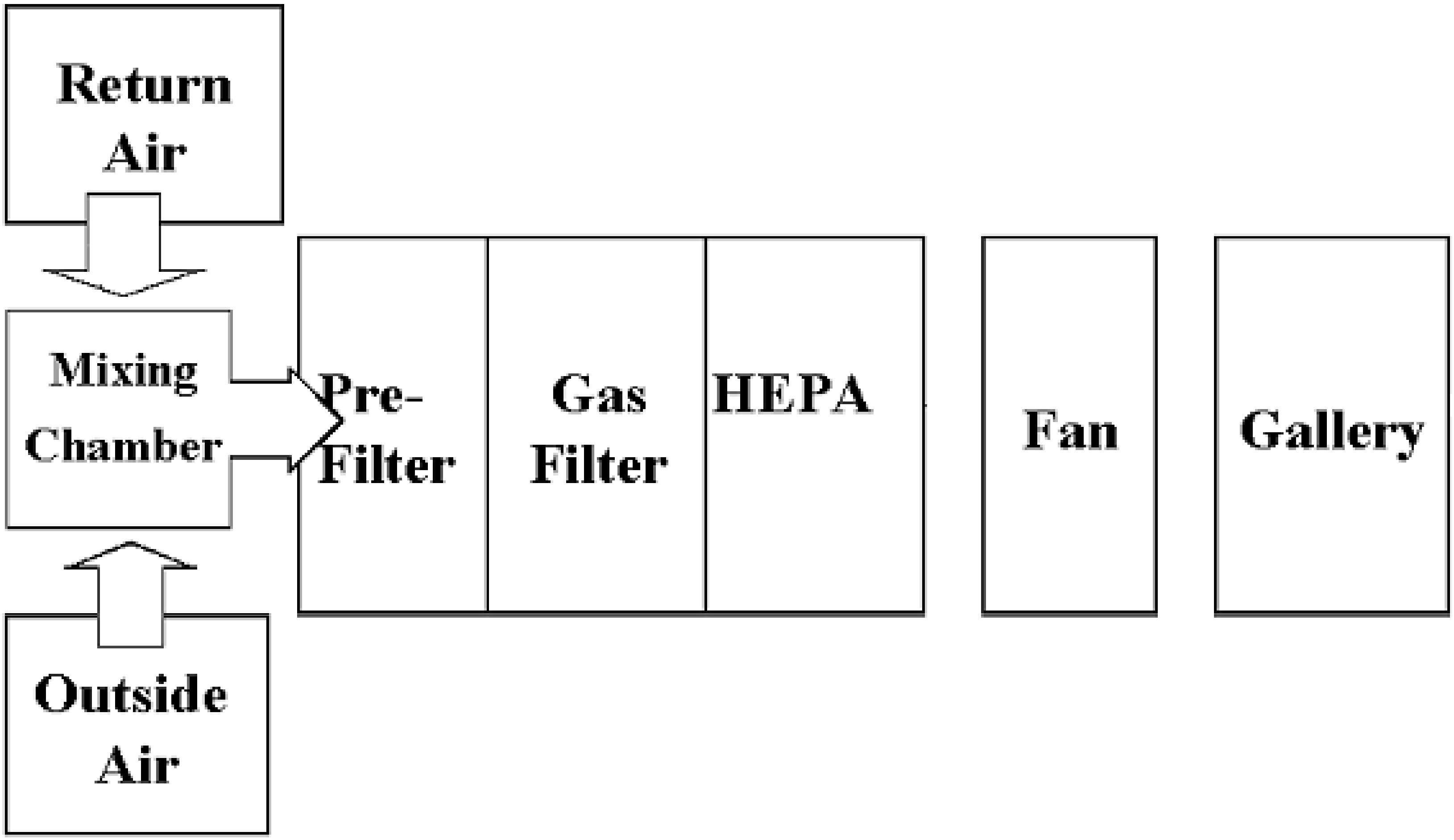
$$C_i = \frac{C_o \times n}{n+S} + \frac{\left(\frac{G}{V}\right)}{n+S}$$

Reasons for ventilation or air handling?

- Heating and/or cooling
- Humidity control
- Providing ”fresh” air

- Filtration?

Air filtration



Dust filters (bag type)

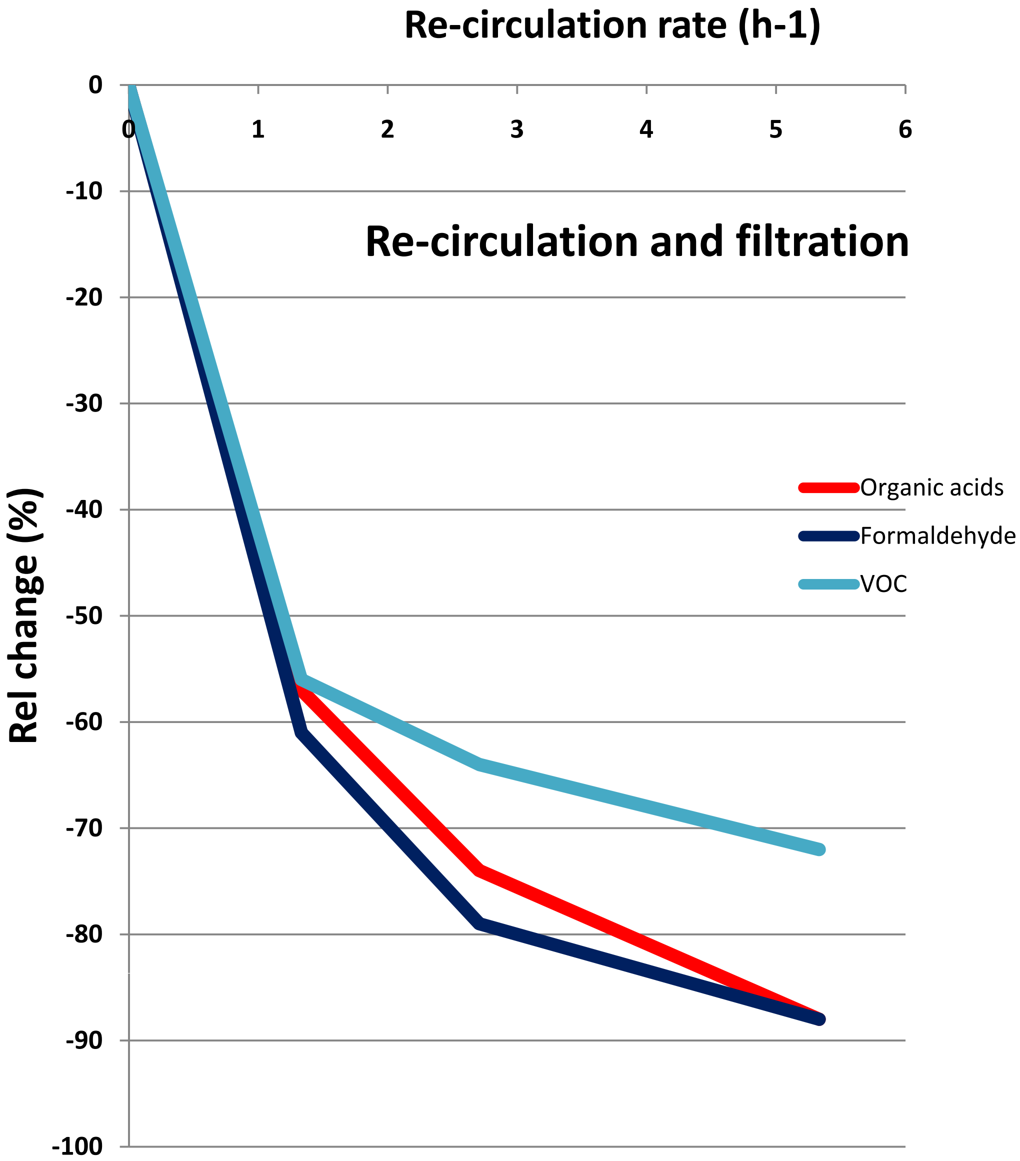
Activated carbon filters (charcoal granulates)

Control of indoor generated pollutants

Source control

Source control

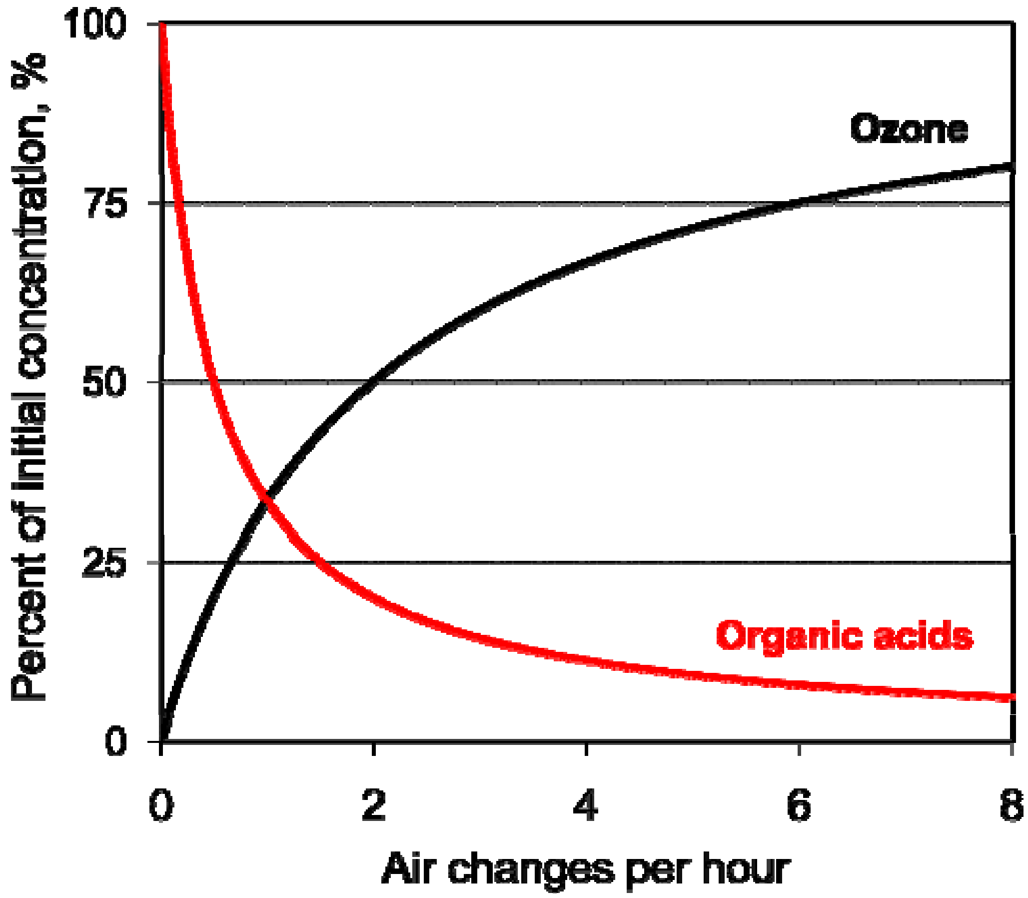
Air cleaners



Energy consumption

80-1000 W depending on fan size and speed

Dilution / infiltration



Passive air cleaning (sorption)

Ryhl-Svendsen & Clausen, *Studies in Conservation* 54(1), 2009

Air exchange rate and surface reactions: Outdoor pollutants

Surface removal rate

$$C_i = \frac{C_o \times n}{n + S}$$

Ozone:

- Office **1-4 h^{-1}** *(Weschler, 2000)*
- Museum storage **2-3 h^{-1}** *(Ryhl-Svendsen & Clausen, 2009)*
- Bedroom **>7 h^{-1}** *(Weschler, 2000)*

Nitrogen dioxide:

- Museum gallery **0.4 h^{-1}**
- Storage room **4.5 h^{-1}** *(Blades et al, 2000)*

… and indoor generated pollutants

Surface removal rate

$$C_i = \frac{\left(\frac{G}{V}\right)}{n + S}$$

Unfired brick (clay)

Sorption on clay brick

- 48 m^3 test room
- Approx. 20°C and 50% RH
- 0.5 m^2 clay wall per 1 m^3 room volume
- Low air exchange rate: 0.3 per hour

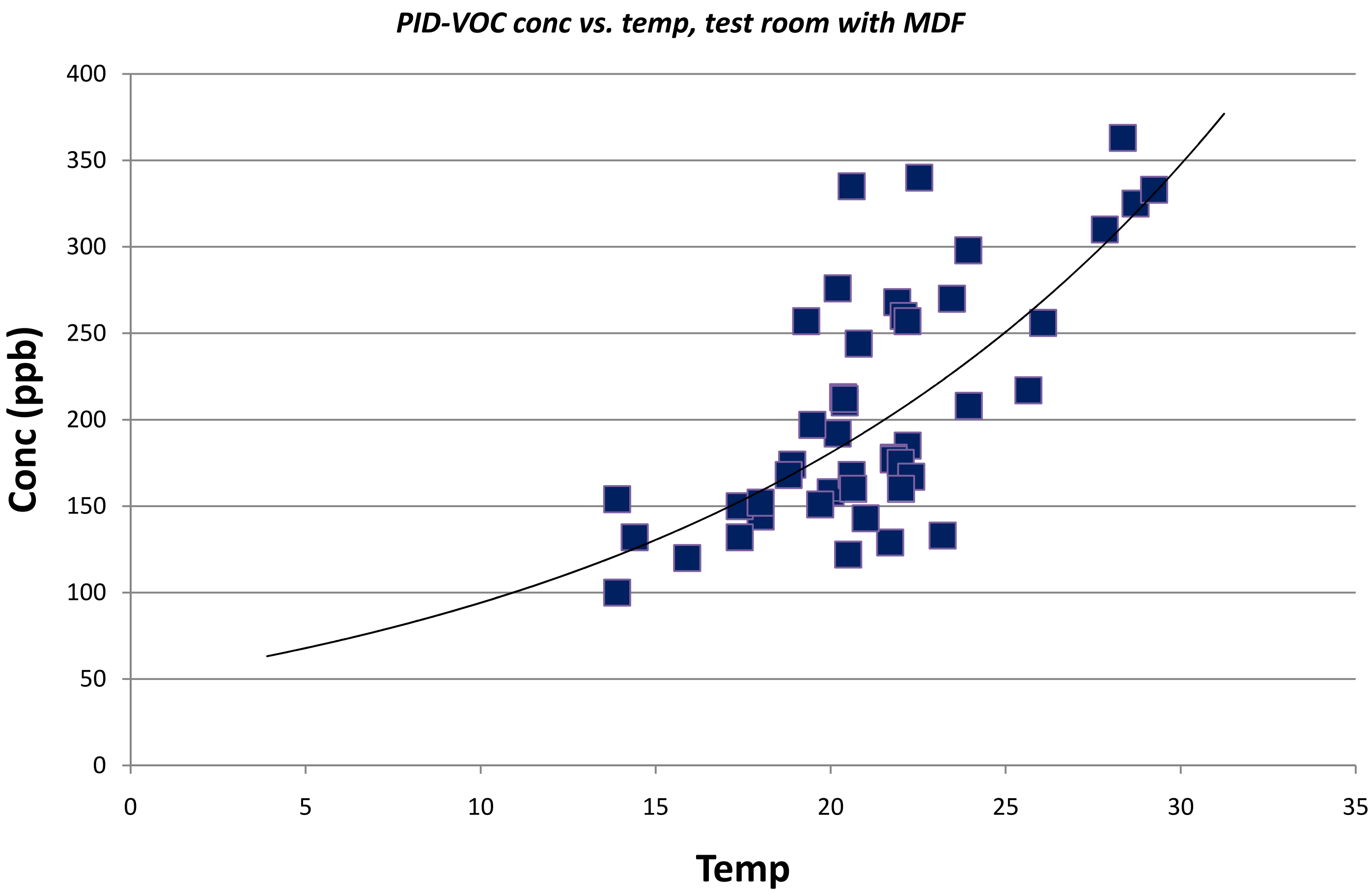
- **Organic acids: conc. decrease 30%**
- **Formaldehyde: conc. decrease 10%**

- Organic acid uptake (surface removal rate):
  1.6 room volume per hour (5x actual ventilation rate)

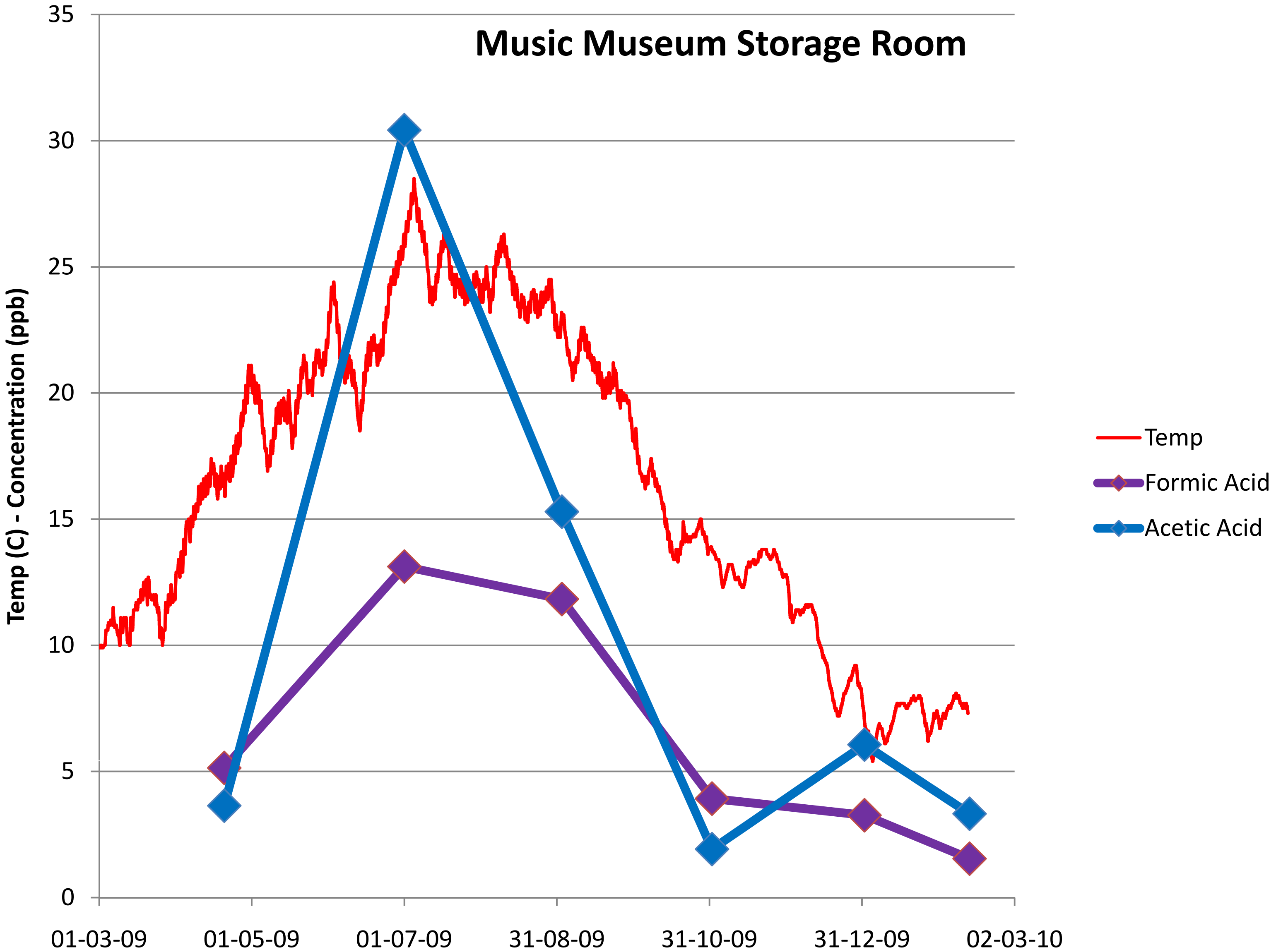
Reducing reaction rate

Cold storage for unstable film materials

Temperature and emission rate: VOCs from wood-fibre board

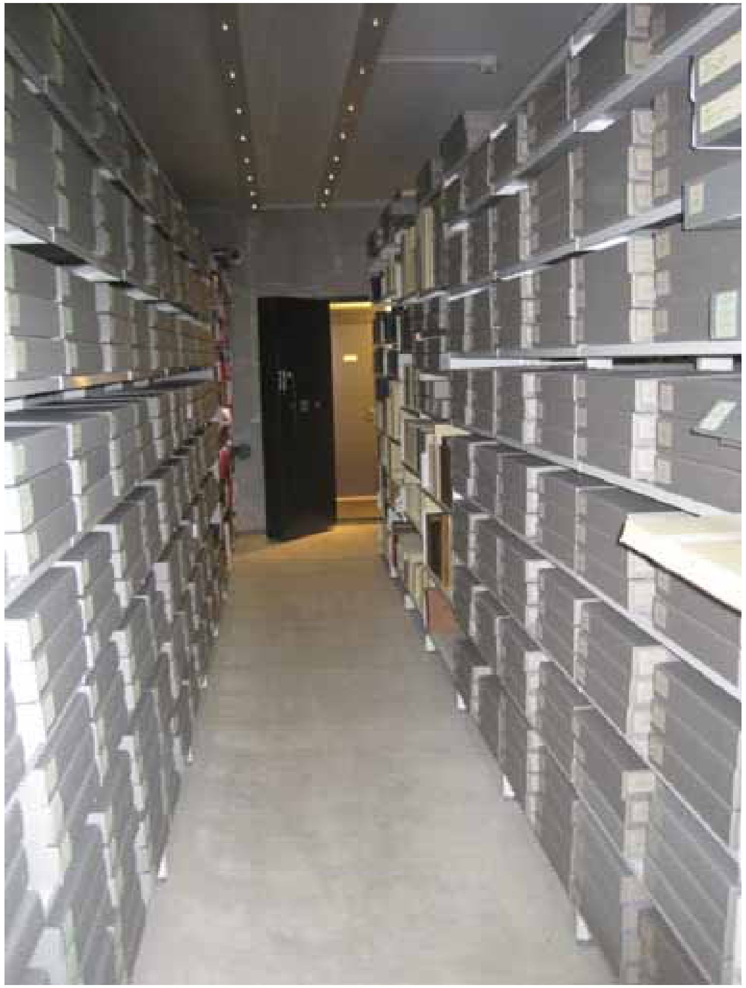


RH approx. 50%



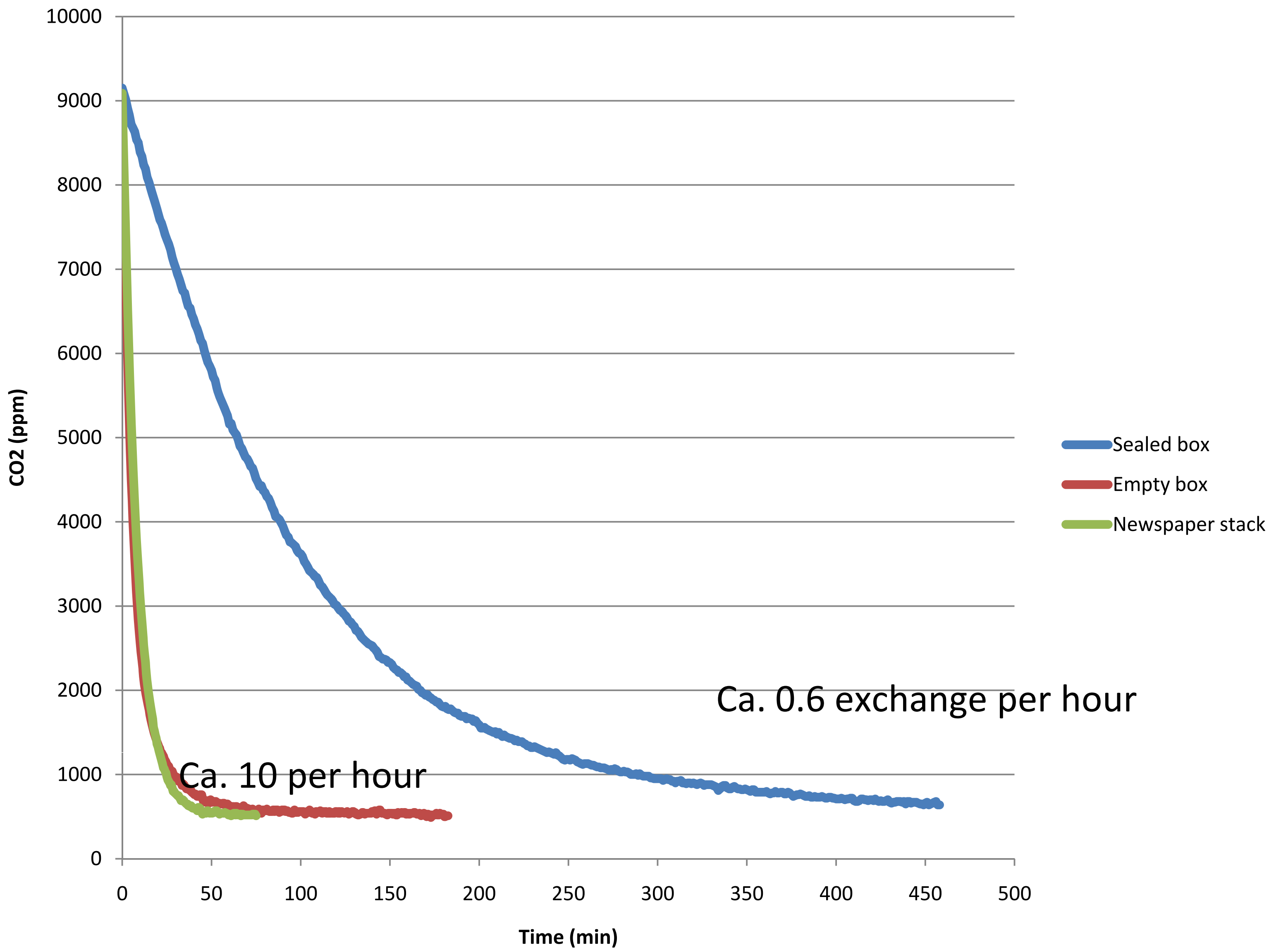
Music Museum Storage Room
Temp (C) - Concentration (ppb)
35
30
25
20
15
10
5
0
01-03-09
01-05-09
01-07-09
31-08-09
31-10-09
31-12-09
02-03-10
Temp
Formic Acid
Acetic Acid

Micro-climates: boxes, books, drawers, paper stacks…



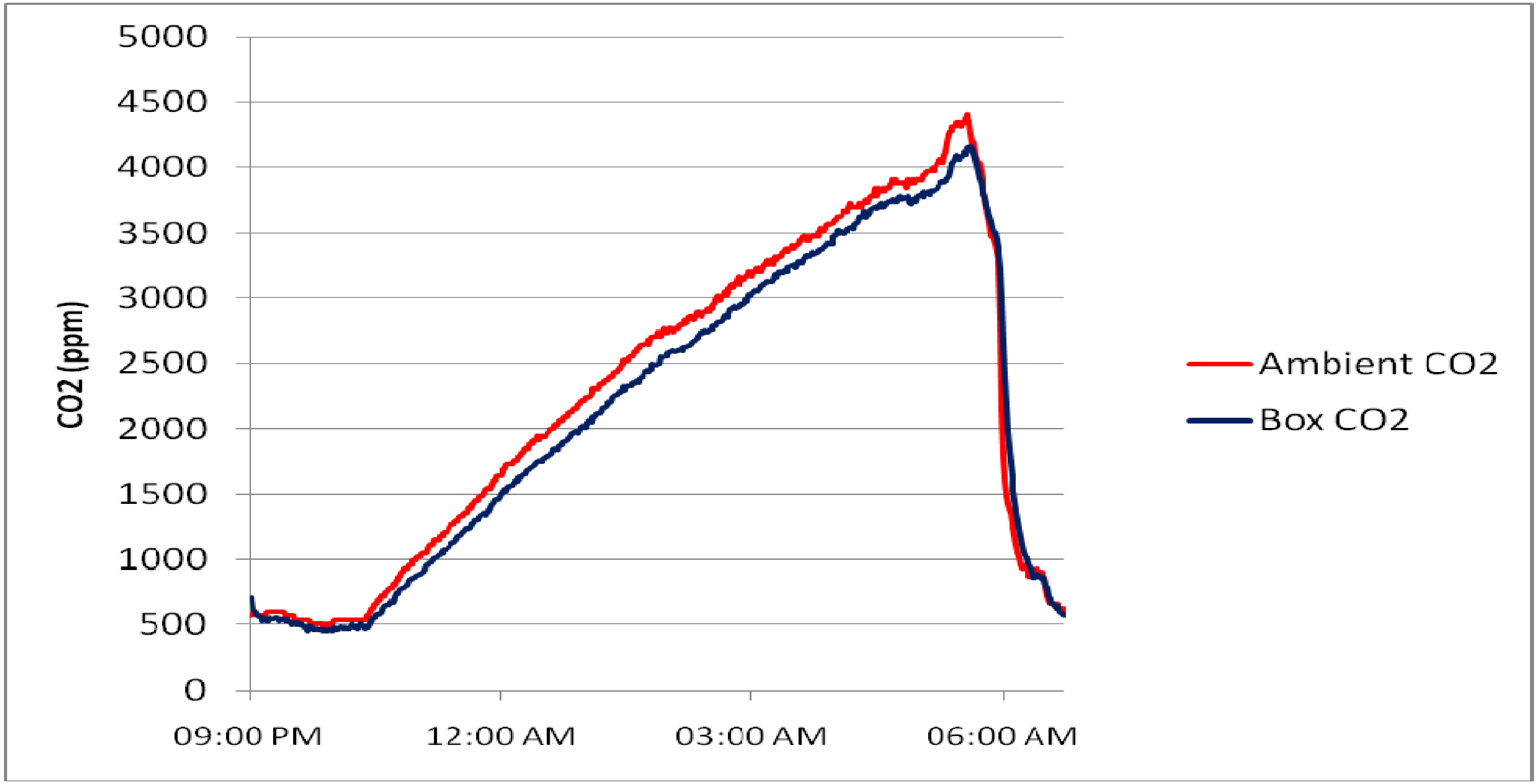
The air exchange of a box?
Or a stack of paper?

And what if the card board is sealed?



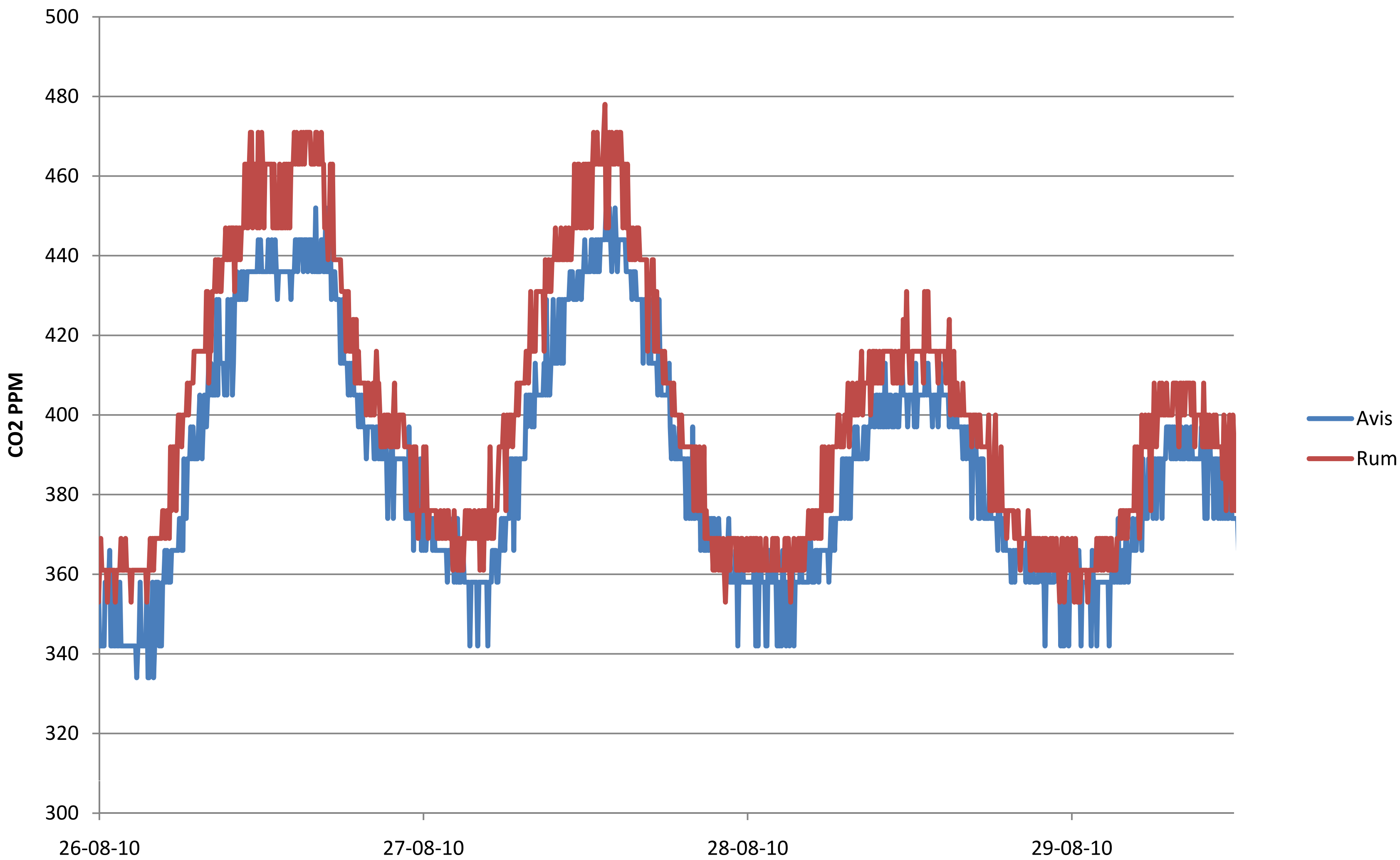
CO2 (ppm)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
400
450
500
Time (min)
Sealed box
Empty box
Newspaper stack
Ca. 0.6 exchange per hour
Ca. 10 per hour

Air diffusion through box board

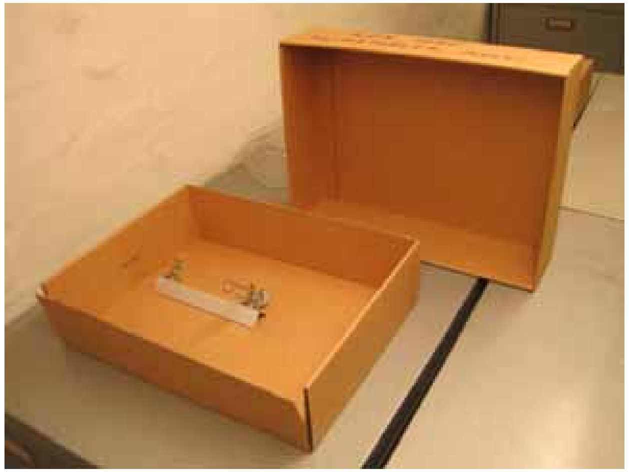


Newspaper stack

Air diffusion through newspaper stack



Pollutants: diffusion and reaction



Gas	Ambient conc. (room)	Level inside box (% of ambient)
CO_2	380 ppm	100%
NO_2	6.9 ppb	60%
Organic acids	20 ppb	45%
O_3	4.9 ppb	<10%