Air pollution

Morten Ryhl-Svendsen
National Museum of Denmark

Compounds and sources

Ozone

Nitrogen dioxide

Sulphur dioxide

Organic acids (acetic + formic)

Volatile organic compounds

Dust and particles

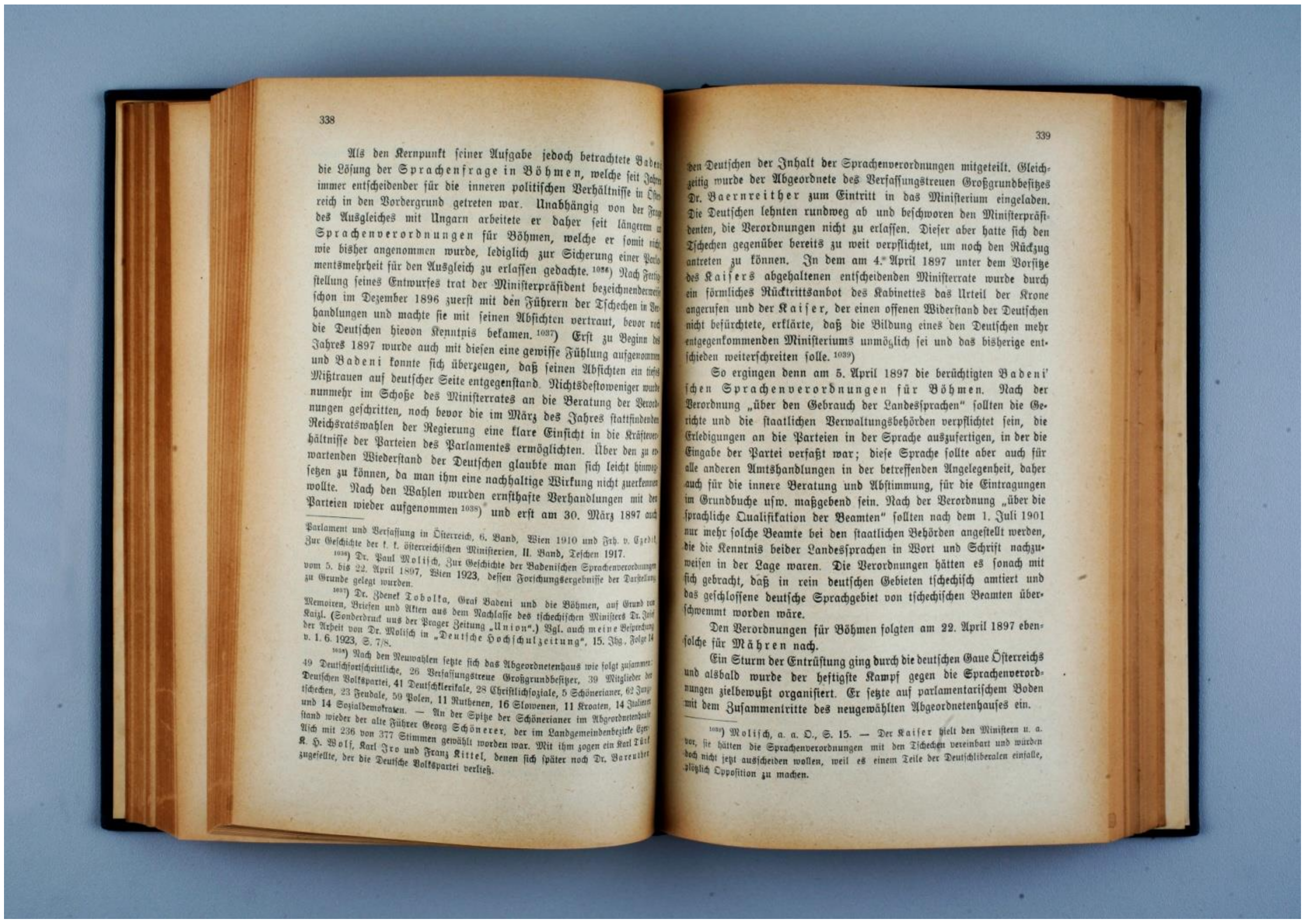
Damage caused by air pollution: *Lead corrosion*

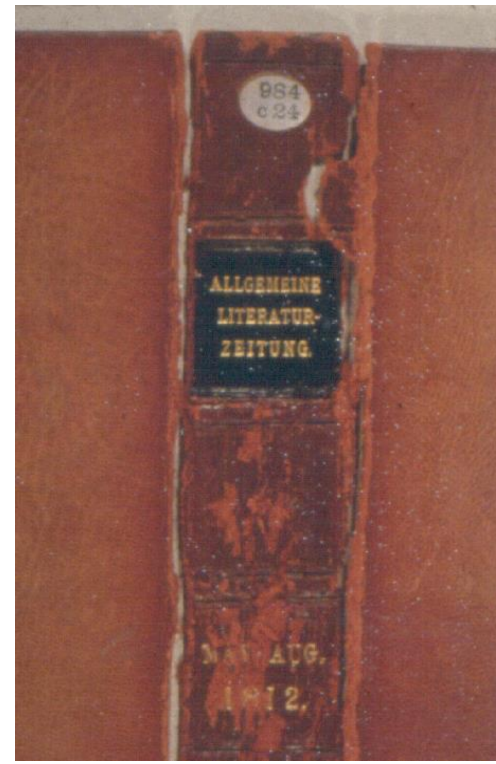
Damage caused by air pollution: *Silver tarnish*

Damage caused by air pollution: *Oxidized rubber*

Damage caused by air pollution: *Soiling*

Damage caused by air pollution:
Paper and leather

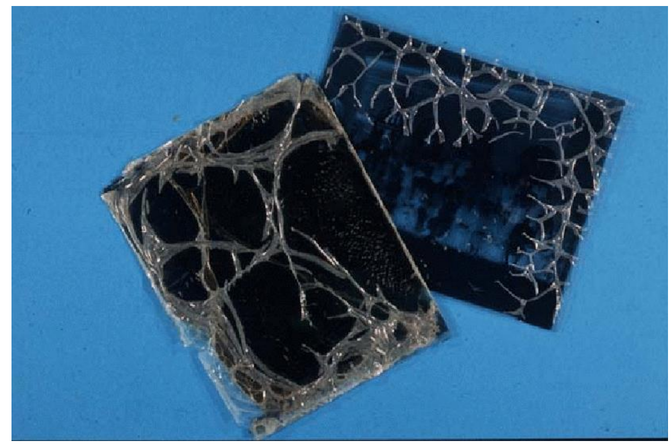




Damage causing air pollution:

Deterioration of plastics,

and acid paper



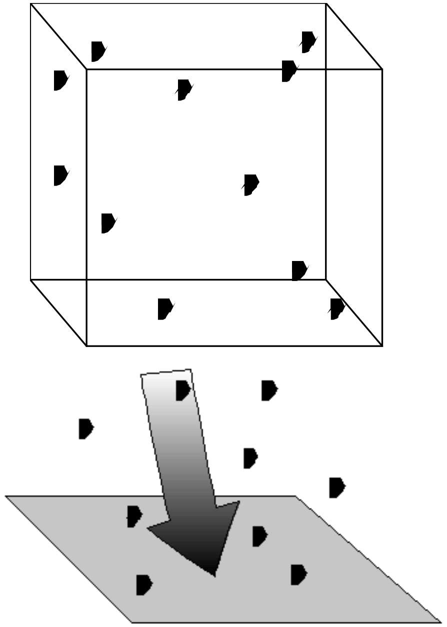
Monitoring

Concentration measurements

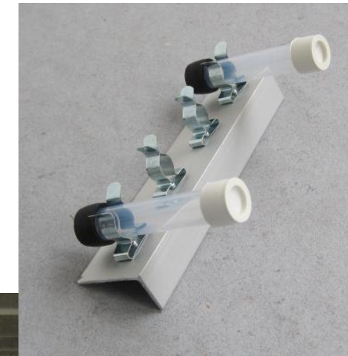
- passive sampling, diffusion tubes
- active sampling, real-time instruments

Dosimetry

- ”dummy” materials
- advanced dosimeters



Diffusion tubes (passive)



Active sampling and real-time monitoring


Ozone Monitor

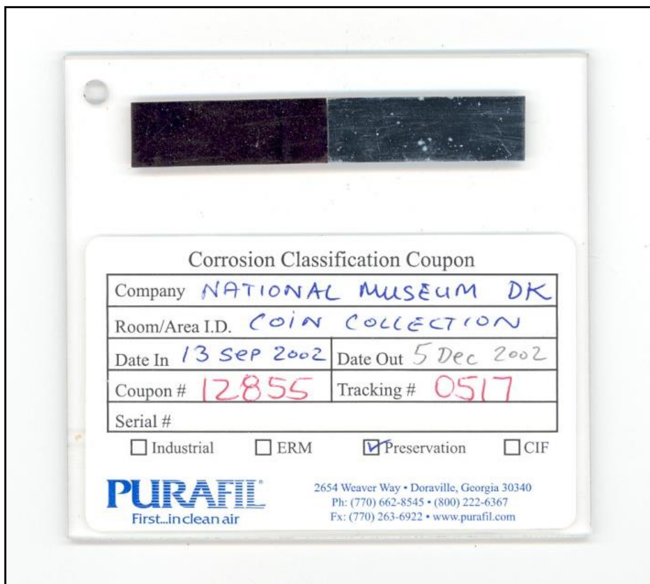

airpointer
Compact Monitoring System by www.recordum.com

Dosimetry: corrosive environments

Commercial dosimeters

Purafil coupons
(silver & copper)
and realtime unit

NILU EWO (polymer)



Control measures

Control measures:
Source control, indoor pollutants (”avoid”)

Source control

Vejle Storage Building: No wooden shelves

Control measures: Block outdoor pollutants

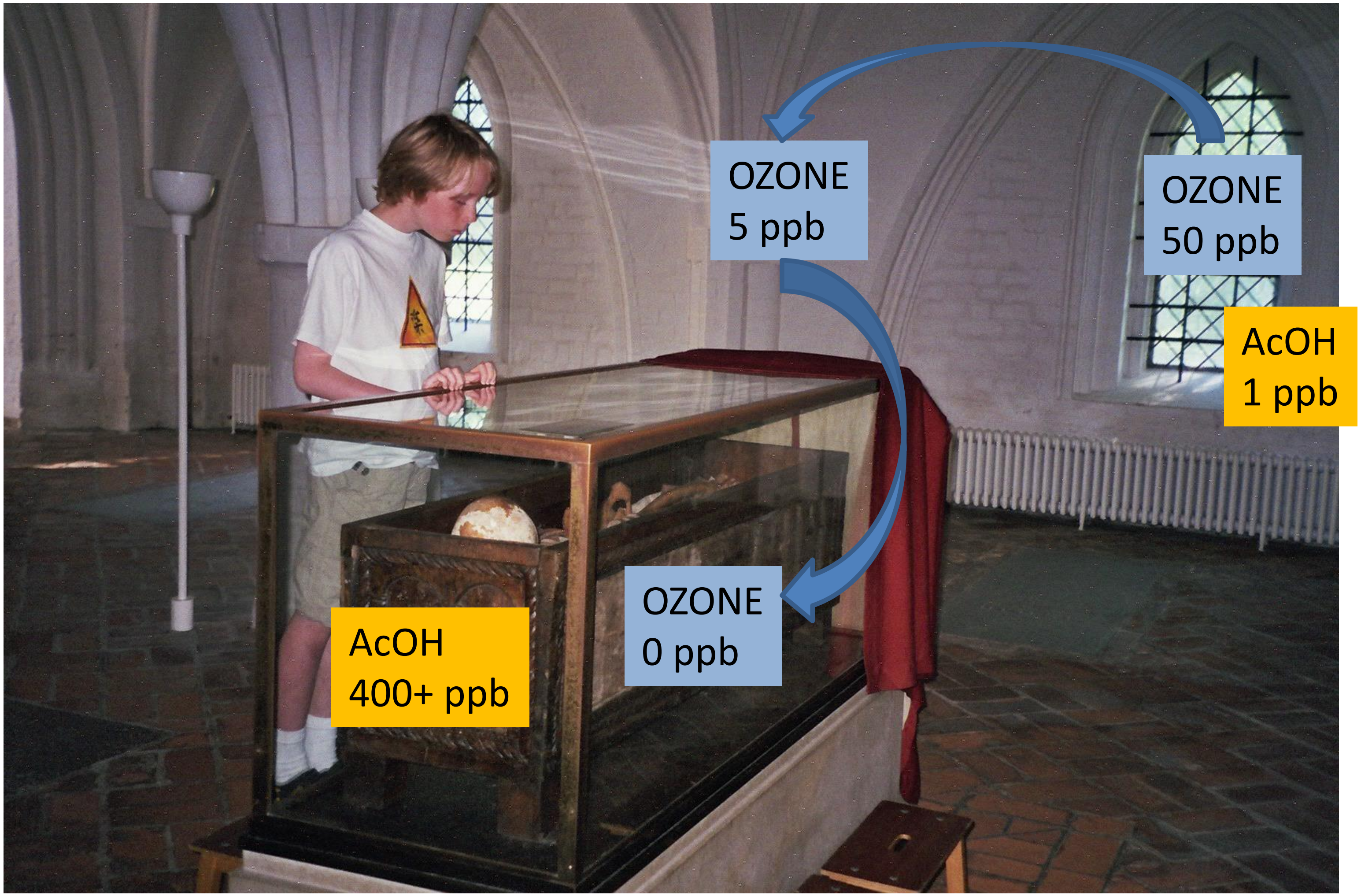
Dust filters (bag type)

Activated carbon filters (charcoal granulates)

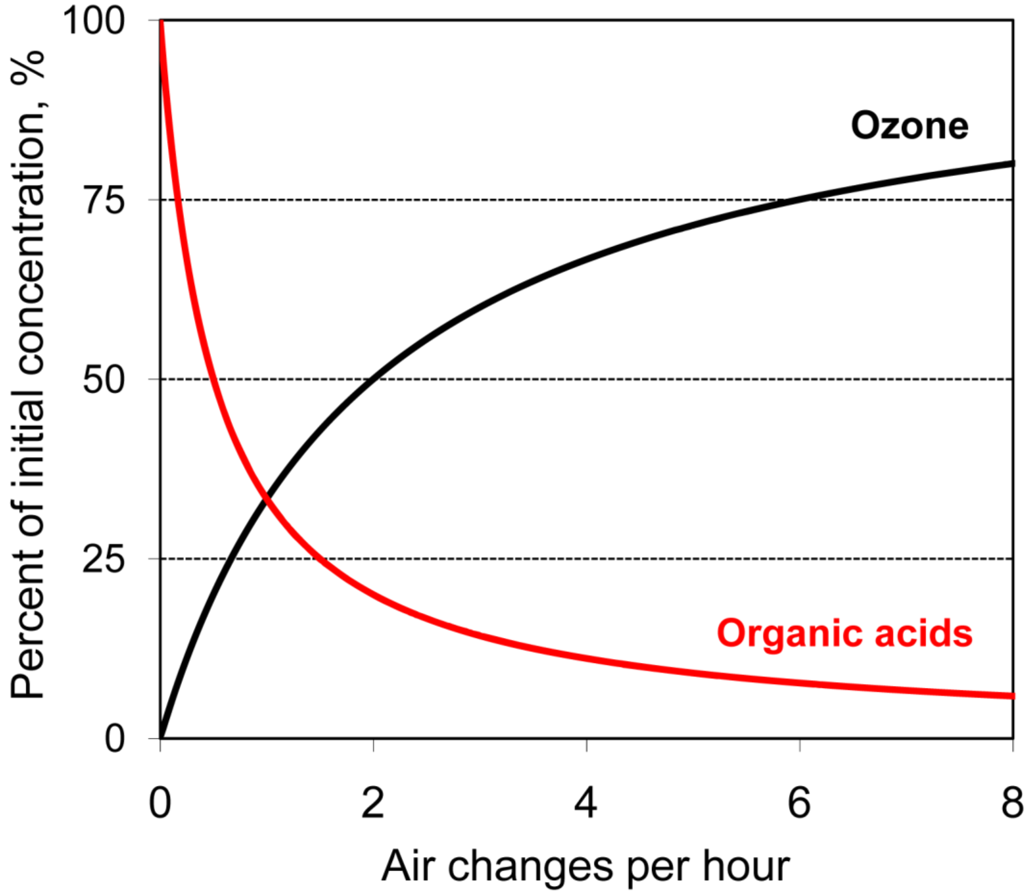
Control measure: Dilute (ventilation)

Air cleaners
(”sink”)

Blocking pollutant's pathway: a double-edged sword



Dilution / infiltration



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

Passive air cleaning (sorption)

Charcoal impregnated non-wowen textile

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

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

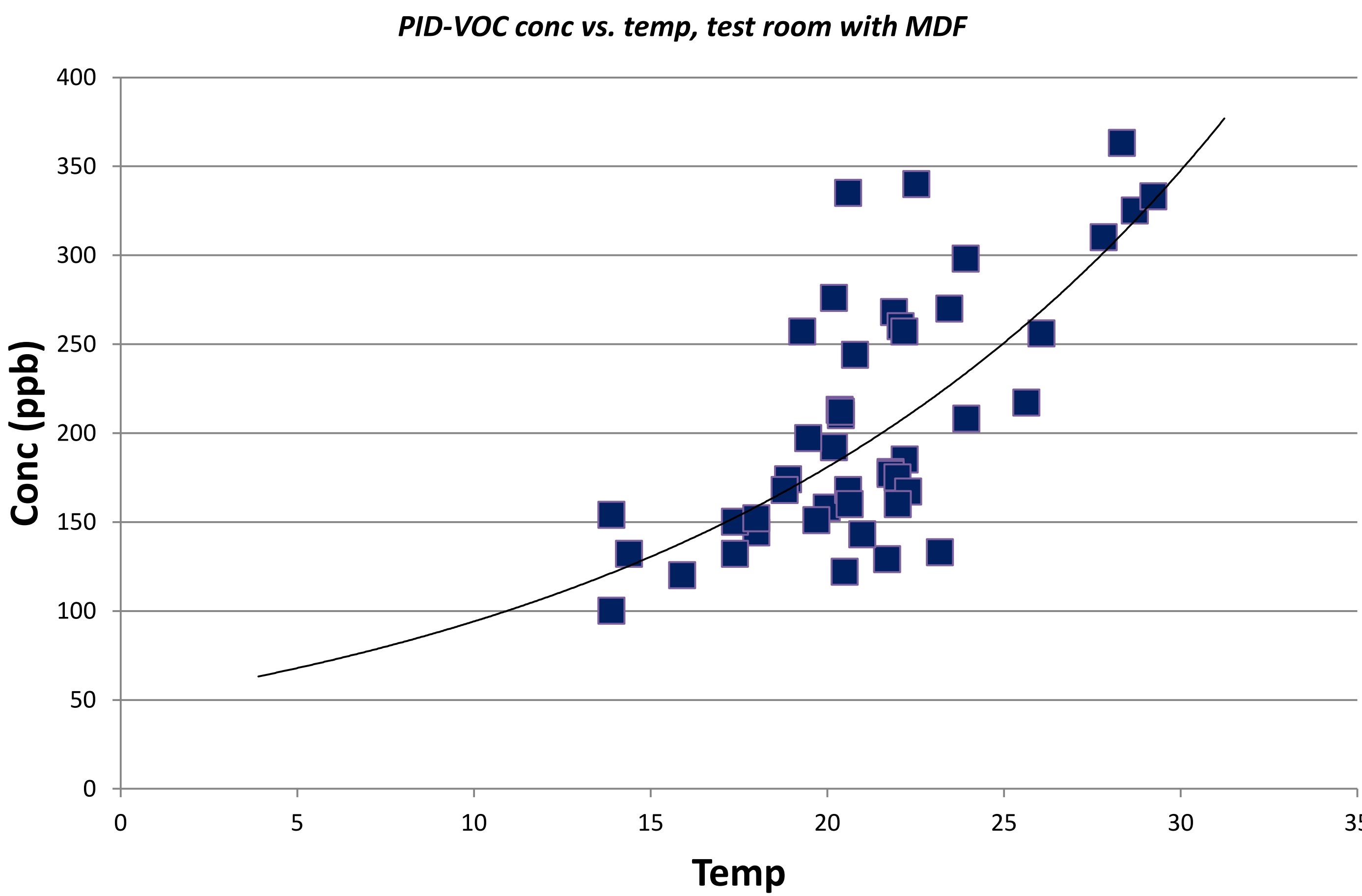
- **Organic acids: conc. decrease 30%**
- **Formaldehyde: conc. decrease 10%**

- 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



Examples of museum environments

Vejle Storage Facility

Intenal recirculation with dehumidification,
no heating

Rural environment

Low air exchange rate (approx . 1 per day)

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

LOW

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

LOW

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

LOW

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

HIGH

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

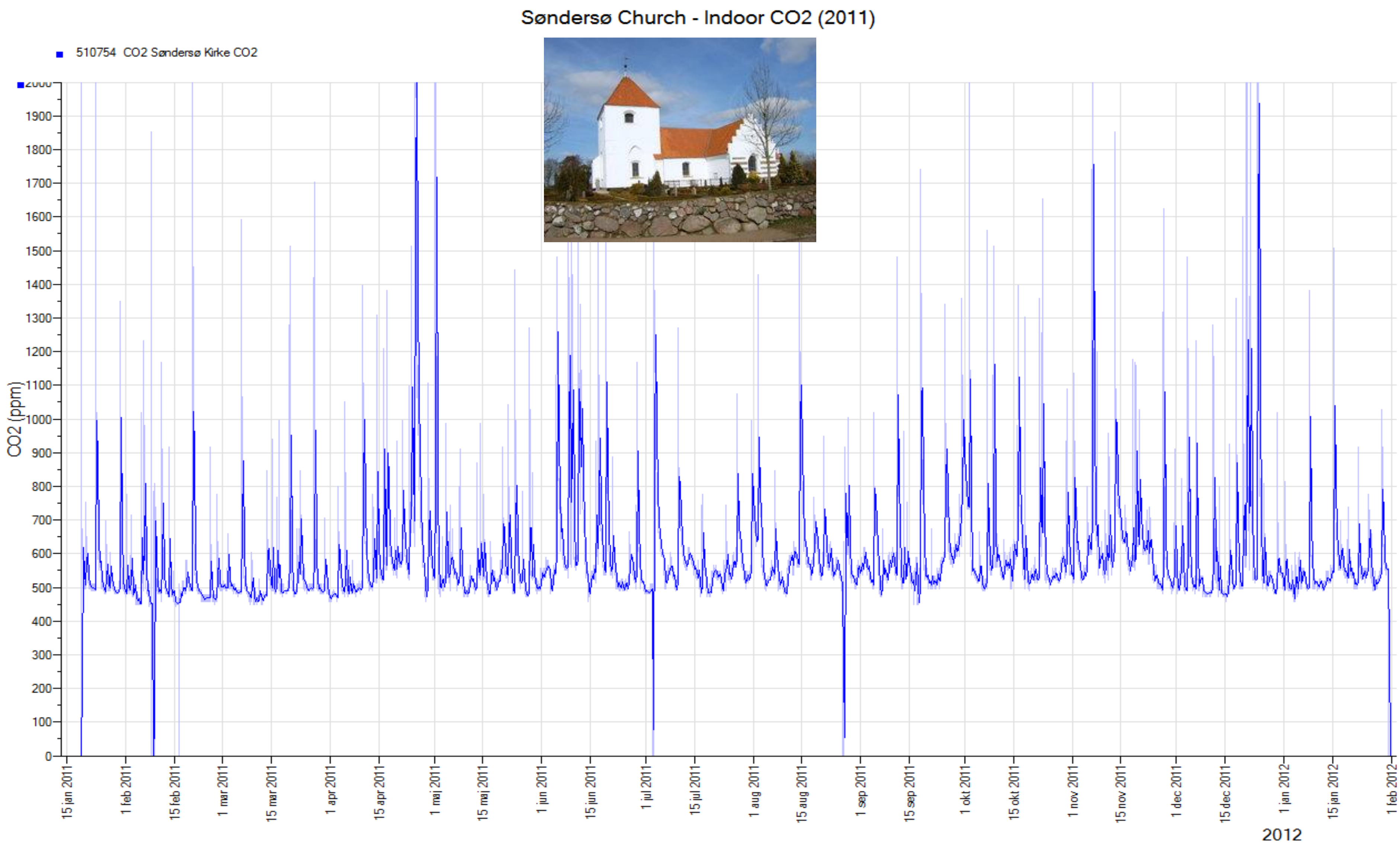
Ozone inside coffin: below detection

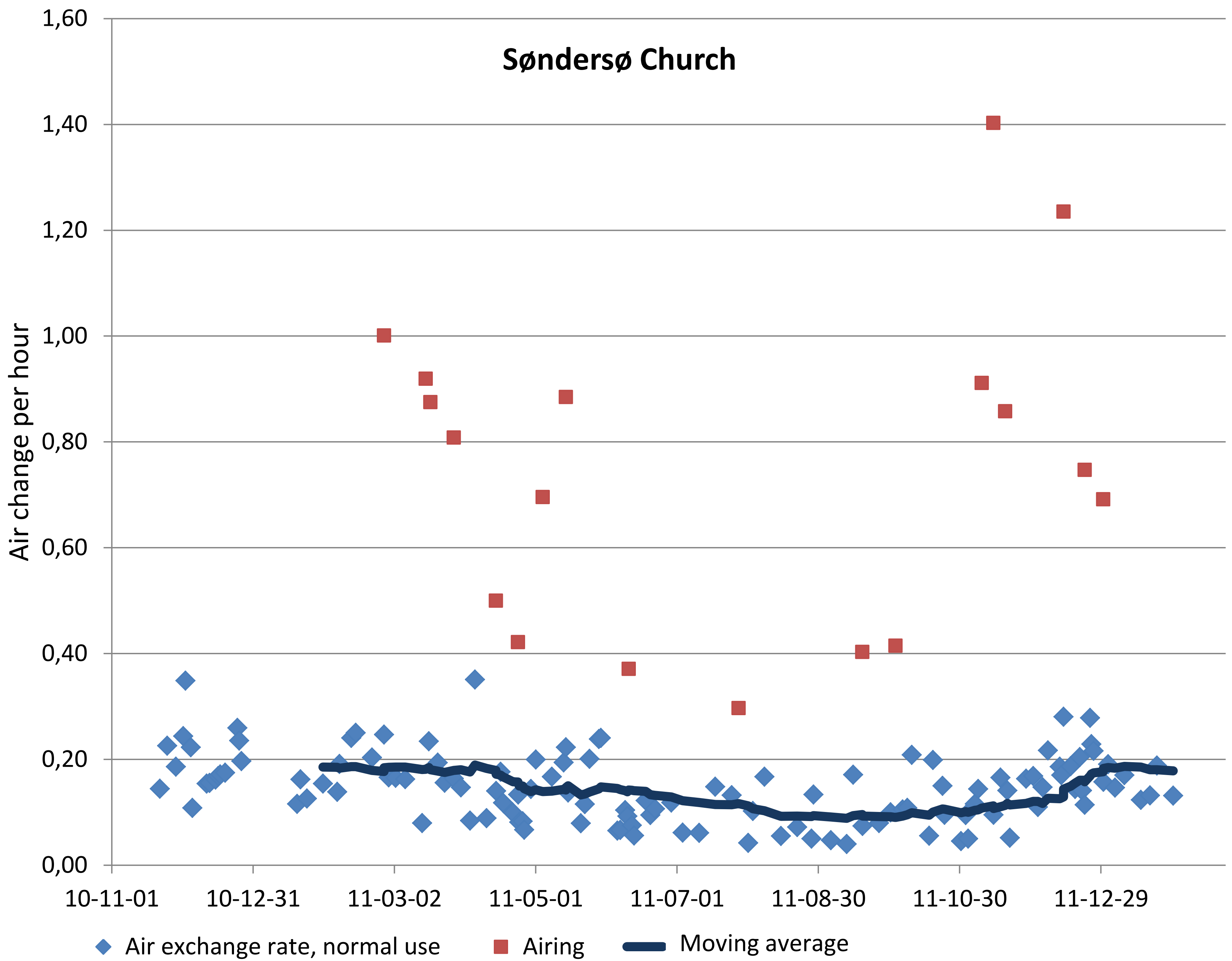
Organic acids outdoor: 1-2 ppb
Organic acids inside church: 1-5 ppb
LOW

Organic acids inside coffin: > 400 ppb
VERY HIGH

Using CO_2 as a tracer gas for air exchange rate measurement

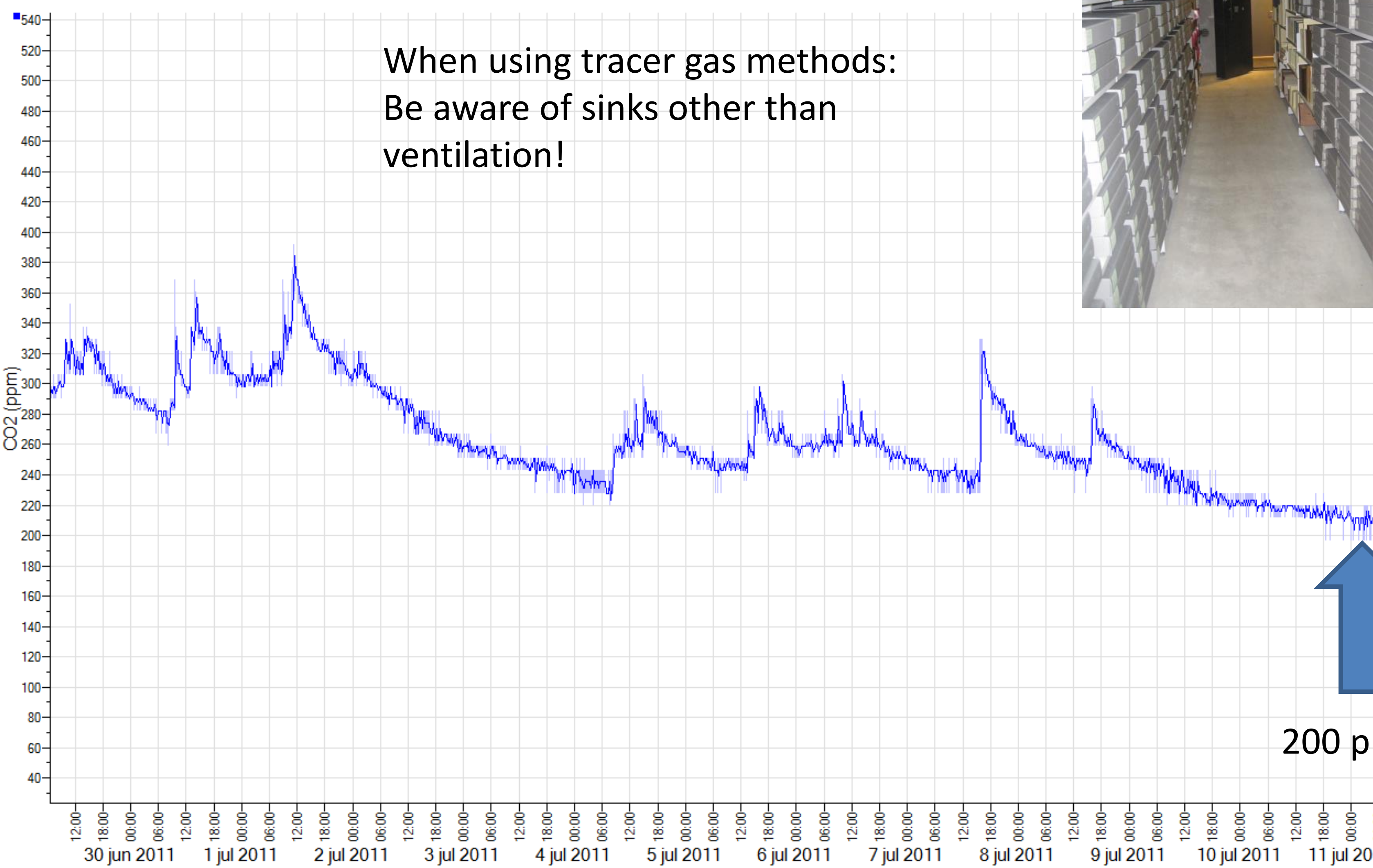
CO2 from people in a church building for one year





Søndersø Church
Air change per hour
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
10-11-01
10-12-31
11-03-02
11-05-01
11-07-01
11-08-30
11-10-30
11-12-29
Air exchange rate, normal use
Airing
Moving average

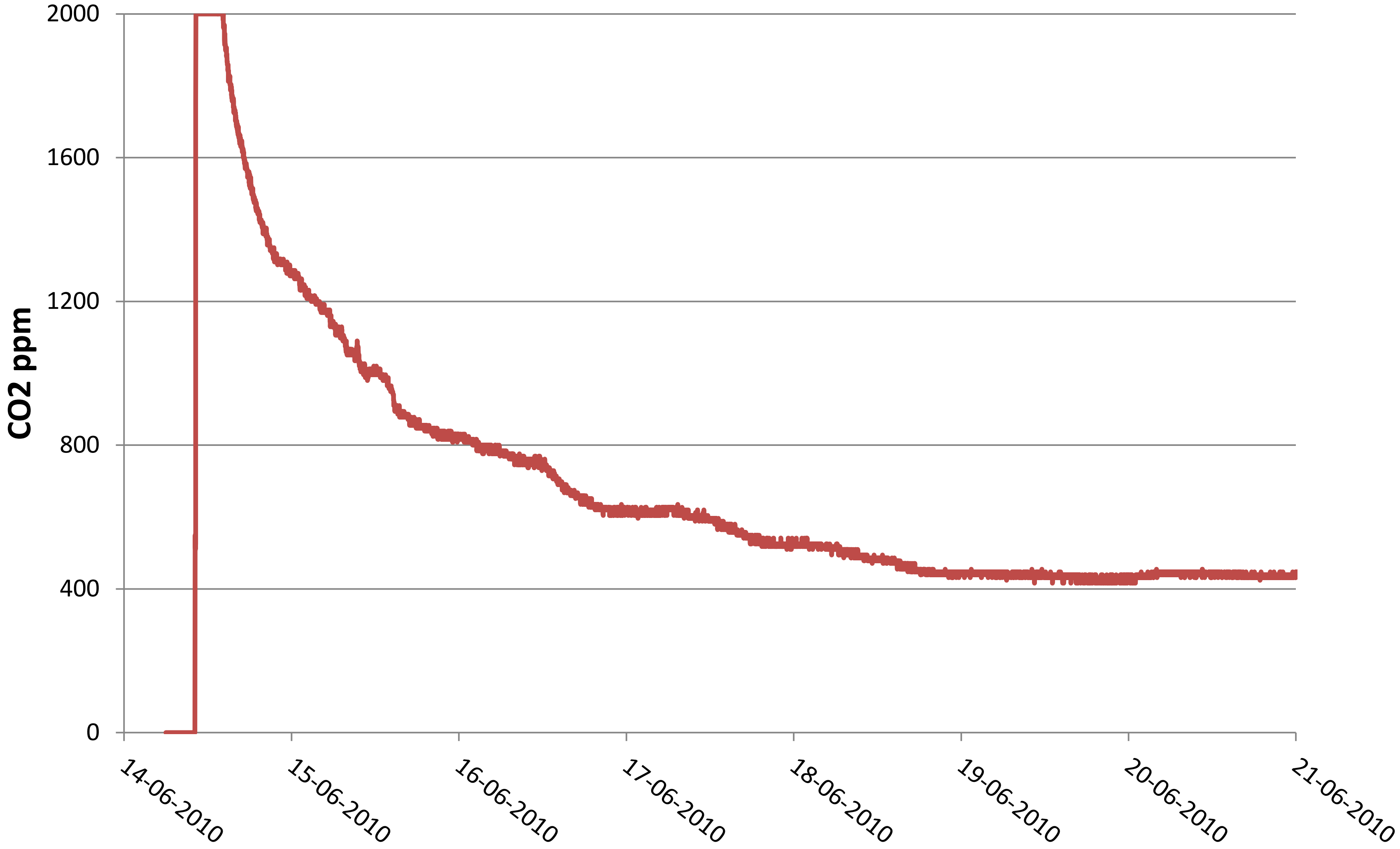
When using tracer gas methods: Be aware of sinks other than ventilation!



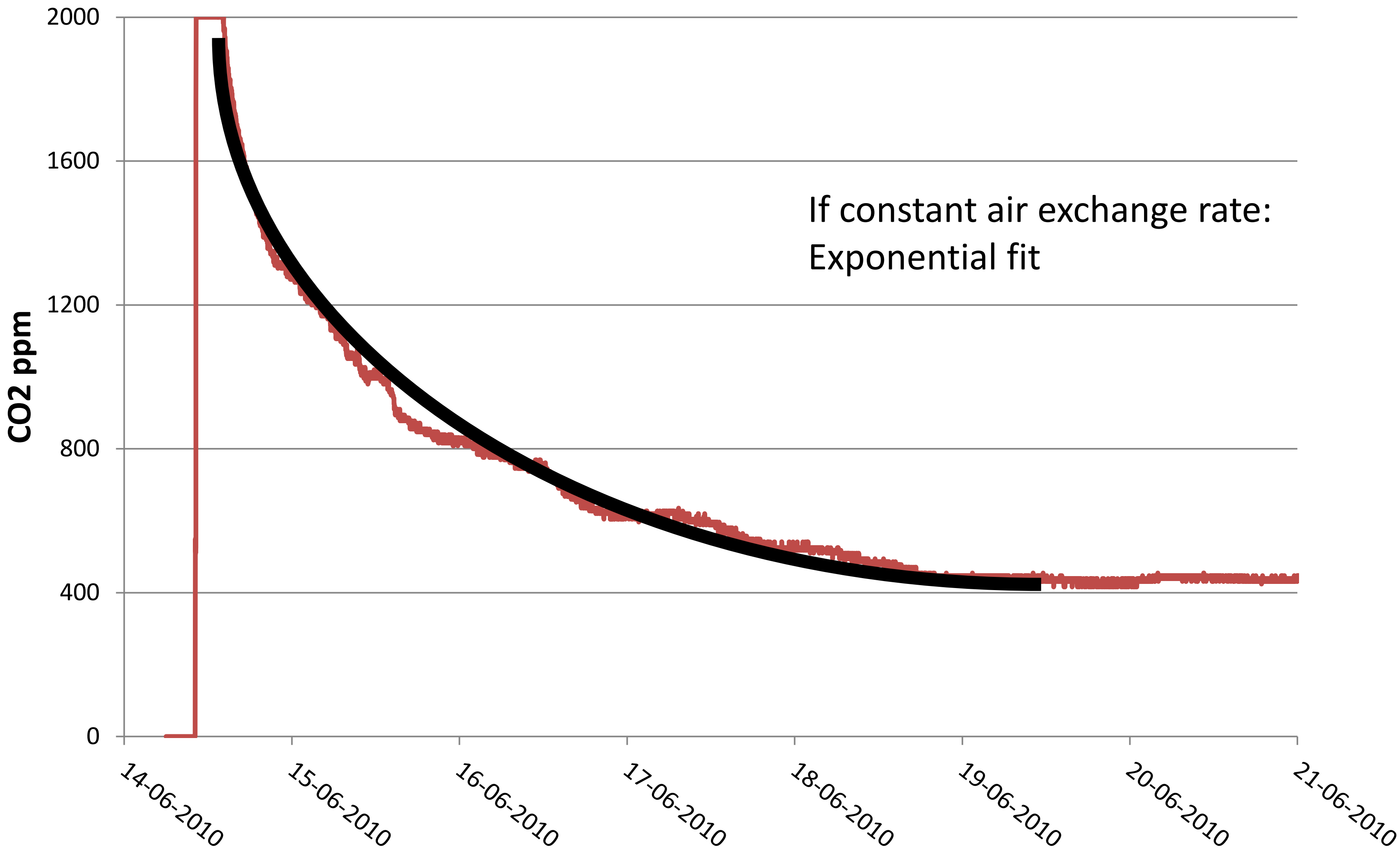
200 ppm !

AER measured in a storage room

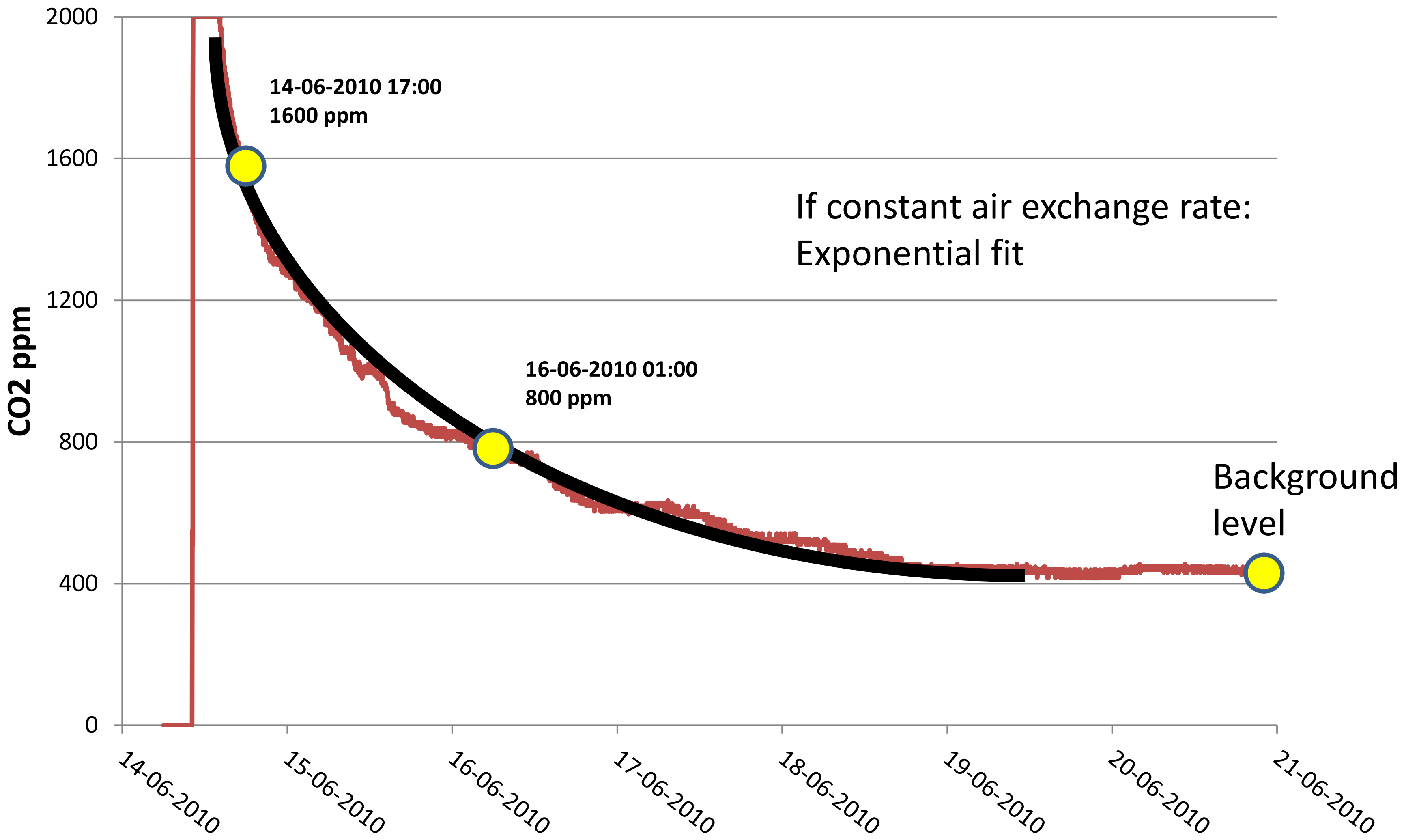
Concentration decay curve



Concentration decay curve



Concentration decay curve



The air exchange rate *n* was calculated from two subsequent measurements of the CO_2 concentration, while the elevated concentration diminished toward the background level:

$$n = \frac{ln(C_1/C_2)}{(T_2 - T_1)}$$

where C_1 and C_2 were the concentration surplus above the background CO_2 concentration (ppm), recorded at the times T_1 and T_2 (day:hour)

1: 14-06-2010 17:00
1600 ppm

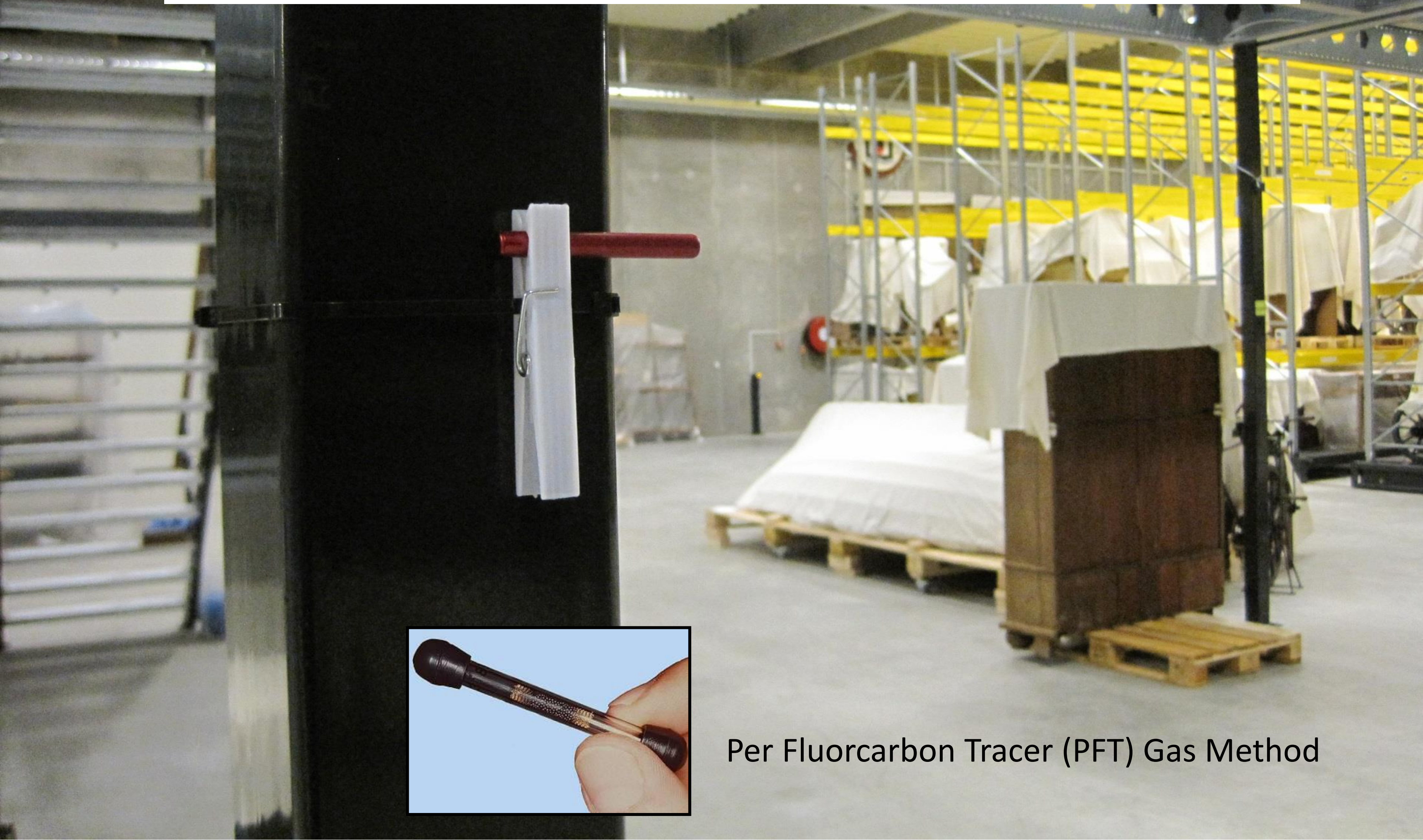
2: 16-06-2010 01:00
800 ppm

3: Background
430 ppm

$$n = \frac{ln((1600 - 430)ppm\,/(800 - 430)ppm)}{(1.3\ day)} = 0.9\ per\ day$$

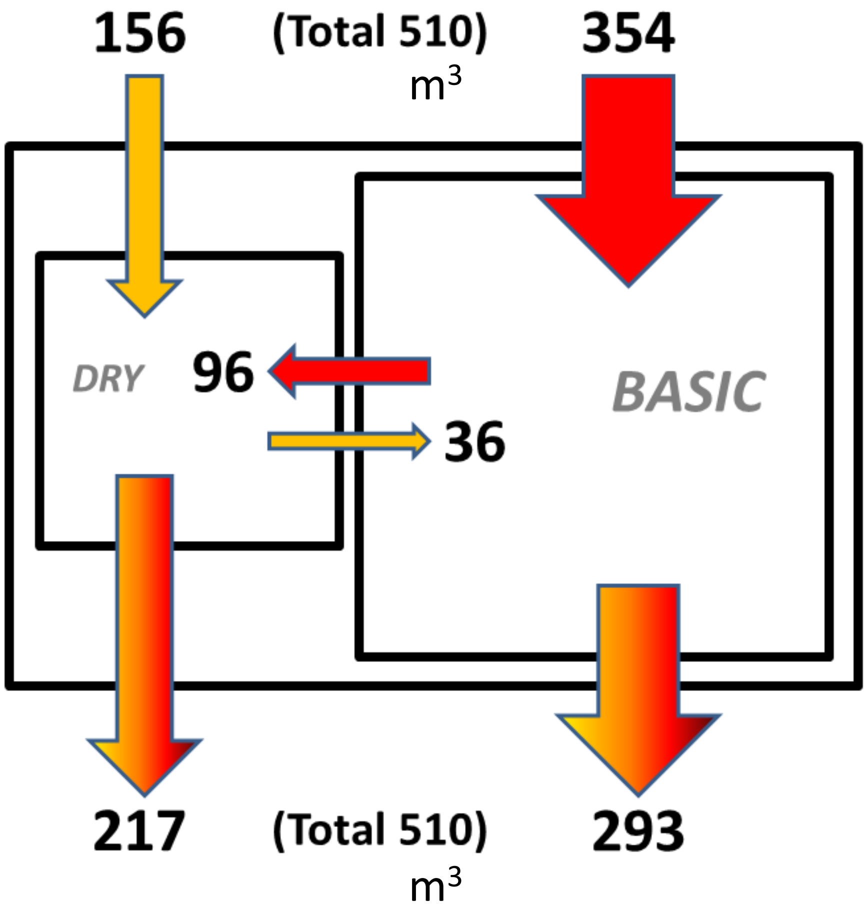
or: 1 air exchange in 1.1 days (27 h)

There are other methods for measuring air exchange rate, e.g. by passiv sampling



Per Fluorcarbon Tracer (PFT) Gas Method

Using two tracer gases



Randers storage building: interchange of air (m^3 per hour).
Total volume 13,400 m^3