Measuring Air Changes per Hour with Carbon Dioxide

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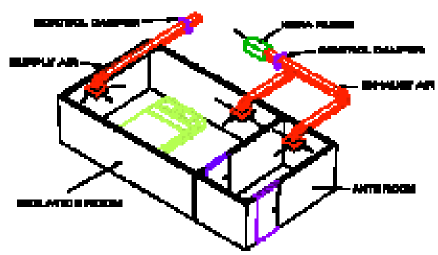
Measuring room air exchange



- Measure air supply & extract
- Negative pressure: extract > supply by ~10%

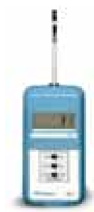
Calculating ACH

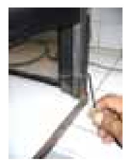
- Q = room ventilation (cfm)
- V = velocity (feet/min)
- A = duct area (square feet)
- ACH = Q/room volume

Measuring room air exchange in low resource settings

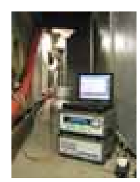
$Q = V \times A$

$ACH = Q/\text{volume}$





Measuring room air exchange using a tracer gas

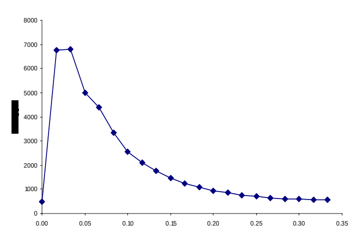


US$ 30,000

Principles:

- Use gas that is not usually present in the room air: SF_6
- Deliver gas and mix with room air
- Measure concentration decay to calculate air exchange
- Also a continuous release methodology

Concentration decay

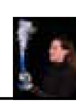


Standard tracer gas technique:

- American Standards and Test Material Committee. 1988. Standard test method for determining air leakage rate by tracer dilution. In Annual Book ASTM Standards & Test Materials. Wash DC. 568-575
- Standard test methods for determining air change in a single zone by means of a tracer gas dilution. Standard E741-00. Philadelphia, Pennsylvania: American Society for Testing Materials.
- Decker J. Evaluation of isolation rooms in health care settings using tracer gas analysis. Appl Occup Envir Hyg 1995;10:887-91.

Other methods: theatrical fog

- Gershey EL, Reiman J, Wood W, Party E. Evaluation of a room for tuberculosis patient isolation using theatrical fog. Infect Control Hosp Epidemiol. 1998 Oct;19(10):760-6.



Measuring natural ventilation

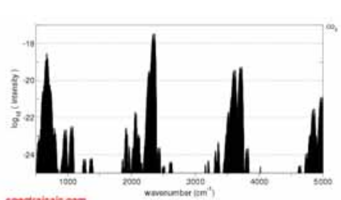




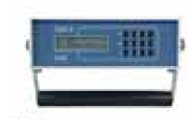
Measuring room air exchange using carbon dioxide as a tracer gas

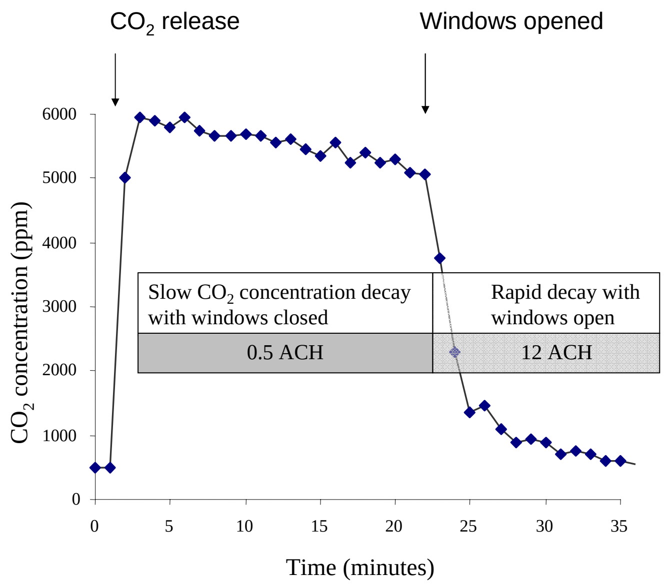
- Infra-red gas analyser to measure CO_2 concentrations
- Advatanges: Cheap
  CO_2 easily available (dry ice, fizzy drinks)
  Can use occupied rooms
- Disadvantages: Not perfect
  CO_2 present in air
  CO_2 produced by occupants

- Menzies R, Schwartzman K, Loo V, Pasztor J. **Measuring ventilation of patient care areas in hospitals. Description of a new protocol.** Am J Respir Crit Care Med 1995;152:1992-9.







Closing apertures

CO_2 release

Small rooms, little ventilation:
Gas cylinder
Large rooms, lots of ventilation:
Fire extinguisher

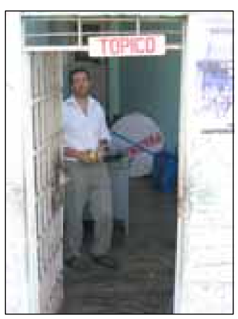
CO_2 release

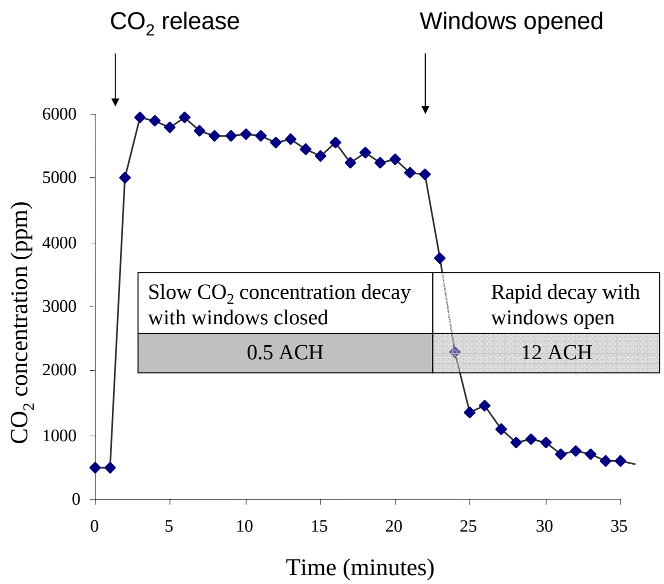
Very big rooms – lots of fire extinguishers

Mixing: Aiming for complete mixing

Mixing

no electricity





Calculation of ACH

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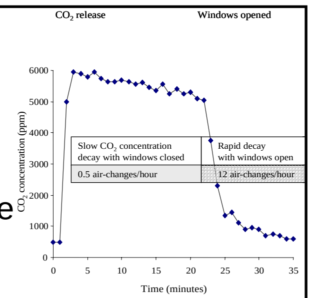
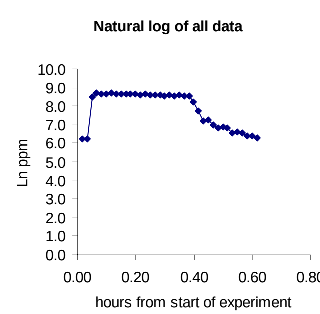


ACH = Absolute ventilation / Room Volume
= Q / V

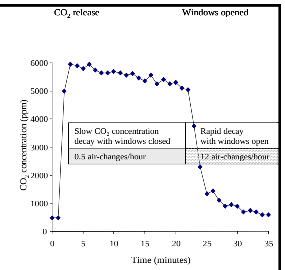
Plot natural log of CO_2 concentration against time

Units: concentration (eg ppm)
vs. time in hours

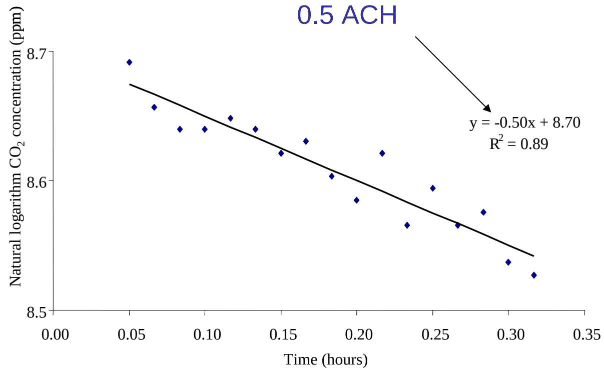
ACH = slope of line of best fit



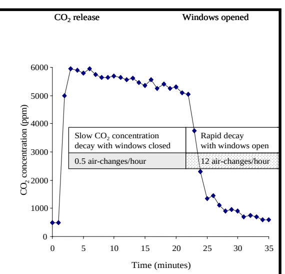
Calculation of ACH



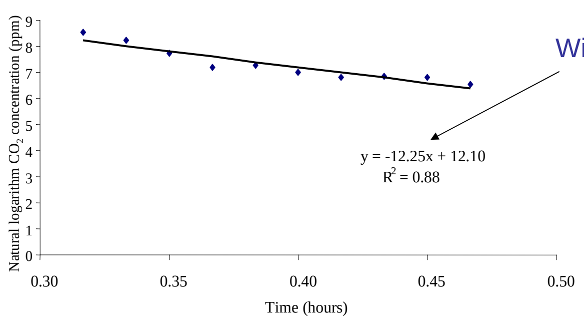
Windows and doors **CLOSED**
0.5 ACH



Calculation of ACH

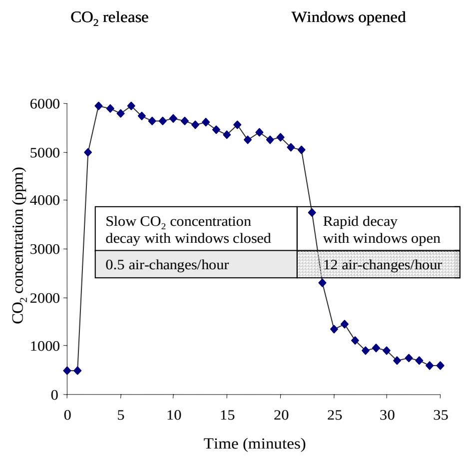


Windows and doors **OPEN**
12 ACH

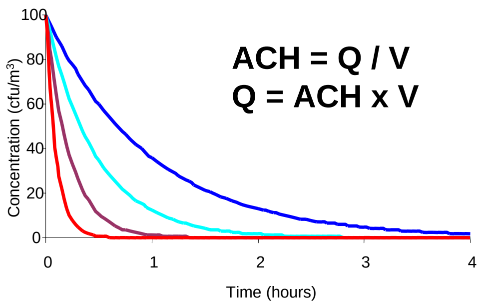


Where to stop?

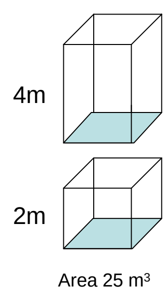
- Depends on room occupants
- Within 200 ppm of baseline



ACH *vs.* Absolute ventilation



ACH = Q / V
Q = ACH x V



$V = 4x25 = 100\ m^3$
12 ACH = 1,200 m^3/h

$V = 2x25 = 50\ m^3$
12 ACH = 600 m^3/h

In models of airborne infection, it is absolute ventilation that is a major determinant of disease transmission

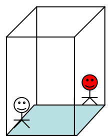
Wells-Riley equation: $C=S(1-e^{-Iqpt/Q})$

Effect of room volume if ACH is constant

Wells-Riley equation: $C=S(1-e^{-Iqpt/Q})$

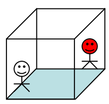
C= new cases
S=susceptibles
I =number of infectors
q=infectious quanta produced per hour
p=pulmonary minute ventilation
t=duration of exposure
Q=absolute ventilation

ACH=12

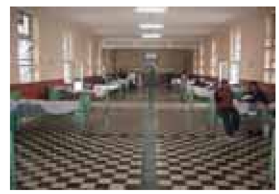


Q=1,200
$C=1x(1-e^{-1x13x0.6x8})/1,200$
=0.05
Risk = 5%

ACH=12



Q=600
C=1x(1-e-1x13x0.6x8)/1,200
=0.10
Risk = 10%

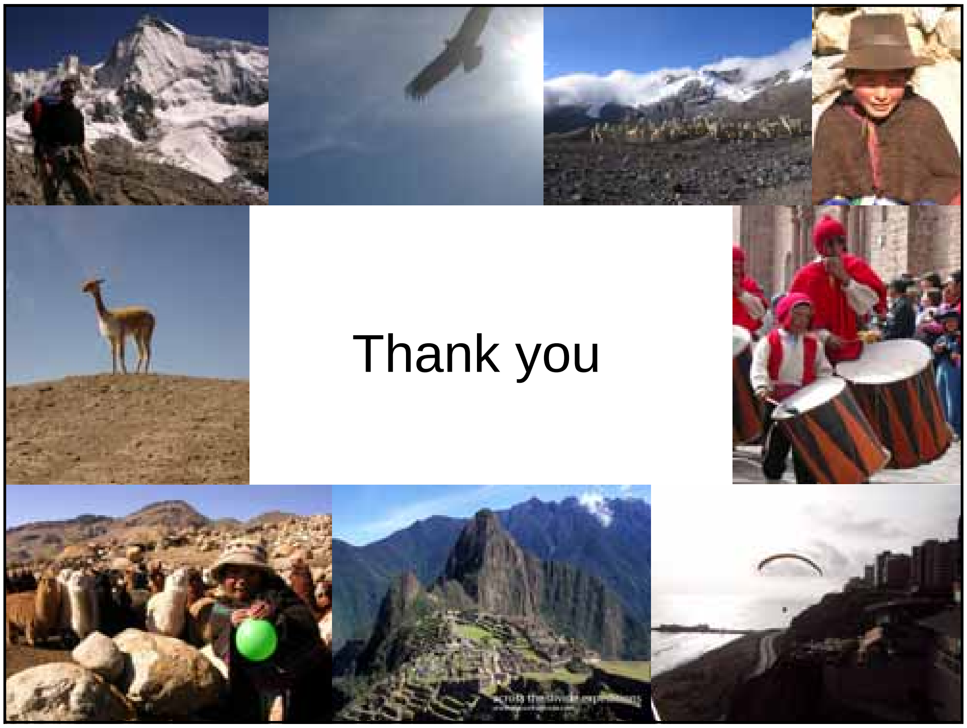


Mechanical ventilation can't deliver high ACH in large rooms due to cost, drafts, fan noise etc
More complex: room crowding / bed spacing / near-far effect

Measuring room air exchange using carbon dioxide as a tracer gas

Conclusions

- Simple
- Easy to do
- Equipment relatively easily available
- Cheap
- A bit rough, but with inherent variability of natural ventilation (wind speed etc) and such high air exchange rates, high precision is less important
- It's fun!


Thank you