AIVC 2017 Workshop: Is Ventilation The Answer To Indoor Air Quality Control In Buildings? Do We Need Performance-Based Approaches?

Indoor CO$_2$ as Metric of Ventilation and IAQ: Yes or No or Maybe So?

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KEY MESSAGES

• Ventilation/IAQ standards do not contain CO$_2$ limits of 1000 ppm$_v$.

• Indoor CO$_2$ can be used as a tracer gas to assess ventilation, but assumptions must be understood and their validity evaluated.

• Indoor CO$_2$ concentrations related to perceptions of human bioeffluents, but not to other important indoor contaminants.

• Typical indoor CO$_2$ concentrations (in nonindustrial) buildings are unlikely to result in adverse health effects.
OUTLINE

Brief background on indoor CO₂

Potential uses and abuses of CO₂

USES
  • Compliance with standards
  • IAQ metric
  • Ventilation surrogate

ABUSES
  • 1000 ppmᵥ de facto limit
  • Peak concentrations to estimate outdoor air per person

BACKGROUND

CO₂ part of ventilation discussions since 1700s

Discussions evolved over time
  • Impacts on building occupants
  • Relation to bioeffluent perception
  • Estimation of ventilation rates
  • Demand controlled ventilation
CO₂ as a Metric: What do the Standards Say?

Most ventilation/IAQ criteria about 1800 mg/m³
ASHRAE 62.1 and CEN 13779/15251 do not contain CO₂ limits
Informative appendices discuss 1800 mg/m³

Exposure limits in industrial environments:
18000 to 54000 mg/m³

LEED v4
Requires CO₂ monitoring in naturally ventilated spaces
Points for monitoring in densely occupied spaces
But no concentration limit

1800 mg/m³ CO₂ and Perception of Body Odor

• Chamber studies since 1930s, later in buildings
  7 to 9 L/s per person, body odor acceptable to most
  individuals entering from clean air

• 80 % acceptability for 1250 mg/m³ > outdoors
  Consistent with 1800 mg/m³

• 1800 mg/m³ reflects acceptable body odor
  But many other important indoor pollutants not
  associated with number of occupants
Impacts of CO₂ on Building Occupants

• Indoor levels rarely close to health-based limits
  Industrial limits not applicable to non-industrial occupants

• 1800 mg/m³ (1000 ppm) viewed as de facto standard
  Not based on CO₂ health impacts
  Linked to 7 L/s per person outdoor air ventilation rate

• Higher CO₂ levels correlate with increased symptoms
  Other contaminants increased with lower ventilation

• Recent studies showing decreased decision-making performance
  as low as 1800 mg/m³; other recent studies don’t show effect

Measured Indoor CO₂ Concentrations (mg/m³)

Office Buildings
EPA BASE: Mean peak 1260, 90th percentile 1650
European Audit Study: Averages from 900 to 1400
Calif. small/medium commercial: Mean 1168, mean peak 3031

Residences
New California homes: 600 to 2000
Tianjin China: Median 2500, 20 % above 3600
Denmark bedrooms, 25 % above 3600

Schools: 2 studies - most below 2000

Most <2000; small fraction >5000; none near industrial limits.
Peak CO$_2$ to Estimate Outdoor Air per Person

\[ Q_{out} = \frac{G_{CO2}}{(C_{in,Steady\ state} - C_{out})} \]

- Well-established tracer gas methods
  ASTM E741, ISO 12569, …

- Single-zone constant injection most common
  Assumptions not always acknowledged (ASTM D6245): single-zone, constant air change, CO$_2$ generation rate constant and known, …
  CO$_2$ generation depends on activity, sex, age, weight, height
  Estimating before steady-state overestimates air change rate

USES AND ABUSES (POTENTIAL)

ABUSE
- 1800 mg/m$^3$ as a definitive IAQ metric
- Stressing on health impacts
- Peak CO$_2$ concentrations to estimate outdoor air per person

USE
- Convenient tracer gas
- Indicator of ventilation per person
- Demand controlled ventilation
CONCLUSIONS

• People are still confused about CO₂ in ventilation and IAQ

• “Limits” in standards either steady-state value linked to ventilation rate or health-based industrial value

• Most measured concentrations below “magic” value of 1800 mg/m³, none in range of industrial limits

• CO₂ is a fine tracer gas, but mass balance still applies

• How to address confusion?
  Reports and papers; Training; Careful review of papers