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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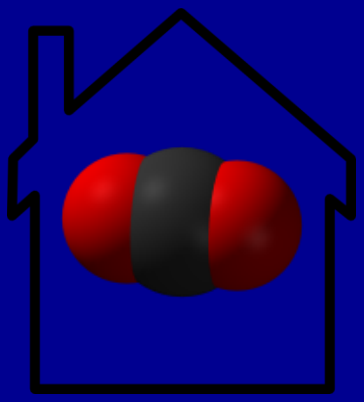
## KEY MESSAGES

- **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 $CO_2$

Potential uses and abuses of $CO_2$

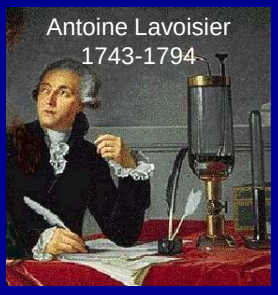


USES
- Compliance with standards
- IAQ metric
- Ventilation surrogate

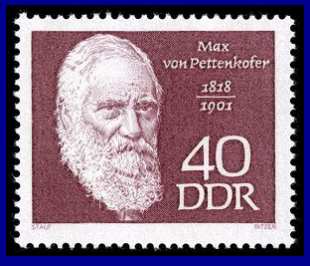
ABUSES
- 1000 $ppm_v$ de facto limit
- Peak concentrations to estimate outdoor air per person

# BACKGROUND

$CO_2$ 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



## $CO_2$ as a Metric: What do the Standards Say?

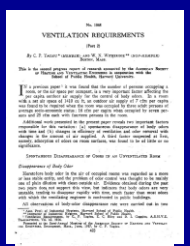
**Most ventilation/IAQ criteria about 1800 mg/m$^3$**
ASHRAE 62.1 and CEN 13779/15251 do not contain $CO_2$ limits
Informative appendices discuss 1800 mg/m$^3$

**Exposure limits in industrial environments:**
18000 to 54000 mg/m$^3$

**LEED v4**
Requires $CO_2$ monitoring in naturally ventilated spaces
Points for monitoring in densely occupied spaces
But no concentration limit

## 1800 mg/m$^3$ $CO_2$ 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/m$^3$ > outdoors**
  Consistent with 1800 mg/m$^3$
- **1800 mg/m$^3$ reflects acceptable body odor**
  But many other important indoor pollutants not associated with number of occupants



VENTILATION REQUIREMENTS

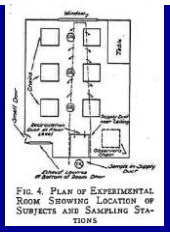


FIG. 4. PLAN OF EXPERIMENTAL ROOM SHOWING LOCATION OF SUBJECTS AND SAMPLING STATIONS

## Impacts of $CO_2$ on Building Occupants

- **Indoor levels rarely close to health-based limits**
  Industrial limits not applicable to non-industrial occupants
- **1800 mg/m$^3$ (1000 ppm) viewed as de facto standard**
  Not based on $CO_2$ health impacts
  Linked to 7 L/s per person outdoor air ventilation rate
- **Higher $CO_2$ levels correlate with increased symptoms**
  Other contaminants increased with lower ventilation
- **Recent studies showing decreased decision-making performance as low as 1800 mg/m$^3$; other recent studies don't show effect**

## Measured Indoor $CO_2$ Concentrations (mg/m$^3$)

**Office Buildings**
EPA BASE: Mean peak 1260, 90$^{th}$ 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 $CO_2$ 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/m$^3$, none in range of industrial limits**
- **$CO_2$ is a fine tracer gas, but mass balance still applies**
- **How to address confusion?**
  Reports and papers; Training; Careful review of papers