Study of carbon dioxide (CO2) sensor performance for building ventilation control

W. Rengie Chan  wrchan@lbl.gov
William J. Fisk and Toshifumi Hotchi
Indoor Environment Group
November 6, 2015
The Indoor Environment Group carries out research enabling healthy, productive and energy efficient built environments in the context of climate change adaptation.

Pollutant Exposures, Health, and Productivity
- Improving IEQ during energy retrofits
- Dampness and mold
- Schools, offices, and homes

Energy-Efficient Building Ventilation
- Technologies, operations and standards
- Reduce energy while improving health and productivity
- Research and demonstrations

Tobacco Smoke in the Indoor Environment
- Composition and chemistry of tobacco smoke
- Assessment of exposures and health impacts

Energy-Efficient Air Quality Control Technologies
- Novel technologies and materials
- Impacts on energy consumption
- Laboratory and field testing

Pollutant Sources, Sinks and Chemical Transformations
- Pollutant sources, transport and chemical transformation
- Experiments in lab and buildings
- Simulations and statistical modeling

Indoor Environmental Quality in Developing Countries
- Design and development of cookstoves
- Reduce environmental and health burdens
Today’s Presentation

• Overview on ventilation in schools
• Overview on demand controlled ventilation and CO2 sensors
• Status of an ongoing CO2 sensors evaluation study at Thousand Oaks Elementary
• Other related work being conducted by Indoor Environment Group
Insufficient ventilation rates common in classrooms

- Past research found ventilation rates often much less than specified in standards, resulting in CO2 often well above 1,000 ppm (parts per million) in concentration.

Ventilation rates estimated from CO2 concentrations measured in elementary classrooms (CRs).

- Texas, 120 CRs
- S.E. US, 140 CRs
- S.E. US, 100 CRs
- Central Valley CA, 51 CRs
- Bay Area CA, 52 CRs
- South Coast CA, 59 CR
- CA Survey, 201 CRs

^median
*mean
Associations between ventilation rates and student school work performance

- Several studies found associations of reduced student performance with lower ventilation rates or with higher CO2 concentrations.

Danish study in four classrooms found increase in speed of school work tasks with increase ventilation rate (no statistically significant influence on accuracy).

Increased ventilation rates in classrooms and student performance

UK study in 12 classrooms with ventilation rates increased from ~ 1 to ~8 L/s per student.

Study found increase in student absence associated with lower ventilation rates

Illness absence decreases 1.6% per each L/s per person increase in ventilation rate.

HVAC challenges and concerns in schools

- Many small, single-zone mechanical ventilation equipment
- Energy costs
- Maintenance costs
- High and variable occupancy
- Large internal gains
- Equipment noise and thermal comfort
- Use of natural ventilation (open windows)
Demand Controlled Ventilation

• CO2 sensors are used to automatically modulate rates of outdoor air supply
• Keep ventilation rates at or above design requirements as occupancy changes
• Reduce energy penalty of over-ventilation during periods of low occupancy
• Most often used in spaces with high and variable occupancy
Temecula Valley USD

Temecula Valley Unified added demand control ventilation (DCV) with variable frequency drives (VFD's) to existing air conditioning units and upgraded the energy management system to include CO2 sensors at French Valley Elementary School. The project was funded with a combination of Southern California Edison and Proposition 39 funding.
Why CO2?

- People exhale CO2, causing concentrations inside occupied buildings to be higher than outdoor air
- The indoor-outdoor CO2 concentration difference is therefore a proxy for ventilation rate per person
- E.g., ventilation rate is ~7.5 L/s per person if indoor CO2 is 700 ppm above the outdoor concentration (400 ppm)
Inaccurate CO2 sensors can affect ventilation system performance

- California Building Standards Code “Title 24” specifies that sensor error must be certified as no greater than 75 ppm for a period of five years after sensor installation.

Study of the accuracy of 208 CO2 sensors located in 34 commercial buildings in California.

Ongoing project at Thousand Oaks Elementary (and two other LBNL spaces)

Reference CO$_2$ instrument calibrated periodically
Performance of two CO2 sensors (3x) measured during past 7 months
Project VentCon

- This research will help California Energy Commission determine if and how to require “dynamic monitoring of ventilation airflows”, and wider use of demand controlled ventilation in Title 24.
Related work

- Our research study the relationships of IAQ, outdoor air quality, occupant activities, and building features affecting energy efficiency, human health & performance.
Study of carbon dioxide (CO2) sensor performance for building ventilation control

W. Rengie Chan  wrchan@lbl.gov
William J. Fisk and Toshifumi Hotchi
Indoor Environment Group
November 6, 2015