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Understanding Indoor CO2, Building Ventilation and Their Affects on IEQ

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This week we welcomed back Dr. Andrew Persily a Fellow at the U.S. National Institute of Standards and Technology (NIST) for a discussion on CO2, Ventilation, impacts on occupants, airborne infectious disease transmission and more. Dr. Persily has worked at NIST for four decades after earning his Ph.D. in Mechanical and Aerospace Engineering from Princeton University. His research has focused on indoor air quality and ventilation in commercial and residential buildings, including the development and application of measurement techniques to evaluate airflow and indoor air quality performance and of multi-zone airflow and contaminant dispersal models. He has published more than 300 journal articles, conference papers and NIST reports. Dr. Persily was a vice-president of ASHRAE from 2007 to 2009, and is past chair of ASHRAE Standard 62.1 (Ventilation for Acceptable Indoor Air Quality) and Standard 189.1 (Design of High-Performance Green Buildings). He is a Fellow of ASHRAE, ASTM and ISIAQ, and recipient of the NIST Bronze, Silver and Gold medals.

Nuggets mined from today's episode:

The roots of NIST can be traced back to founding of our country. The power to coin money, to regulate the alloy and value of coin, and to fix the standard of weights and measures throughout the US, was granted to Congress in the Articles of Confederation in 1776 and in the US Constitution. A story about a great fire in Baltimore responded to by multiple fire departments whose fire hoses couldn't be connected, is an example of the need for consistency in our everyday lives.

NIST has about 3500 employees in Gaithersburg, MD, Boulder, CO and its other facilities.

Being named one of the NIST's 40 fellows is a great accomplishment and honor.

In the mid 1980s problem buildings were in the news; and the EPA (with the help of a group of industry experts) ran an IAQ study to randomly select and measure 100 nonproblem buildings to create an IAQ baseline, referred to as the EPA BASE Study. Nothing else of this scale has been done since on this topic.

NIST's research interests are driven by industry research needs and innovation. For example, the need to measure very small lengths, particularly in the context of semi-conductor manufacturing is becoming increasingly important.

Building design is not a high-tech industry and can be slow to change. Preferring someone else be the guinea pig for a new product; consumers may elect to choose a traditional product offering.

The first energy crisis in the 1970s stimulated rising awareness and interest in energy efficiency, which was followed by interest in IAQ issues in the 1980s. Subsequently, chem warfare, bioterrorism, green buildings, sustainability, airborne infection, disease transmission have generated interest in building airflow and IEQ over the years. While some of the reasons for research interest and motivation have changed, fortunately, physics don't change.

Discussions of CO_2 levels indoors is over 100 years old. The first US ventilation standard was issued in 1946. Some of the early studies of ventilation requirements were motivated by body odor perception (associated with the products of occupant metabolism) and CO_2 levels. ASHRAE Standard 62-1989 had a 2500 ppm of CO_2 limited which was reduced to 1000 ppm in 1989. Subsequent versions of the standard have not contained a CO_2 limit.

After decades of confusion and mischaracterization about CO_2 levels indoors ASHRAE released a position document on CO_2. The position document is neither a design guide nor a technical report; rather an official statement by the ASHRAE board of directors.

CO_2 is a useful tracer gas because it is easy to measure and with building occupants there is a built-in injection systems.

Studies on affect of CO_2 on cognitive performance have shown inconsistent results. More study on CO_2 and cognitive performance and other human impacts is needed.

Low indoor levels of CO_2 doesn't mean good IAQ as there are many indoor emission sources (e.g. furnishings)

CO_2 tracer gas studies involve: releasing CO_2, monitoring the levels of concentration decay overtime and doing the math to estimate the air change rate.

For testing purposes, a CO_2 fire extinguisher can be used to release CO_2 in an unoccupied space.

Indoor CO_2 measurements should be compared with outdoor CO_2 measurements because outdoor levels of CO_2 are not constant.

It is important to point out mistakes in tracer gas testing due to inherent quirks such as need for instrument calibration and varying temperature.

There is an energy saving opportunity when areas designed for high occupancy are at low or zero occupancy. Some building codes require CO_2 demand control ventilation to ensure the building is receiving sufficient levels of outdoor air. This can be complicated related to questions such as: how many HVAC systems, how many sensors are needed, where should sensors be placed, and will adequate maintenance be done on the sensors and other control components?

While a famous green building had sophisticated sensors which provided valuable information feedback; the building lacked the capability to modulate the amount of outdoor air. Therefore, the efforts and cost provided no benefit!

When you look close enough at any building, you will find problems.

Dr. Kishor Khankari, text chat comment: "Buildings are for the people, building design is not occupant centric."
Response by Andrew Persily- "Buildings aren't to brag about low utility bills. They are not about marble lobbies. Buildings are to support the occupants and their

activities."

What is your opinion of sophisticated new building systems? New systems and technology are great but the question must always be asked: who will take care and maintain them?

There is an association between CO_2 >1,000 ppm and sick buildings, but it's probably not the CO_2 but rather other contaminants that increase with low ventilation rates.

Historically, based on workplace safety limits, CO_2 wasn't a concern until levels of 5,000-10,000 ppm.

CO_2 and infectious airborne aerosols are very different. Filtration will reduce infectious airborne aerosols, but filtration has no effect on CO_2.

Human production of CO_2 is related to diet, body size and age, and the level of physical activity.

Online tool for calculating expected CO_2 concentrations:

REFERENCES

CO_2 Tool:
https://pages.nist.gov/CONTAM-apps/webapps/CO2Tool/#/

CO_2 levels on submarines:
https://nap.nationalacademies.org/read/11170/chapter/5

Handbook of Indoor Air Quality is being revised. - Chapter in new book is menu not a cookbook:
https://link.springer.com/referencework/10.1007/978-981-10-5155-5

ROUNDUP

HVAC system- start with what you have, realize you have specific options based on your system and when adding more sophistication consider who will maintain.

To solve a problem, you must search for answers where the problem is.

Analysis of the ventilation data from the EPA BASE study shows that buildings are not always operated as they were intended.

Up and coming issues:
Emerging sensors cost less and measure more. What to do with the devices? What to do with the data?

The pandemic has brought IAQ and ventilation to center stage again.

Seizing opportunities provided by new crises.

Climate change and resiliency are other important trends.

Among other areas, his former division at NIST is working on: integrating buildings onto smart grid data exchange, and new, low GWP refrigerant blends.

The 7 fundamental units of measure: Mass, Time, Electric Current, Amount of Substance, Illumination, Distance & Temperature.

Z-Man signing off

Trivia:
At what time does counting solar mean time begin?

Answer:
Midnight at Greenwich Royal Observatory
Answered by: Don Weekes