Human-Building Interactions and the Environment

BEARS | SinBerBEST

William W Nazaroff, University of California, Berkeley, California USA
Wei-Chung Victor Chang, Nanyang Technological University, Singapore

Supported by:

Funded by: National Research Foundation

Mission

To acquire information, create knowledge, and convey understanding to ensure that indoor environmental quality provided for building occupants is maintained or improved while energy efficiency gains are achieved.

Sustainability and Human/Building Interactions

- Buildings: major energy end use; large CO_2 emissions
- Energy needed for indoor environmental quality (IEQ)
- Good IEQ required for high performance buildings
- Knowledge gaps are large for attaining good IEQ with high efficiency in buildings in tropical climates

Why is IEQ so important?

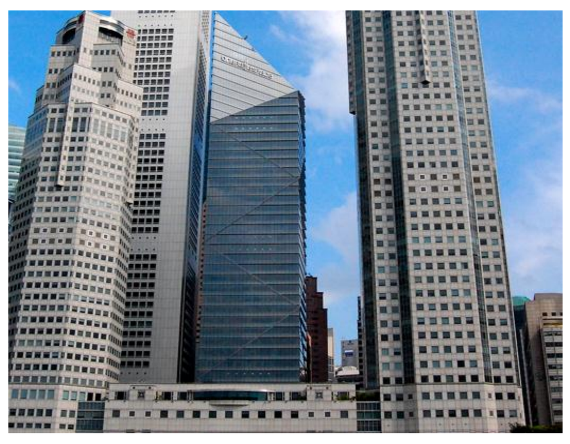
- Quality of life: Health risks of degraded IEQ
- Economy: huge capital stock; IEQ affects performance
- Energy/climate: Buildings must become sustainable

Why is achieving good IEQ so difficult?

- Overlapping domains: buildings, environment, health
- Inherent complexity: 10^9 buildings × 10^{10} people × many IEQ parameters that vary with time
- Influencing factors are physical and psychosocial

What will SinBerBEST do?

- Advance knowledge and insight on human-building interactions, focusing on tropical climates, so that
- IEQ goals are achieved, even as
- Buildings become more energy & resource efficient



Simple model for indoor pollutants

$$C \sim f \times C_{out} + \frac{E}{Q + kV}$$

C – indoor pollutant concentration (µg/m^3); C_{out} – outdoor pollutant concentration (µg/m^3); f – infiltration factor (–); E – indoor emission rate (µg/h); Q – ventilation rate (m^3/h); k – indoor removal loss-rate coefficient (h^{-1}); V – indoor volume (m^3)

Principles of effective IEQ control

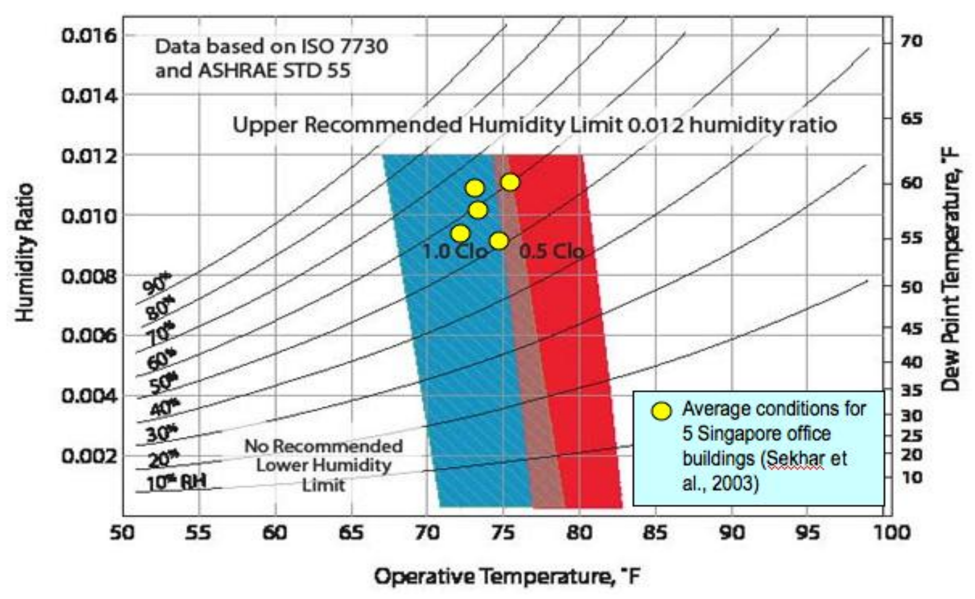
1. Source control: Limit E
2. Protect from outdoor pollutants: Reduce f
3. Provide adequate ventilation: Sufficient Q
4. Apply air cleaning when necessary: Use k

Mature IEQ Topics

- Enough is known to support asking incisive questions, well grounded in knowledge
- Example 1: Ventilation
- Example 2: Thermal comfort

Emerging IEQ Topics

- Understanding is not yet adequate to ask incisive questions for all important aspects
- Example 1: Indoor microbiome
- Example 2: Climate change & IEQ



Work Packages

WP4.1 – Heating, ventilating, and air-conditioning system hygiene
WP4.2 – Human factors for thermal comfort
WP4.3 – Bioaerosols in tropical buildings
WP4.4 – Temperature & humidity effects on indoor pollutant dynamics
WP4.5 – Critical reviews
WP4.6 – Coordination and outreach

Energy Use in Singapore Offices

- Energy index: 12-55 kWh m^{-2} month^{-1}
- For 10 m^2 of office space with electricity cost of S\$0.28/kWh, electricity cost = S\$34-S\$150/month. This is a small fraction of the typical wage of an office worker.

Energy index data: SC Sekhar et al., *Indoor Air* 13, 315, 2003.

Ventilation and Sick-Building Syndrome (SBS)

… as the ventilation rate drops from 10 to 5 liters per second per person, relative SBS symptom prevalence increases approximately 23% and as ventilation rate increases from 10 to 25 liters per second per person, relative prevalence decreases approximately 29%.

Source: WJ Fisk et al., *Indoor Air* 19, 159-165, 2009.

Priorities for improved IEQ in (US) offices

Action	Net Benefit (*)
Increase ventilation rate to 10 L/s per person	\$5.6 B/y
Further Increase ventilation rate to 15 L/s per person	\$13.5 B/y
Add economizer when absent	\$11.8 B/y
Eliminate winter indoor T > 23°C	\$3.4 B/y
Reduce dampness and mold 30%	\$0.5 B/y

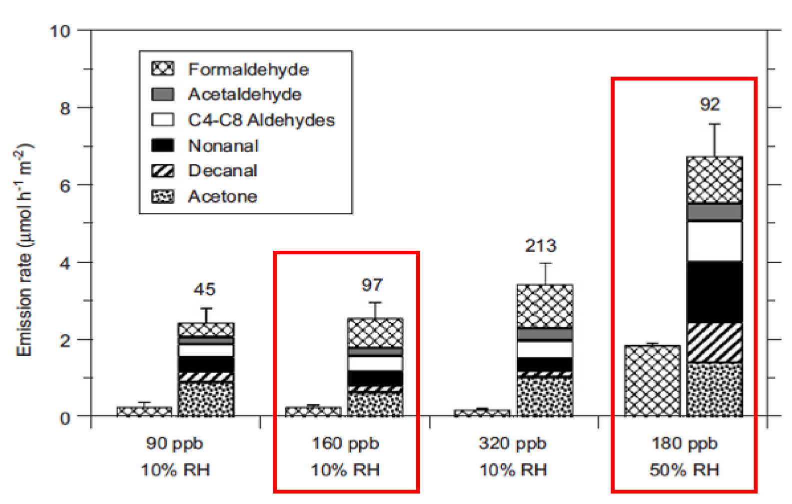
(*) Benefits account for performance improvements, decreased SBS symptom prevalence, reduce short-term absence, and include effects of increased energy consumption. Actions in blue have potential relevance for tropical climate

Source: WJ Fisk et al., *Indoor Air* **21**, 357-367, 2011.

Ozone (O_3) and its byproducts

- Respiratory irritant; association between ambient O_3 levels and acute morbidity and mortality.
- Ozone indoors is typically 20-70% of outdoor level.
- Byproducts of ozone-surface chemistry are a health concern.

Source: BK Coleman et al., *Atmospheric Environment* 42, 642, 2008.



Byproduct emission rates from cotton exposed to ozone at different relative humidities. For each material, the left bar represents the average emission rates without ozone during a 180-min conditioning period, and the right bar represents the average emissions during the initial 90-min ozone exposure period. The number above the right bar is the 90-min average residual ozone concentration in ppb; the supply air ozone concentration is part of x-axis label.

Summary

- High-performance buildings must have good indoor environmental quality to achieve their purpose
- Energy efficiency and good IEQ requires improved understanding of key issues
- IEQ knowledge gaps in tropical climates include HVAC hygiene, thermal comfort, bioaerosols, and temperature/humidity effects on pollutant dynamic behavior
- SinBerBEST will enhance knowledge that will advance IEQ science and improve building practice