Building Ventilation, Occupants, and Microbiome

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April 11, 2016
Introduction

- Microbial Communities are Diverse in Indoor Environments
- Both Human Sources and Outdoor Microbiome are Important
- Literature Presents Different Conclusions on the Relative Importance

- Confounding Factors Need Better Understanding
- Occupant Activates Need Examination
- Not all Buildings are Equal
Case Study of a LEED Certified Building

The most statistically significant parameters were occupants’ perceptions of odors and relative humidity, while biological contaminants exhibited lower statistical associations with the examined health outcomes.
Case Study of a LEED Certified Building

- Occupants experienced **fewer symptoms** in PA DEP Cambria building than in an average BASE office building in 15 out of 19 categories.
- Biggest advantage: 23% less occupants experienced headache, 19% less experienced eye irritation, 19% less irritability or nervousness in PA DEP Cambria building compared to an average BASE office building.
- Biggest disadvantage: 11% more occupants experienced dry or itchy skin and 7% more had cough compared to an average BASE office building.
  - Related to the perception of dry indoor air.
  - Elevated concentrations of PM10 when compared to BASE.
- Relationship between **occupant perceptions** and indoor environmental conditions is evident.
- LEED certified building had a **higher quality of the environment** when compared to the BASE study buildings.
Big Box Retail Buildings

<table>
<thead>
<tr>
<th>Measurement Parameters</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveys of Employees</td>
<td>Employees’ Perception</td>
</tr>
<tr>
<td>Ventilation</td>
<td>SF$_6$ Decay</td>
</tr>
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<td></td>
<td>CO$_2$ Mass Balance</td>
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<td></td>
<td>AHU Flow</td>
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<td></td>
<td>Outdoor Weather</td>
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<tr>
<td>IEQ</td>
<td>VOCs, Aldehydes, Ozone</td>
</tr>
<tr>
<td></td>
<td>Particles (PM$<em>{10}$, PM$</em>{2.5}$)</td>
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<tr>
<td></td>
<td>SVOCs</td>
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<tr>
<td>Temperature, RH</td>
<td>Thermal Comfort Indicator</td>
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</table>

Very few contaminants above REL (reference exposure level)
Concentrations similar/lower than in other building types (exception was formaldehyde)
Summary of air exchange rate for different environments (N = number of spaces, S = number of studies)

The measured outdoor air exchange rates (RP-1596) ranged from 0.20 to 1.5 h⁻¹, with an average of 0.63 h⁻¹ and standard deviation of 0.37 h⁻¹.
Big Box Retail Buildings

- Comparison with standards, air exchange rates were multiplied by the total building volume and then normalized by total floor area of the store.

- ASHRAE standards 62.1-2010 minimum floor-based ventilation rate in the breathing zone for a retail sales space is $0.6 \text{L/s/m}^2$ and $1.2 \text{L/s/m}^2$ for a grocery store (supermarket).

- The measured outdoor air exchange rates (RP-1596) ranged from 0.20 to 1.5 $\text{h}^{-1}$, with an average of 0.63 $\text{h}^{-1}$ and standard deviation of 0.37 $\text{h}^{-1}$.

- *Seasonal influence on the bacterial community and occupants are important contributors*
Big Box Retail Buildings

- Air exchange rates affect employee environmental perceptions.
- Employee perception of overall environmental quality satisfaction has significant correlation ($r=0.296$, with $p=0.000$) with the number of common colds.
- When the air exchange rate increases from $0.6 \text{h}^{-1}$ to $1.2 \text{h}^{-1}$, the probability of number of common colds is decreased by 43% (example: $3 \rightarrow 2$ or $1 \rightarrow 0$).
- To reduce the frequency of common colds, we recommend increasing the air exchange rate.
UVGI for Continuous Disinfection

B. Atrophaeus
M. Parafortuitum

\[ P = e^{-zD} \]

Eulerian Approach:
\[ \frac{\partial}{\partial x_j} \left( C u_j \right) - \frac{\partial}{\partial x_j} \left( \lambda + \lambda_s \right) \frac{\partial C}{\partial x_j} = -zEC \]
\[ f_{rm} = \frac{C_{UVon}}{C_{UVoff}} \]

Lagrangian Approach:
\[ D = \int Edt \approx \sum_i E_i \Delta t_i \]
\[ f_{rm} = \frac{n}{N} \]

<table>
<thead>
<tr>
<th>Inlet velocity</th>
<th>6 ACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV fixtures heat output</td>
<td>2 x 25W</td>
</tr>
<tr>
<td>Visible light lamp heat output</td>
<td>57 W</td>
</tr>
<tr>
<td>Microorganisms supply</td>
<td>12 l/min</td>
</tr>
</tbody>
</table>
UVGI for Continuous Disinfection

Perfect mixing fraction remaining divided by curve-fitted fraction remaining indicates that lower fan speed can be effective.
Indoor Environment in Vehicles

Risk of airborne infection transmission based on Numerical investigation:

• Ventilation method (air distribution method, location of air exhaust opening, airflow rates) greatly influenced the risk

• Seat arrangement made a difference on the risk by changing spatial relationship of passengers

• Existence of standing passengers influenced the risk among seated passengers

• Chamber experiments showed influence of walking and seated occupants on fluorescent biological aerosol particles (60-70% from floor)
Conclusions

• Buildings tend to be *diverse* with respect to ventilation and occupant population, so microbiome is expected to exhibit the same trend

• Expected *influencing factors* building size and type, dynamic ventilation rates and mode, temperature, RH, infiltration rates, occupant population, indoor microbial sources, and outdoor microbiome

• It is possible to complement the *statistical studies* with the deterministic *numerical studies* to enhance the understanding of influencing factors and their importance for indoor microbiome

• *Definition of microbiome* is important as many studies use different species for their investigation, so results are not directly comparable