Introduction

Exposure to air pollutants occurs mostly indoors, where building characteristics, consumer products, and indoor activities, along with ambient air, all affect indoor air chemistry. Yet, the risk paradigm for ambient air pollution largely omits these factors, and epidemiological analyses leave these sources of heterogeneity uncharacterized as noise. In a changing environment, which will modify indoor-outdoor air exchange rates, the options about how to best manage indoor environments to minimize risk of air pollution become even less clear.

A comprehensive approach to indoor air quality model can be useful to help develop public health guidelines that take into account both ambient air quality and the indoor sources in a particular environment. For example, should people ventillate their houses while cooking if they live near dense traffic? An indoor air quality model can also be useful for developing guidelines and recommendations about adapting building design and use, particularly with respect to measures that attempt to achieve higher energy efficiency by controlling infiltration. Finally, a model may also be useful to indoor air quality practitioners as a diagnostic tool for unexplained indoor sources, using reverse modeling.

A new Simple Indoor Air Chemistry Simulator (SIACS) is being developed with the objective of using it as a screening-level indoor air quality model to identify research questions to be explored with a more complex model with more detailed chemistry.

Factors to Consider:

- Locations with different outdoor conditions
- Daytime vs. nighttime
- High outdoor pollution episodes (e.g., wildfires)
- Present vs. projected ambient concentrations
- Present vs. projected meteorological conditions
- Passive infiltration changes, window opening, weatherization

Model Formulation and Input

\[
aPC_{ij}\text{Infiltration from outdoor}
\]

\[
aC_i\text{Exfiltration to outdoor}
\]

\[
\frac{dC_i}{dt} = -j_iC + \sum_{n,m} e_{x,n,m}C_{n,m}C_m + \frac{E}{V} + A_iC - a_iC_i
\]

\[
E = \frac{A_i \int (w \times 2 + b_k (T - T_0)) + q_i}{V}
\]

Figure 1. Processes included in the model.

The model assumes the building contains a single well-mixed zone: considers VOC, NOx, ozone chemistry; and accounts for emissions, deposition, ventilation, and filtration. Indoor concentrations of species \( i \) are solved by mass conservation equation:

- Prescribed input variables for the model are listed in tables 1 and 2.
- For photochemistry, SIACS currently uses the chemical mechanisms from Nazaroff and Cass (1986)\(^1\), where \( k_{pa} \) and \( j_i \) represent reaction and photolysis rate constants, respectively.
- The air exchange rate accounts for air flow due to infiltration and ventilation using the extended Lawrence Berkeley National Laboratory (LBNL) parameterization:\(^2,4\)

Table 1. Input variables with time-dependent values

<table>
<thead>
<tr>
<th>Ambient Conditions</th>
<th>Indoor Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_o )</td>
<td>Indoor temperature</td>
</tr>
<tr>
<td>( u )</td>
<td>Integrated photon flux, 300 – 400 nm</td>
</tr>
<tr>
<td>( E_{cm} )</td>
<td>Integrated photon flux, 400 – 700 nm</td>
</tr>
<tr>
<td>( E_i )</td>
<td>Emission of species ( i )</td>
</tr>
</tbody>
</table>

Table 2. Descriptions of input variables related to building characteristics and values used for preliminary analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Notes: Values for Preliminary Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V )</td>
<td>Volume</td>
<td>350 m(^3) (based on 140 m(^2) x 2.5 m)</td>
</tr>
<tr>
<td>( L_{ael} )</td>
<td>Effective leakage area for infiltration</td>
<td>0.1 m(^2); estimated from Chan et al. (2015)(^3)</td>
</tr>
<tr>
<td>( P )</td>
<td>Penetration factor</td>
<td>Assumed to be 1.</td>
</tr>
<tr>
<td>( Q_{vent} )</td>
<td>Ventilation flow rate</td>
<td>Assumed to be 0.</td>
</tr>
<tr>
<td>( b_k )</td>
<td>Stack coefficient</td>
<td>0.0000290 (L/s)/(m/cm(^2)), for a two-story home; Breen et al. (2010)(^4)</td>
</tr>
<tr>
<td>( k_x )</td>
<td>Wind coefficient</td>
<td>0.000021 (L/s)/(m/cm(^2)), for a two-story house with typical shading by other houses across the street; Breen et al. (2010)(^4)</td>
</tr>
<tr>
<td>( v_i )</td>
<td>Deposition velocity for species ( i )</td>
<td>Depends on surface types.</td>
</tr>
</tbody>
</table>

Summary and Next Steps

- A simple screening-level indoor air quality model is being developed based on chemistry mechanism of Nazaroff and Cass (1986)\(^1\) and Lawrence Berkeley National Laboratory infiltration parameterization\(^2,4\).
- Preliminary analysis suggests:
  - that infiltration due to just seasonal differences seems about as significant as indoor photochemistry at low levels of indoor emissions; and
  - significantly reduced exposures indoor compared to outdoors in the absence of indoor sources.
- Future work include:
  - updating the gas-phase mechanism and adding primary aerosols, secondary organic aerosol formation and heterogeneous chemistry; and
  - performing analysis with more realistic ambient conditions (temperature, wind speed, concentrations), emissions rates, indoor light conditions, and ventilation rates.

References