Defining Safe Building Air
Criteria for Safe Air and Water in Buildings
ASHRAE Winter Meeting
Chicago, IL
January 27, 2008

by
Francis (Bud) J. Offermann PE CIH
Indoor Environmental Engineering
San Francisco, CA
(415)-567-7700 www.IEE-SF.com
Safe Building Air Criteria - Outline

- Purpose and Intent
- Limitations
- Scope
- Exposure Criteria
- Exposure Limits for Select Indoor Air Contaminants
- Validation Methods
- Appendices
  - Baseline Concentration Data
  - Building Risk Factors
  - IAQ Management Plan
Safe Building Air - Purpose and Intent

• Purpose and Intent

To review and assess indoor air contaminant exposure data suitable for:

- providing a framework for the design of healthy and energy efficient buildings (e.g. implementation of ASHRAE Standard 62 IAQ procedure)
- providing a framework for the assessment of the health acceptability of indoor air in existing buildings

“Safe building air” is defined as indoor air that is “not unhealthy”.

Understanding IAQ - Biophysical Model

Stimuli Generation Rate
- area
- emission rate

Indoor Concentration of Stimuli
- ventilation
- filtration
- surface deposition
- reaction

Occupant Exposure To Stimuli
- time exposed
- breathing rate
- protection

Occupant Sensitivity To Stimuli
- expectation
- predisposition

Occupant Reaction To Stimuli
- thermal
- skin
- eyes/nose
- respiratory
- CNS

Stimuli Removal Rate
Exposure Criteria Development

**Exposure Data**
- Collect exposure data
  - measurement capability
  - exposure studies

**Health Effect Data**
- Collect health effect and exposure data
  - epidemiological studies
  - bio assay tests
  - biophysical modeling

**Exposure Criteria**
- Produce exposure criteria from correlations of exposure and health effect data
  - epidemiological studies
  - bio assay tests
  - biophysical modeling
Limitations

Insufficient information for determining indoor air is safe (i.e. not unhealthy)

- insufficient analytical capabilities to assess all indoor air contaminant exposures

- insufficient health based exposure criteria for interpreting acceptability of measured indoor exposures.
<table>
<thead>
<tr>
<th>Starfleet Tricorder</th>
<th>TR-590 Tricorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>circa 2268</td>
<td>circa 2370</td>
</tr>
</tbody>
</table>
Safe Building Air - Limitations

• Limitations

At this time, only single contaminant exposures.

- insufficient current knowledge to assess combinations of contaminant exposures which can result in health effects that are:
  - independent
  - additive
  - antagonistic
  - synergistic
Safe Building Air - Limitations

- Example of unhealthy air NOT diagnosable by air testing.

Indoor Environment: Laser printer test lab.

Occupant Symptoms: Respiratory irritation/chest tightness (some employees wear disposable respirators and achieve some relief)

Air Test Results: VOC’s (MS-TD-GCMS), Aldehydes (DNPH-HPLC), PM$_{2.5}$ and PM$_{10}$ (SSI-Gravimetric), Ozone (UV-Spectrometry), all BELOW non-industrial health guidelines and LESS than the median concentrations in the EPA BASE study of office buildings.
• Example of unhealthy air not diagnosable by air testing.

Hypothesis: respiratory irritation caused by exposure to ultra-fine (i.e. 0.06 to 0.1 µm) particles of cyclic siloxanes, oily substance vaporized in printing process and then condensed into particles.

Currently, NO health exposure guidelines exist for these silicone compounds.
Safe Building Air - Limitations

Decamethylcyclopentasiloxane (D5)
MW 370.77
Safe Building Air - Limitations

Electron microscope photo of sub-micron particles formed by condensation.
Limitations

We can, however, determine if the air is unhealthy for those air contaminants that are:

- measurable and
- have health based exposure criteria and
- excluding combined exposure effects

Air contaminant concentrations below established health based exposure criteria constitute “necessary but insufficient” criteria for declaring the air in a building is safe.
Safe Building Air - Scope

- **Scope**

  Air contaminant exposures related to the following health end points:
  - non-cancer health effects including irritant effects
  - cancer effects
  - reproductive toxicity effects

  **NOT included are odor and thermal comfort factors, since these are criteria for “acceptable IAQ” and not “safe air”**.

  Limited to non-industrial indoor environments (e.g. offices, schools, residences, health care, etc.)
Safe Building Air - Exposure Criteria

- Non-Cancer Health Effect Exposure Criteria
  - California OEHHA CREL’s for volatile organic compounds including formaldehyde
  - EPA NAAQS for outdoor criteria air contaminants (e.g. carbon monoxide, sulfur dioxide, nitrogen dioxide, PM\textsubscript{10} and PM\textsubscript{2.5} particle, ozone, and lead)

These criteria have been established for the protection of sensitive individuals (e.g. asthmatics, children, elderly).
Safe Building Air - Exposure Criteria

- Cancer Health Effect Exposure Criteria
  - California Proposition 65 - No Significant Risk Levels (NSRL provides < 1/100,000 excess cancer case)
  - EPA AHERA requirements for asbestos
  - EPA requirements for radon gas.
Safe Building Air - Exposure Criteria

- Reproductive Toxicity Health Effect Criteria

  - California Proposition 65 - Maximum Allowable Dose Levels (MADLs are < 1,000 the no observable effect dose)
Safe Building Air - Exposure Limits

• Exposure Limits for Select Indoor Air Contaminants

Construct a short list of indoor air contaminants and the recommended exposure limits based upon:

- frequently encountered indoor air contaminants with
- significant health risks

The European Commission “The INDEX Project” has produced a short list which we will draw upon and perhaps include a few additional air contaminants.
## Safe Building Air Exposure Limits (µg/m³)

<table>
<thead>
<tr>
<th>Compound</th>
<th>OSHA 8-hour PEL</th>
<th>OEHHA CREL</th>
<th>NSRL C</th>
<th>MADL R</th>
<th>Minimum Criteria</th>
<th>Residential Median</th>
<th>Office Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>360,300</td>
<td>140</td>
<td>4.5</td>
<td>-</td>
<td>4.5</td>
<td>20</td>
<td>7.2</td>
</tr>
<tr>
<td>Benzene</td>
<td>3,200</td>
<td>60</td>
<td>0.7</td>
<td>-</td>
<td>0.7</td>
<td>1.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>920</td>
<td>9</td>
<td>2</td>
<td>1.2</td>
<td>1.2</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>d-Limonene</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>7.1</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>52,400</td>
<td>9</td>
<td>0.3</td>
<td>-</td>
<td>0.3</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>a-Pinene</td>
<td>36,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>0.6</td>
</tr>
<tr>
<td>Styrene</td>
<td>426,000</td>
<td>900</td>
<td>-</td>
<td>-</td>
<td>900</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Toluene</td>
<td>753,700</td>
<td>300</td>
<td>-</td>
<td>350</td>
<td>300</td>
<td>8.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Xylene</td>
<td>434,200</td>
<td>700</td>
<td>-</td>
<td>-</td>
<td>700</td>
<td>5.4</td>
<td>7.2</td>
</tr>
</tbody>
</table>

**Health Effects:**
- **NC**: Non-cancer
- **C**: Cancer
- **R**: Reproductive toxicity

**Residential:** California ARB - 2006, 108 New Home Study  
**Office:** EPA - 1994, 100 Office Building BASE Study
Safe Building Air - Validation

- Validation Methods
  - EPA Compendium of Methods for the Determination of Air Pollutants in Indoor Air with associated EPA specific analytical methods (e.g. TO-15/17 for VOC’S, ASTM 5197 for formaldehyde and other aldehydes)
  - EPA methods for asbestos and radon.
• Baseline Concentration Data

Provide baseline indoor air contaminant concentration data (e.g. EPA BASE study of air contaminant concentrations in 100 non-problem office buildings)

Present data as percentiles (e.g. minimum, 10th, 25th, 50th, 75th, 90th maximum)
Building Risk Factors

- Do not constitute data that the building air is NOT safe.
- Are known to increase the risk of unsafe building air.
• Building Risk Factors

Present a list of building risk factors, which while by themselves do not constitute data that the building air is not safe, are factors which are known to increase the risk of unsafe building air.

- inadequate supply of outdoor air
- visible moisture condensation (e.g. mold)
- odors (e.g. mold, ETS, chemicals)
- concentrations of mold spores statistically significantly higher indoors than outdoors on a genera basis
Building Risk Factors

- concentrations of carbon monoxide statistically significantly higher indoors than outdoors
- surface accumulations of dust
- reliance on total VOC concentration measurements (should measure individual VOC concentrations)
- lack of an occupant complaint-response system (i.e. the backbone of an IAQ Management Plan)
Safe Building Air - Appendices

- IAQ Management Plan

Safe Building Air - Conclusions

• Concentrations below exposure criteria do NOT equal the air is “safe” because of:

  - insufficient analytical capabilities to assess all indoor air contaminant exposures

  - insufficient health based exposure criteria for interpreting acceptability of measured indoor exposures.
Thus, at this time:

We should not, in the pursuit of energy efficiency, reduce outdoor air ventilation rates in buildings.

Instead we should minimize the energy impacts with heat recovery strategies.
Safe Building Air - Conclusions

• At this time, we can determine if the air is unhealthy for those air contaminants that are:
  - measurable and
  - have health based exposure criteria

• Concentrations below the recommended exposure criteria can NOT be said to represent “Safe Air”.

• Reducing “Risk Factors” and following the upcoming ASHRAE IAQ Design Guide, can reduce the probability of “Unsafe Air”.
For energy efficient healthy buildings with reduced outdoor air ventilation rates (e.g. the IAQ Procedure), we MUST first overcome the limitations of insufficient:

- measurement capability (i.e. develop new analytical instruments – real time mass and chemical analyses of ppb concentrations of all air molecules and particles)

- health effect exposure knowledge (i.e. using exposure and health data develop health based exposure criteria)
Safe Building Air - Conclusions

With the new instrumentation and the associated health based exposure criteria, we can confidently develop energy efficient buildings with lower, or no, outdoor air ventilation, through:

• implementation of new air cleaning technologies

• reducing the indoor air contaminant emission rates
Defining Safe Building Air
Criteria for Safe Air and Water in Buildings
ASHRAE Winter Meeting
Chicago, IL
January 27, 2008

by
Francis (Bud) J. Offermann PE CIH
Indoor Environmental Engineering
San Francisco, CA
(415)-567-7700 www.IEE-SF.com