Formaldehyde in New Homes

Ventilation vs. Source Control

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  — IEE-SF

• LBNL Team
  — Sherman, Hotchi, Russell, Stratton, and Others
Formaldehyde is an irritant and a carcinogen.

Odor threshold: about 800 ppb.

Widely varying health standards:

- US HUD (8-h): 400 ppb
- Germany: 100 ppb
- WHO, Japan (0.5-h): 80 ppb
- Sweden (0.5-h): 50 ppb
- Canada (8-h): 40 ppb
- California ARB (8-h): 27 ppb
- US NIOSH (8-h): 16 ppb
- CA OEHHA (chronic): 7.5 ppb

*Goal is to reduce / minimize exposure, may not be viable to declare homes “safe” from formaldehyde.*
Formaldehyde in bulk material, diffuses to surface

Conventional Understanding:
Increase ventilation $\rightarrow$ reduce air conc. $\rightarrow$ increase emissions
Background 2

- Limited recent formaldehyde data for U.S. new homes
  - California New Home Study:
    - 108 homes: Summer/Winter, North/South splits

- Composite wood products are largest sources in homes

- Few examples of apportionment in finished homes
Formaldehyde highest in new homes, Concentrations decrease with age

Single-family houses in Japan
(New in 1st year)

Concentration (ug/m³)

24 h mechanical ventilation
Local exhausts
Natural ventilation

1st year
2nd year
3rd year

Park JS, Ikeda K. Variations of formaldehyde and VOC levels during 3 years in new and older homes. Indoor Air. 2006 Apr;16(2):129-35.
Formaldehyde Emission Standards

- **CA: Composite Wood Air Toxic Control Measure**
  - Approved 2007 under authority to regulate outdoor air
  - Phased implementation 2009-2012

- **U.S. Formaldehyde Standards in Composite Wood Products Act**
  - Approved 2010 to be implemented by Jan 1, 2013
  - Based on CA standards
Emissions Determinants

- **Source**
  - Concentration within material
    - Decreases with time
  - Diffusion rates and barriers
  - Connection to indoor air

- **Environmental**
  - Temperature
  - Humidity
  - Solar insolation

Source: Berge et al. (1980)
Formaldehyde release from particle board. Holz als Roh- und Werkstoff, 38, 251-255
Controlling Formaldehyde

- **Source control:**
  - Seal with low-permeability laminate
  - Resin formulations that chemically bind formaldehyde

- **Options requiring energy use in building**
  - Dehumidification
  - Air cleaning / treatment
  - Ventilation?
Research Questions

- Can increasing ventilation substantially reduce formaldehyde concentrations in new homes?
- To what extent do emissions increase when air exchange is increased?
- Do homes built with low-emitting materials have lower formaldehyde concentrations? How much?

- This information is needed to evaluate the cost-effectiveness of ventilation and source control!
Existing Data: California New Home Study

California New Home Study Data

These homes built prior to formaldehyde emission standards

Built: 2002-5
Data: 2006-7
N=108
Ventilation impact in CA new homes
Summer data

Built: 2002-5
Data: 2006-7
Age: 1.8-5.5 y

Summer
N=48

Formaldehyde (ppb)

Air Exchange Rate (1/h)
Ventilation impact not explained by age variations

Built: 2002-5
Data: 2006-7
Age: 1.8-5.5 y
Summer
N=48
Ventilation impact not explained by T or RH variations

Built: 2002-5
Data: 2006-7
Age: 1.8-5.5 y
Summer
N=48

Indoor Temp (F)

Indoor RH (%)

Air Exchange Rate (1/h)
Emission suppressed at low AER

- Built: 2002-5
- Data: 2006-7
- Age: 1.8-5.5 y
- Summer
- N=48

$F, \text{ df (2.3, 2): } P<0.1$
Ventilation Intervention Study

- Modify AER in 9 homes with other parameters fixed
  - Materials
  - Temperature
  - Rel. Humidity
  - Season

- AER control via mechanical ventilation

- Measure AER & concentrations, calculate emissions

<table>
<thead>
<tr>
<th>Material</th>
<th>Age (yrs)</th>
<th>Floor area (ft²)</th>
<th>ACH 50</th>
<th>Low-emitting Material#</th>
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<tbody>
<tr>
<td>R1</td>
<td>2.0</td>
<td>2100</td>
<td>1.2</td>
<td>1,2,3</td>
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<tr>
<td>R2</td>
<td>1.5</td>
<td>150</td>
<td>4.0</td>
<td>1,2,3</td>
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<tr>
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<td>1300</td>
<td>4.3</td>
<td>-</td>
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<td>R9</td>
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<td>3440</td>
<td>4.0</td>
<td>2</td>
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</tbody>
</table>

#1= Wood products compliant with CA Title 17 or low- or no- formaldehyde standards, 2= Wet surface finishing certified as low-emitting, 3= Carpet materials and backing low-emitting.
Lower concentration with increased AER in each study home

May - Sep 2011
Age: 0.3 - 2.5 y
N = 9 homes
Emission impact of AER varies

May - Sep 2011
Age: 0.3 - 2.5 y
N = 9
Study of Source Control

Measure concentrations and AER in new homes constructed with low-emitting materials

- 10 LEED / Indoor Air Plus homes in New Mexico (NM)
  - 0.3 – 2.5 years old
  - ATCM compliant wood products
- 8 California homes complying with ATCM:
  - 0.3 – 1.1 years old
- Additional data being collected in CA-compliant homes

Compare to CNHS and NM conventional homes
Low-emitting materials yield lower formaldehyde concentrations
Low-emitting materials yield lower emission rates, still depend on AER.
Conclusions

• Emission limits on composite wood products reducing formaldehyde in new homes
• Increasing ventilation can reduce near-term concentrations, exposures
• Benefits of adding ventilation depend on starting point b/c emissions increase
• Increasing ventilation should deplete sources more rapidly
• Open questions
  — What is value of health benefits?
  — How much impact does higher ventilation have in long term?
  — Time evolution of homes with low-emitting materials?
Extra Slides

- The following slides will not be shown unless requested or needed
No Mechanical Ventilation Benefits only by Increasing AER

- Built: 2002-5
- Data: 2006-7
- Age: 1.8-5.5 y
- Summer
- N=48
Health Benefit Calculation

- Methodology described in Logue et al., Environmental Health Perspectives, 2012
- 10 ppb reduction for 100K people for 1 year saves 5 DALYs
- Assume 25K homes for every 100K people living in new homes
- $100K per DALY -> $500K per year ->
- $20 per 10 ppb per year
- 10 ppb lower over 10 years -> $200 per home
Ventilation impacts in CA new homes (Adjusted to 77 F and 50% RH)

Estimated formaldehyde (ppb) at 77 F and 50% RH

Built: 2002-5
Data: 2006-7
Age: 1.8-5.5 y
Summer
N=48
No Clear Age Signal in CNHS

Built: 2002-5  
Data: 2006-7  
Age: 1.8-5.5 y  
Summer  
N=48