Ventilation and Source Control to Reduce Formaldehyde in New Homes

Brett C. Singer
Co-Authors: Erin L. Hult, Henry Willem
Lawrence Berkeley National Laboratory

bcsinger@lbl.gov

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Contributors

• LBNL
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• External contributors
  – Kurt Roth & Peter Engelmann, Fraunhoffer Inst.
  – Ari Rappaport, IBACOS
  – Bud Offermann & Justin Offermann, IEE
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Identified IAQ Hazards

- Compiled data on 272 pollutants from 77 studies; compared to health-based standards (97)
- Identified 9 with concentrations exceeding standards in many homes & robust data

Acetaldehyde
Acrolein
Benzene
1,3-Butadiene
1,4-Dichlorobenzene
Formaldehyde
Naphthalene
NO$_2$
PM$_{2.5}$

Indoor Air 2011, 21:92-109
Prioritize Using Disability Adjusted Life Years

\[ \text{DALY} = \text{YLL} + \text{YLD} \]

- YLL = Years lost to premature death
- YLD = Equivalent years lost to disability
- DALY valued at $50,000 - $160,000

\[ \text{Intake} \times \frac{\Delta \text{Disease}}{\Delta \text{Intake}} \times \frac{\Delta \text{DALYs}}{\Delta \text{Disease}} = \text{DALYs per pollutant} \]

Logue et al., Environmental Health Perspectives, 2012
Most Harmful Air Pollutants in Homes

**Priority Pollutants**
- PM$_{2.5}$
- Secondhand Smoke
- Mold / Moisture
- Radon
- Formaldehyde
- Acrolein

Control of formaldehyde key to good IAQ in low-E homes!

Logue et al., EHP 2012

DALYs per year per 100K people
Formaldehyde Background

- Formaldehyde is an irritant and a carcinogen
- Emitted from resin used to bind manufactured wood products and some flooring materials
- Emissions increase with T and RH
- Concentrations in homes vary seasonally
- Levels in homes have decreased sharply since 1980s
- New regulations should lead to further reductions
  - California Air Toxic Control Measure
  - US: Formaldehyde Emissions from Composite Wood Products
Formaldehyde Standards

- Wide range of standards for acute and chronic exposures.
- California OEHHA reference exposure levels (RELs)
  - 1h: 55 µg m\(^{-3}\)
  - 8h: 9 µg m\(^{-3}\)
  - Chronic: 9 µg m\(^{-3}\)
Formaldehyde highest in new homes; Concentrations decrease with age

Single-family houses in Japan (New in 1st 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.
Physics of Formaldehyde Emissions

- Formaldehyde in bulk material, diffuses to surface
- Conventional Understanding:
  Increase ventilation \(\rightarrow\) reduce air conc.\(\rightarrow\) increase emissions
How can we mitigate formaldehyde exposure in homes?

**Ventilation Control**

Applicable to new & existing homes; can vary amount of ventilation as needed. Uses energy. Theory & measurements suggest that reduction in air is not proportional to ventilation increase.

**Source Control**

Most robust and requires no site energy; mostly limited to new homes and remodels. Magnitude of effectiveness not documented.

**Air Cleaning**

Emerging option with new technologies and products coming to market. Uses energy. Not examined in this study.
Analysis of RIOPA data raised questions about ventilation control

(Hun, Indoor Air, 2010)
Data from CA New Home Study (CNHS) supports effectiveness of ventilation control

Formaldehyde (ppb) vs. Air Exchange Rate (h⁻¹)

These homes built prior to formaldehyde emission standards

Built: 2002-5
Data: 2006-7
N=108
Data from CNHS supports effectiveness of ventilation control

Formaldehyde (ppb) vs. Air Exchange Rate (1/h)

- Built: 2002-5
- Data: 2006-7
- Age: 1.8-5.5 y
- Summer
- N=48
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)
Emissions a bit lower at low AER

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

Summer
N=48

F, df (2.3, 2): P<0.1
LBNL Ventilation Intervention Study

- Vary AER in 9 homes; other parameters fixed
  - Materials
  - Temperature
  - Rel. Humidity
  - Season
- AER control via mechanical ventilation
- Measure AER & concentrations, calculate emissions

<table>
<thead>
<tr>
<th></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>
</tr>
<tr>
<td>R2</td>
<td>1.5</td>
<td>150</td>
<td>4.0</td>
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<tr>
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<tr>
<td>R4</td>
<td>0.3</td>
<td>1475</td>
<td>0.6</td>
<td>1,2,3</td>
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<tr>
<td>R5</td>
<td>7.5</td>
<td>1300</td>
<td>4.3</td>
<td>-</td>
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<tr>
<td>R6</td>
<td>0.8</td>
<td>1570</td>
<td>1.0</td>
<td>2,3</td>
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<td>R7</td>
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<td>2260</td>
<td>0.7</td>
<td>2,3</td>
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<td>R8</td>
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<tr>
<td>R9</td>
<td>2.5</td>
<td>3440</td>
<td>4.0</td>
<td>2</td>
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</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 achieved with increasing 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
Increasing ventilation reduced formaldehyde less than if emissions were constant.
Acetaldehyde response to ventilation consistent with constant emission sources

Observations
Constant emission model
Concentration dependent emission model
Bayesian simulator ‘true’ values
Bayesian simulator Concent-dependent emission model
How much lower is formaldehyde in homes built with low-emitting materials?

Measure concentration & ventilation rate in new homes constructed with low-emitting materials

- 11 LEED / EPA Indoor airPLUS homes in NM
  - 0.3 to 3.5 years old
  - ATCM compliant wood products
- 4 low-emitting homes from vent. control study

Compare to homes with conventional materials

- 54 homes from CNHS (2-5 years old)
- 3 homes from vent. control study
- 2 control homes from New Mexico
Homes with low-emitting materials have lower formaldehyde concentrations

**Unadjusted**

**Adjusted for T, RH, house age**

- **24% reduction**
- **42% reduction**
Conclusions

• Increasing ventilation rates in residences decreases the indoor formaldehyde concentration

• Ventilating is 20-60% less effective at reducing short-term formaldehyde concentrations than a constant emission rate model would suggest
  • Over longer term, ventilation increases emission rate which depletes sources faster

• Building homes with low-emitting materials reduces formaldehyde concentrations by roughly 40%

Hult EL et al. Formaldehyde exposure mitigation in US residences: Ventilation and source control. Pending submission to Indoor Air. Will also be available as an LBNL report at http://eetd.lbl.gov/publications
Bibliography I

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
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<th>Journal/Conference</th>
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*Available at http://eetd.lbl.gov/publications


Willem H et al. 2013. Ventilation Control of Volatile Organic Compounds in New U.S. Homes: Results of a Controlled Field Study in Nine Residential Units. LBNL-6022E*

*Available at http://eetd.lbl.gov/publications