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
  - Randy Maddalena, Doug Black, Doug Sullivan, Elizabeth Heredia, Brennan Less, Thuy Nguyen, , Phil Price, Chris Stratton

- External contributors
  - Kurt Roth & Peter Engelmann, Fraunhoffer Inst.
  - Ari Rappaport, IBACOS
  - Bud Offermann & Justin Offermann, IEE
  - Wenhao Chen & Kazz Kumagai, CDPH

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

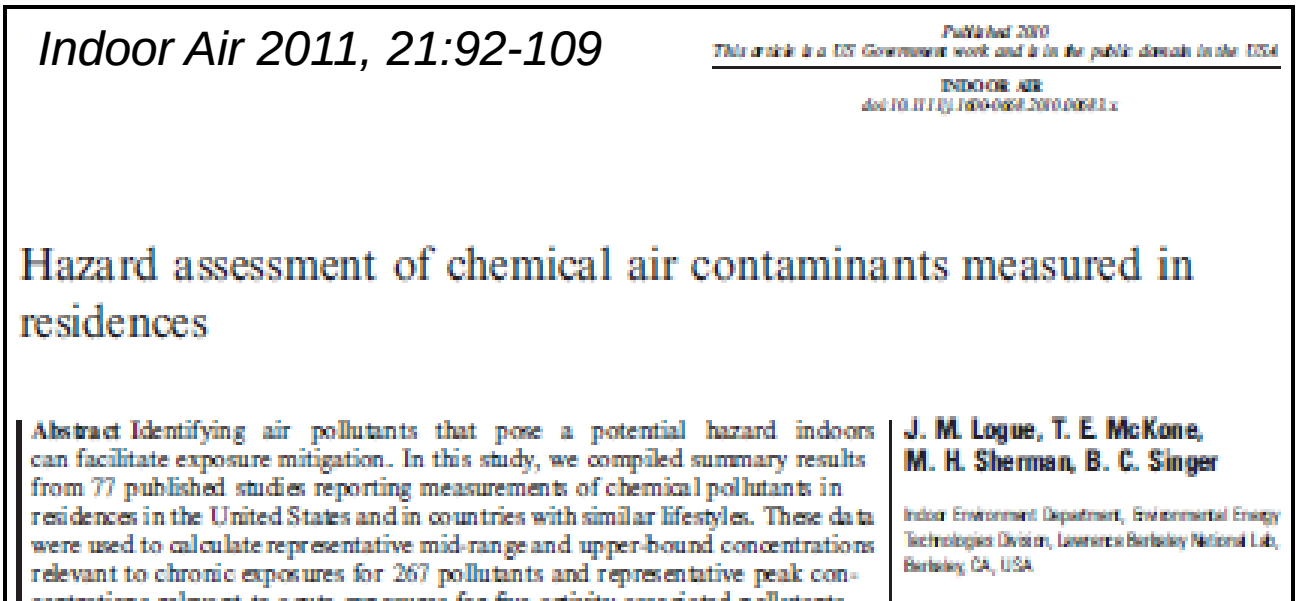
Formaldehyde

Naphthalene

NO_2

$PM_{2.5}$

Indoor Air 2011, 21:92-109



Published 2010
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INDOOR AIR
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Hazard assessment of chemical air contaminants measured in residences

Abstract Identifying air pollutants that pose a potential hazard indoors can facilitate exposure mitigation. In this study, we compiled summary results from 77 published studies reporting measurements of chemical pollutants in residences in the United States and in countries with similar lifestyles. These data were used to calculate representative mid-range and upper-bound concentrations relevant to chronic exposures for 267 pollutants and representative peak con-

J. M. Logue, T. E. McKone, M. H. Sherman, B. C. Singer

Indoor Environment Department, Environmental Energy Technologies Division, Lawrence Berkeley National Lab, Berkeley, CA, USA

Prioritize Using Disability Adjusted Life Years

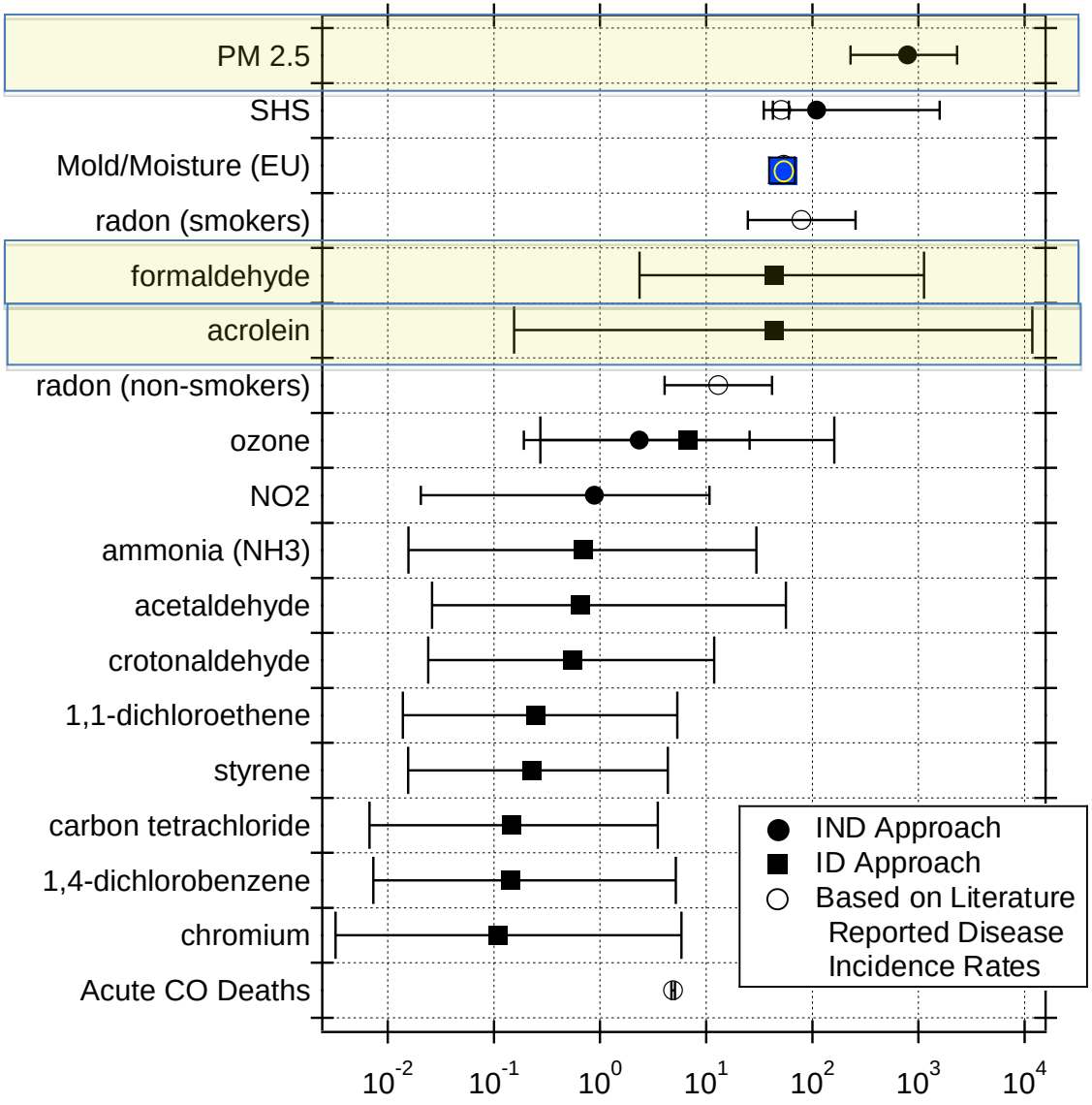
$$DALY = YLL + YLD$$

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

Intake X $\frac{\Delta \textit{ Disease}}{\Delta \textit{ Intake}}$ X $\frac{\Delta \textit{ DALYs}}{\Delta \textit{ Disease}}$ → ***DALYs per pollutant***

Logue et al., Environmental Health Perspectives, 2012

Most Harmful Air Pollutants in Homes



DALYs per year per 100K people

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

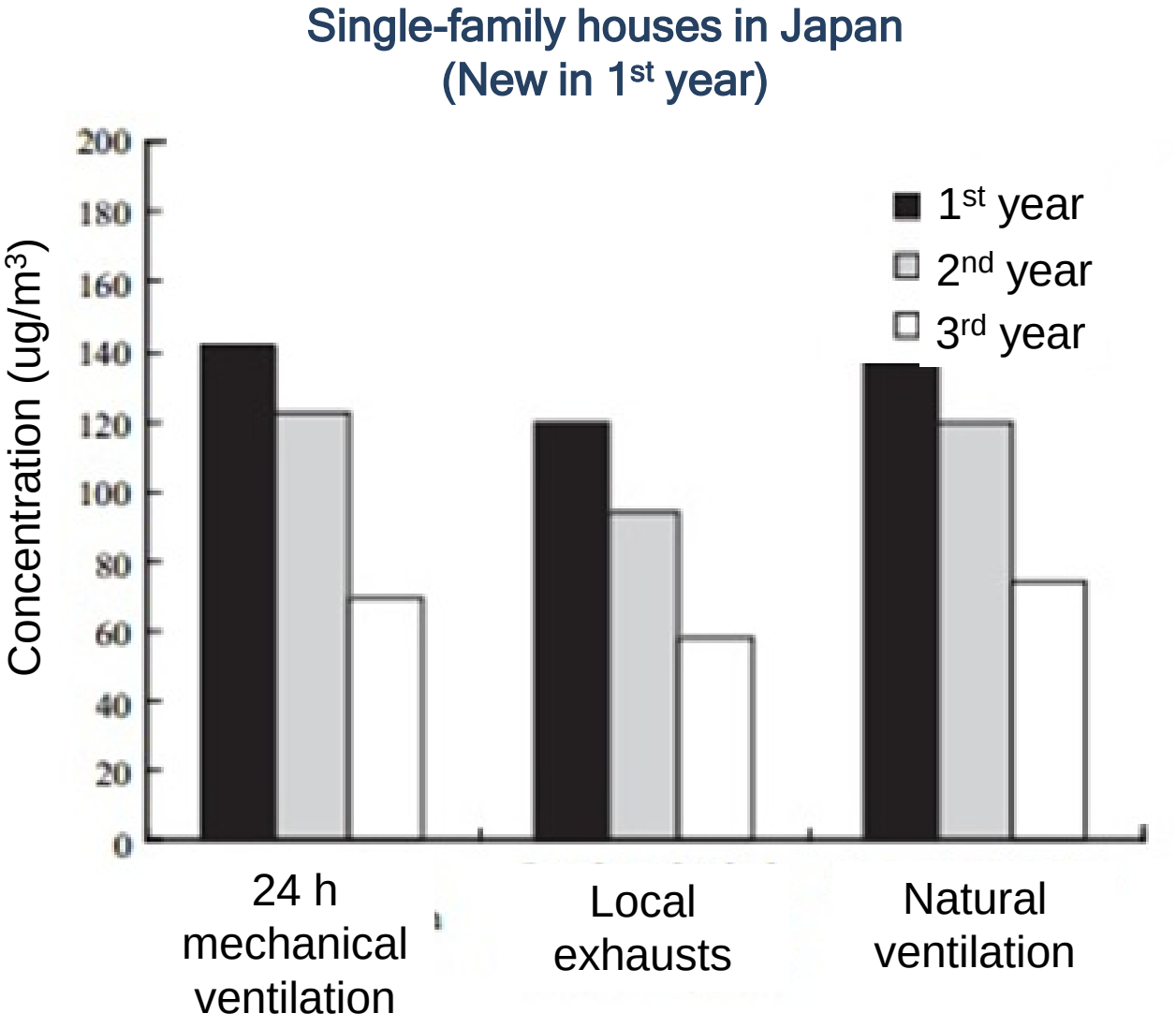
Formaldehyde Background

- 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

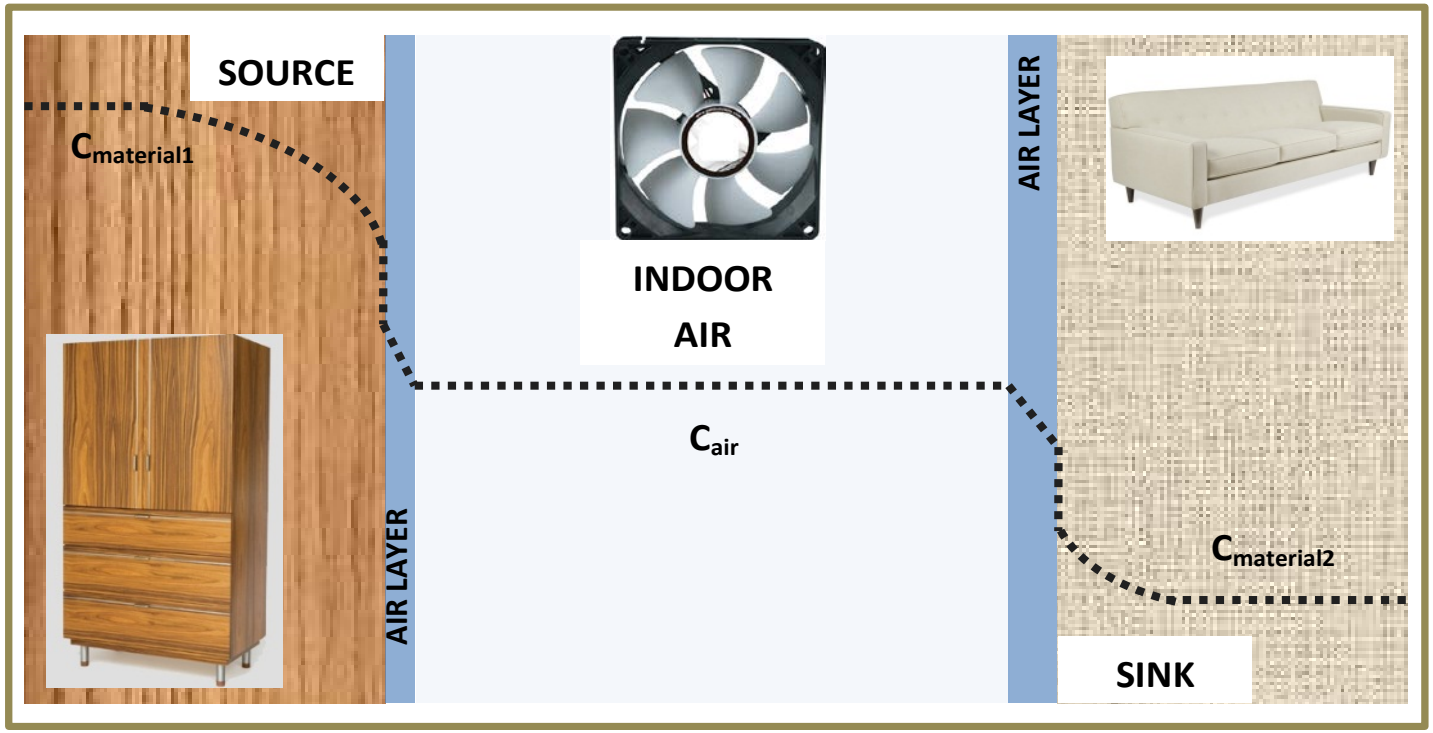
- Wide range of standards for acute and chronic exposures.
- California OEHHA reference exposure levels (RELs)
  - 1h: 55 $\mu g\ m^{-3}$
  - 8h: 9 $\mu g\ m^{-3}$
  - Chronic: 9 $\mu g\ m^{-3}$

Formaldehyde highest in new homes; Concentrations decrease with age



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 ➔reduce air conc.➔ 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.

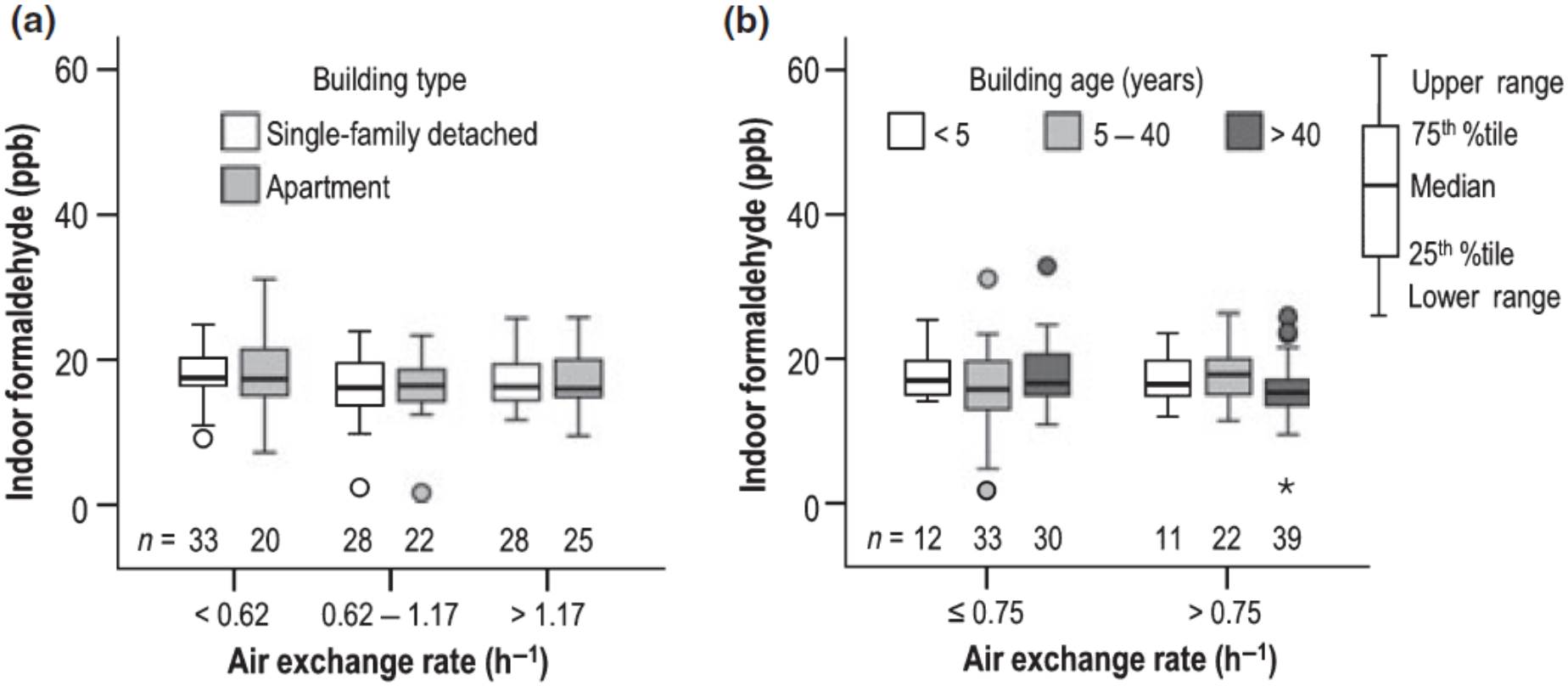
Magnitude of effectiveness not documented.

Air Cleaning

Emerging option with new technologies and products coming to market. Uses energy.

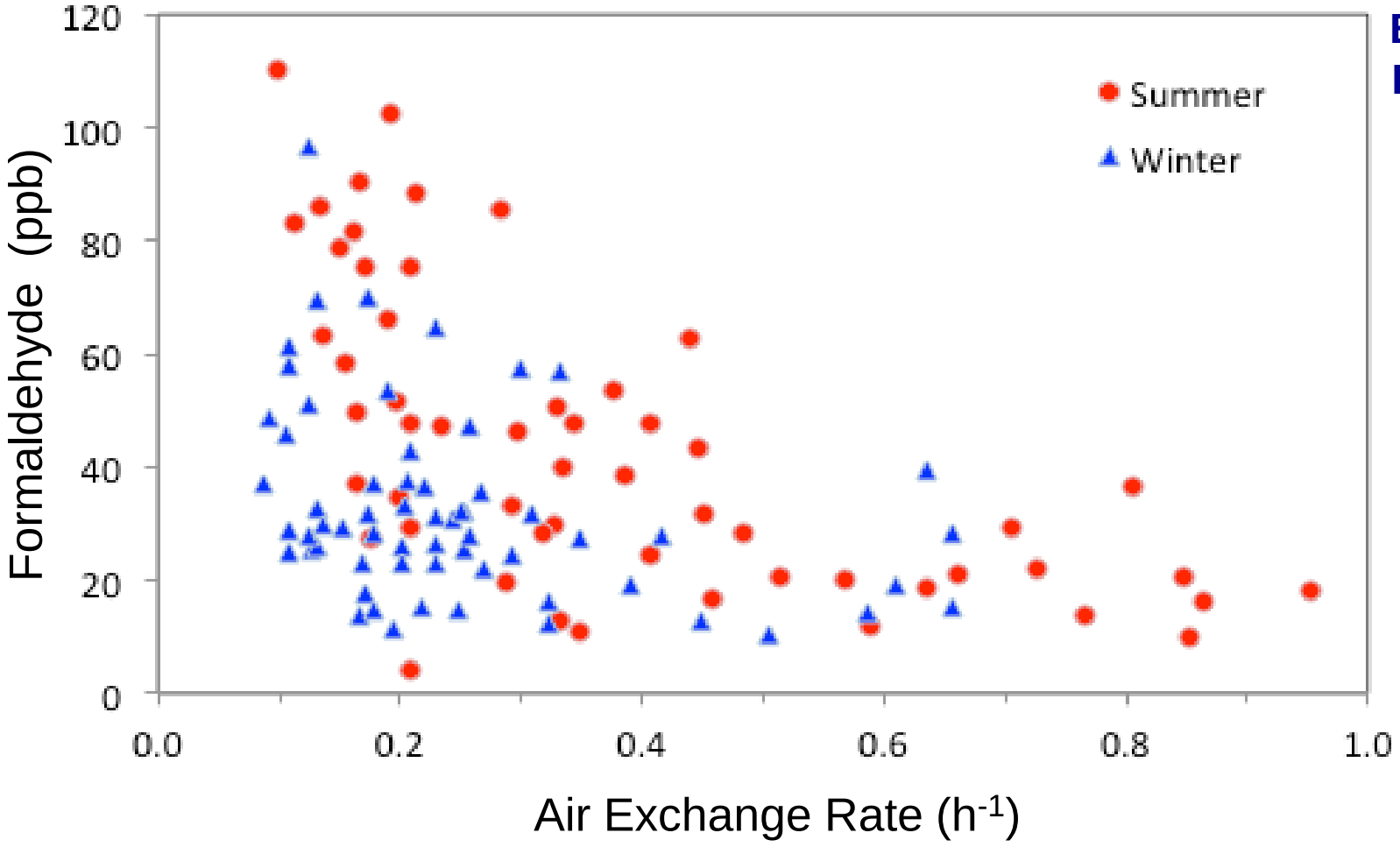
Not examined in this study.

Analysis of RIOPA data raised questions about ventilation control



(Hun, Indoor Air, 2010)

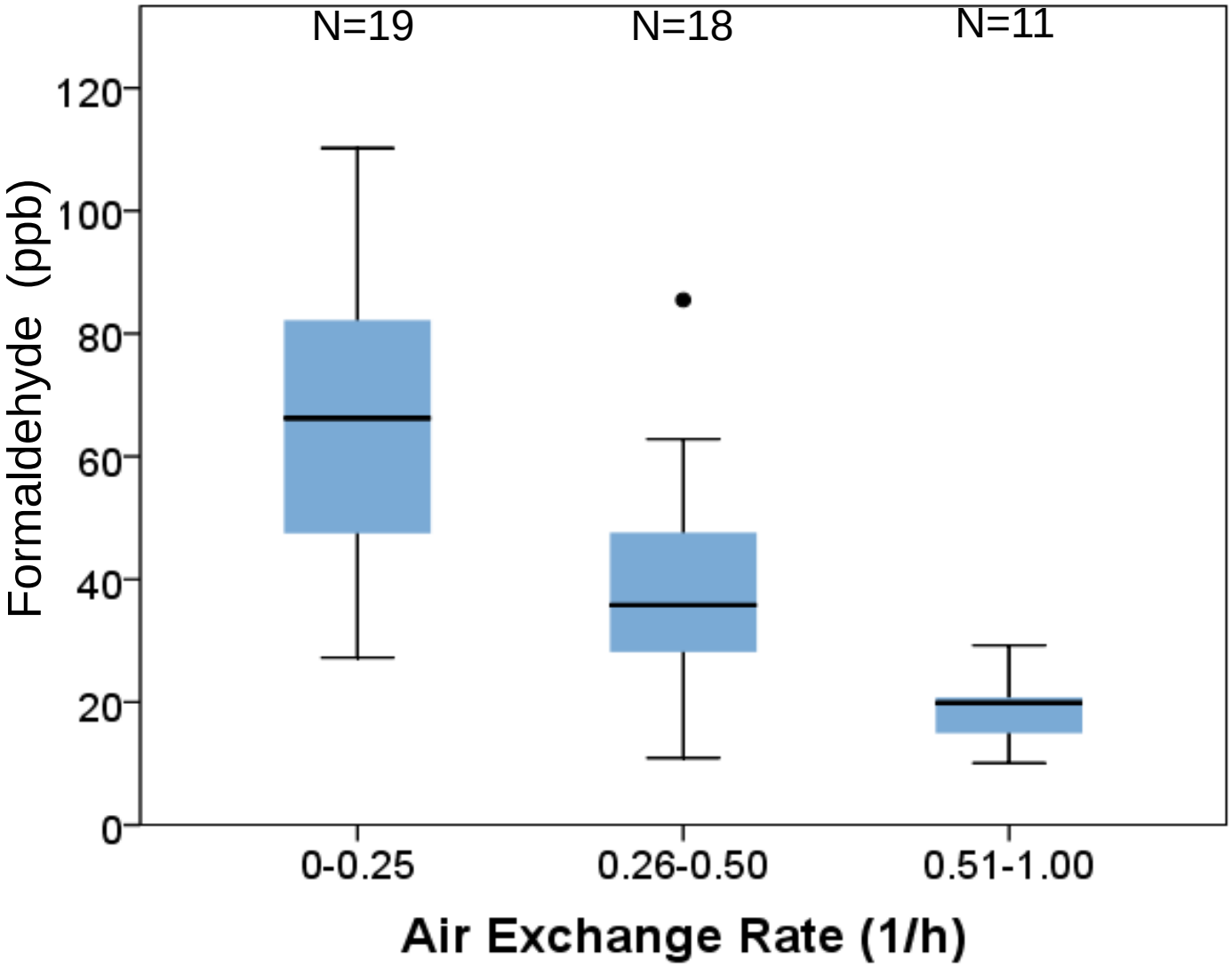
Data from CA New Home Study (CNHS) supports effectiveness of ventilation control



Built: 2002-5
Data: 2006-7
N=108

These homes built prior to formaldehyde emission standards

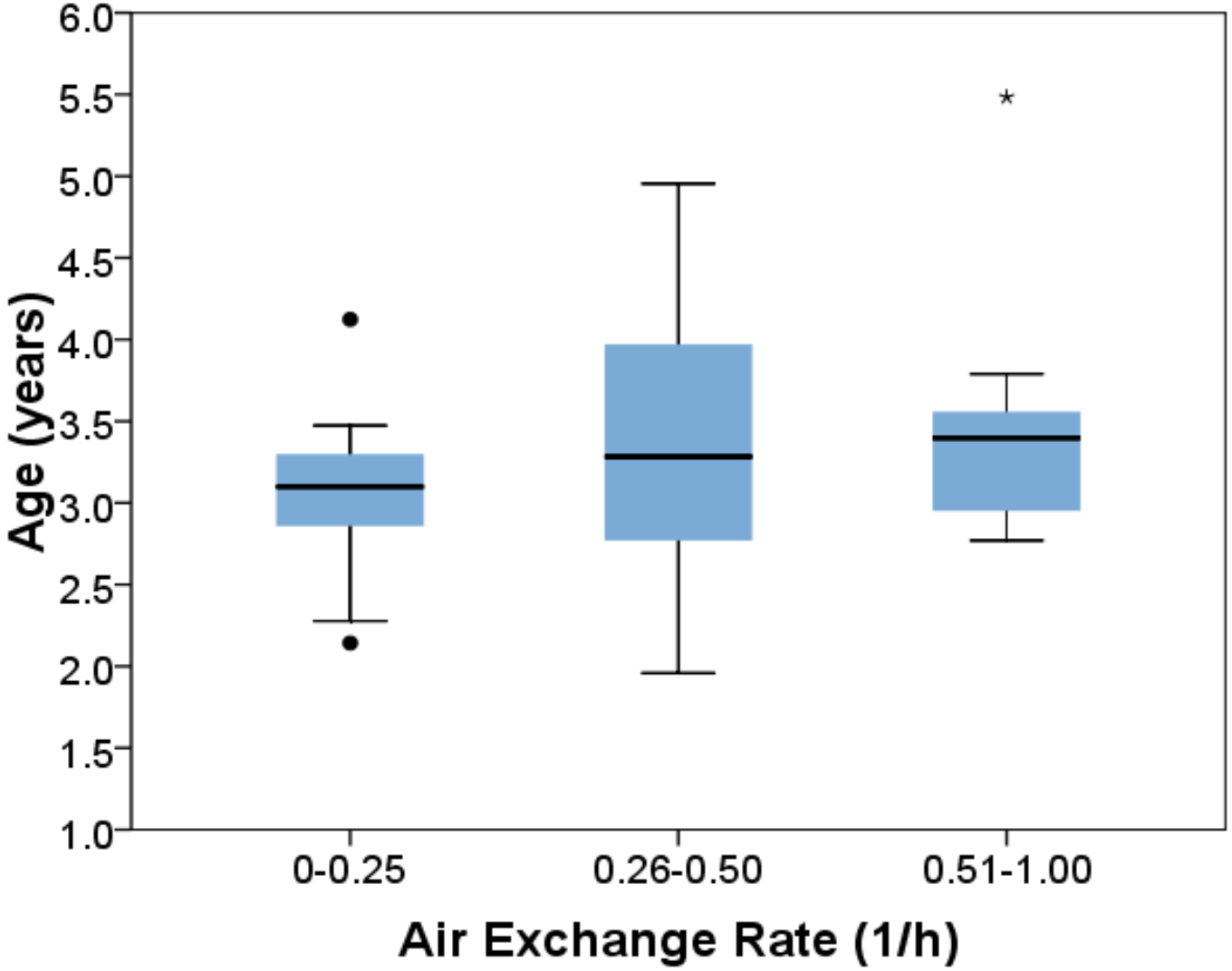
Data from CNHS supports effectiveness of ventilation control



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

Summer
N=48

Ventilation impact not explained by age variations



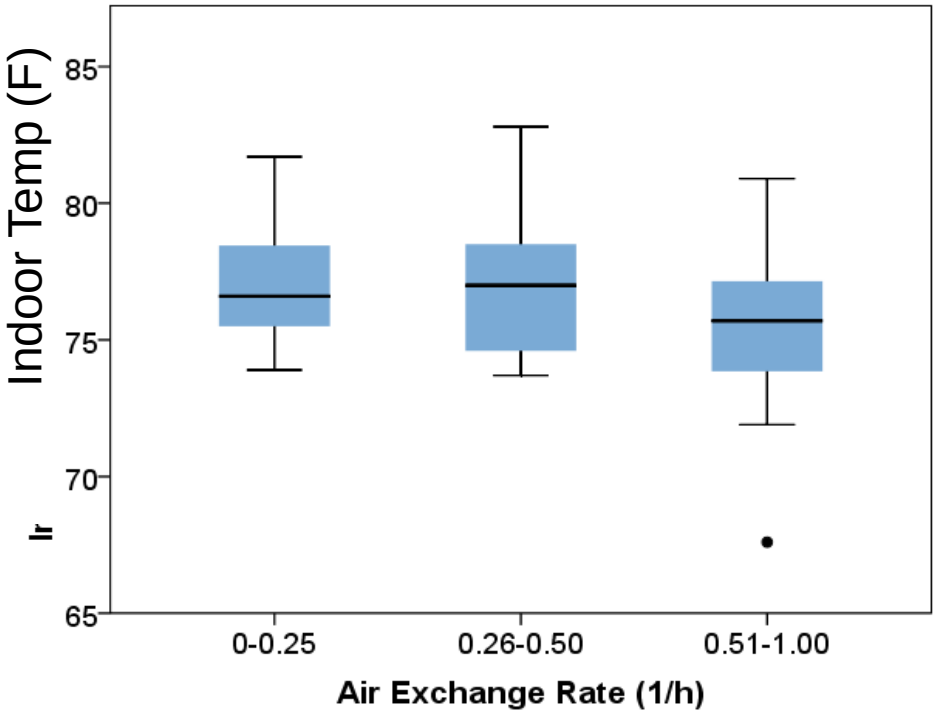
Built: 2002-5
Data: 2006-7
Age: 1.8-5.5 y

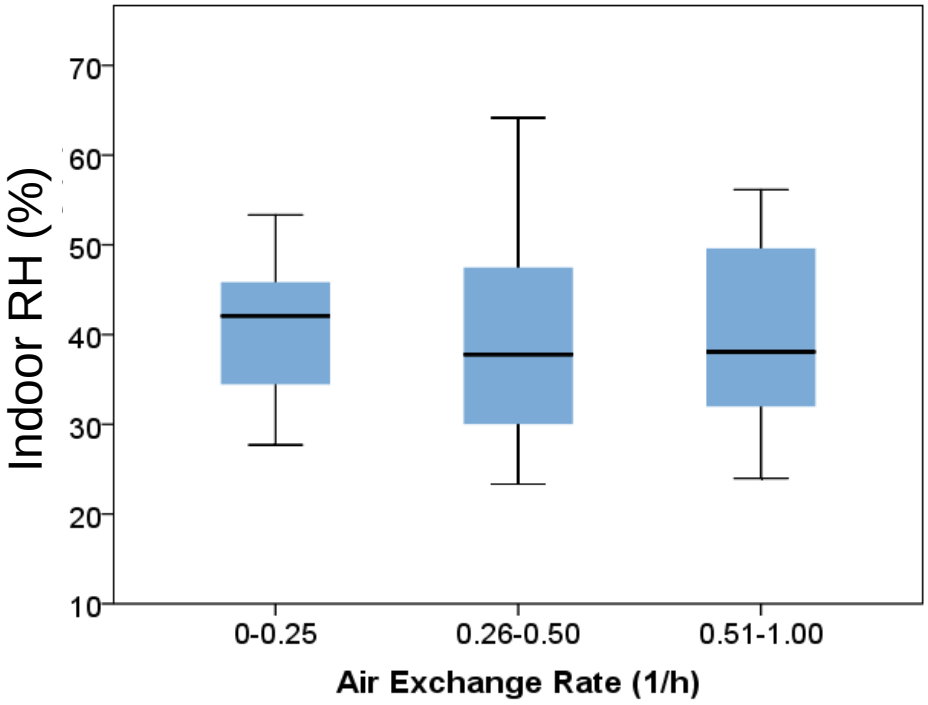
Summer
N=48

Ventilation impact not explained by T or RH variations

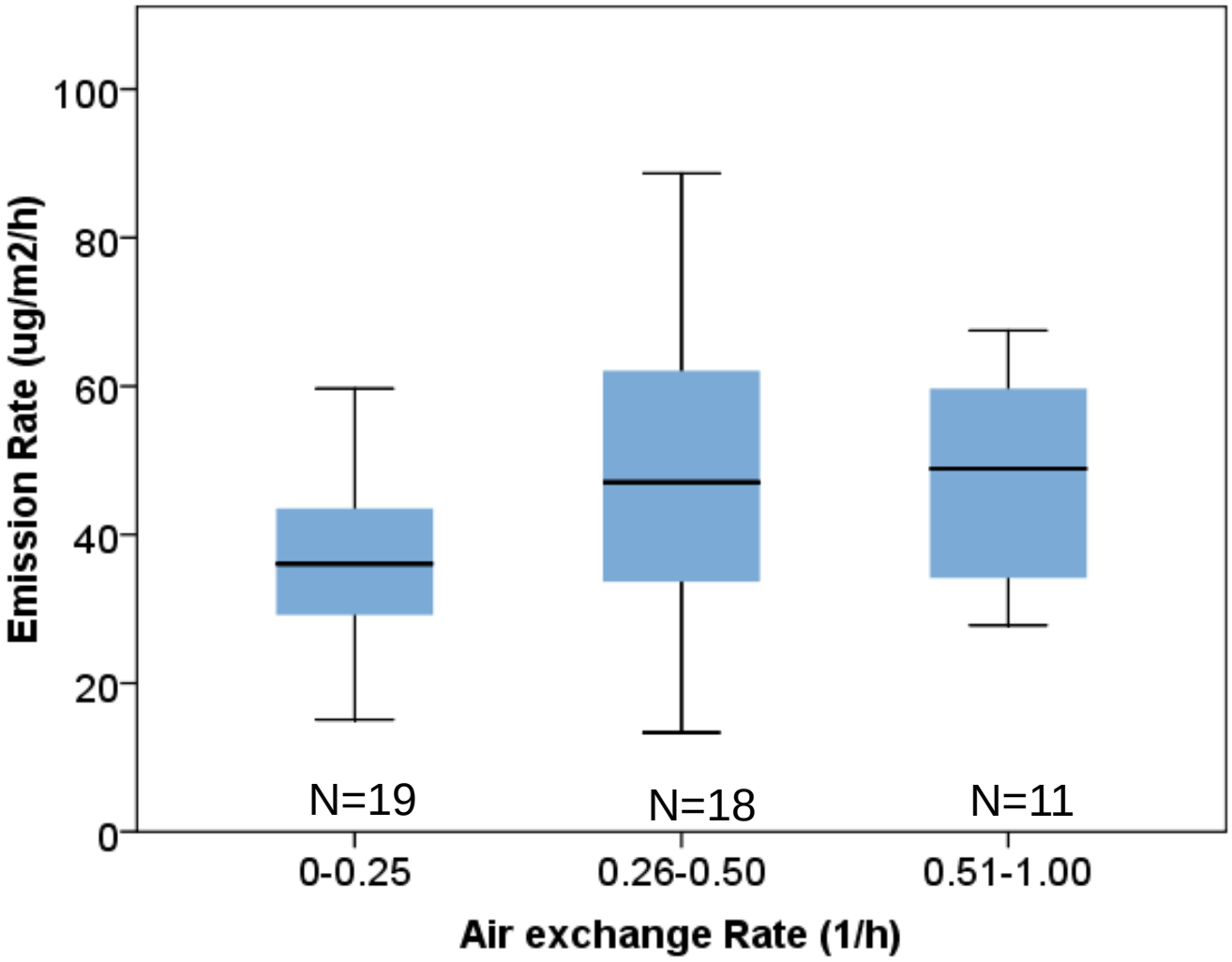
Built: 2002-5
Data: 2006-7
Age: 1.8-5.5 y

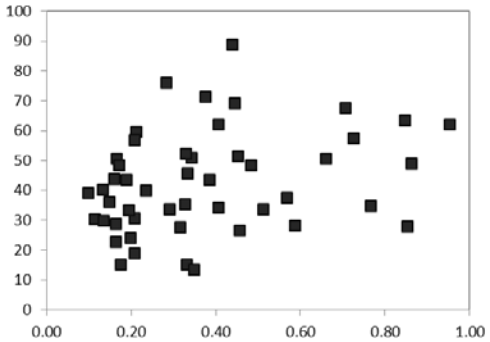
Summer
N=48





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

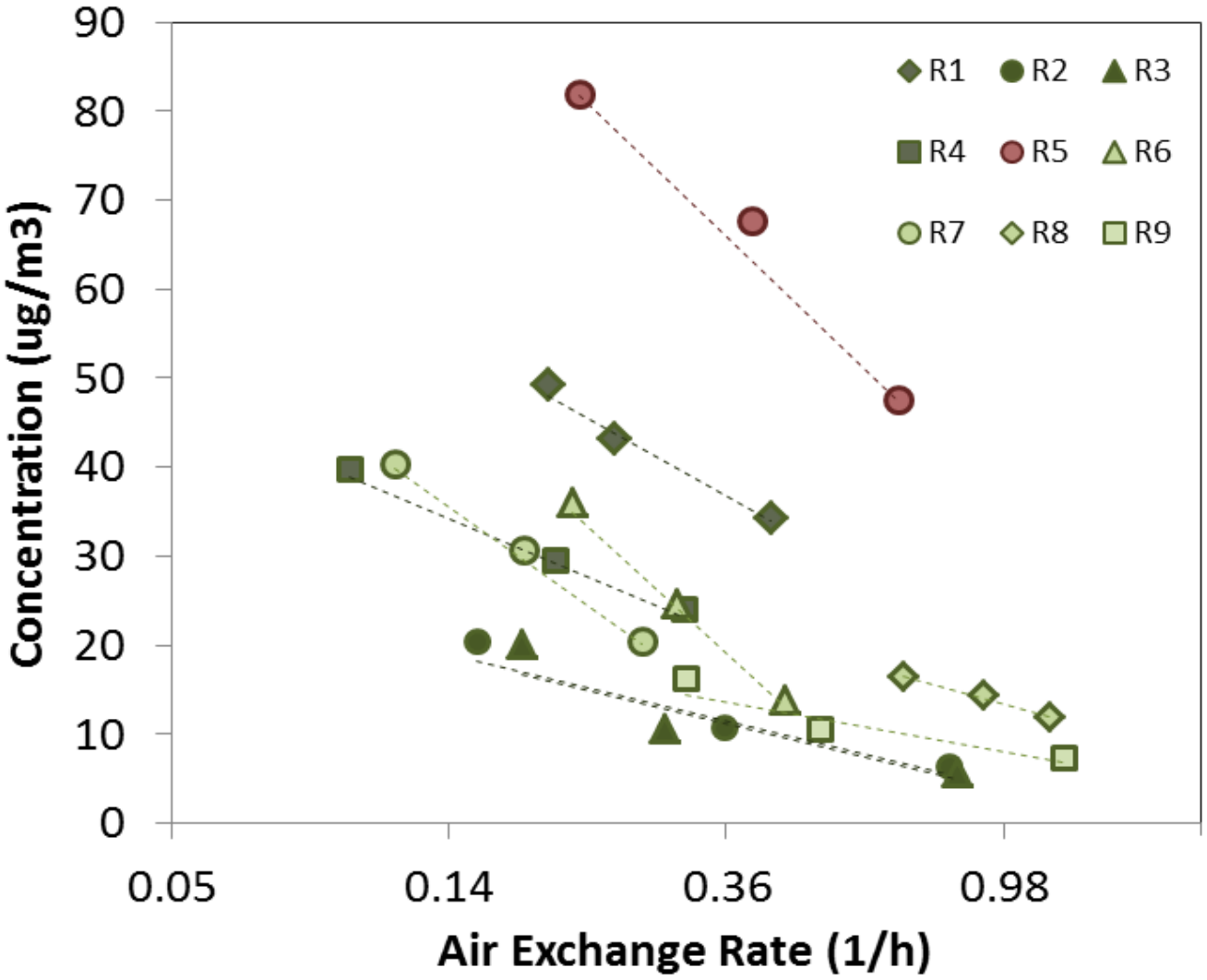
LBNL Ventilation Intervention Study

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

	Age (yrs)	Floor area (ft^2)	ACH 50	Low-emitting Material[#]
R1	2.0	2100	1.2	1,2,3
R2	1.5	150	4.0	1,2,3
R3	1.5	150	4.0	1,2,3
R4	0.3	1475	0.6	1,2,3
R5	7.5	1300	4.3	-
R6	0.8	1570	1.0	2,3
R7	1.0	2260	0.7	2,3
R8	2.5	1600	1.0	2
R9	2.5	3440	4.0	2

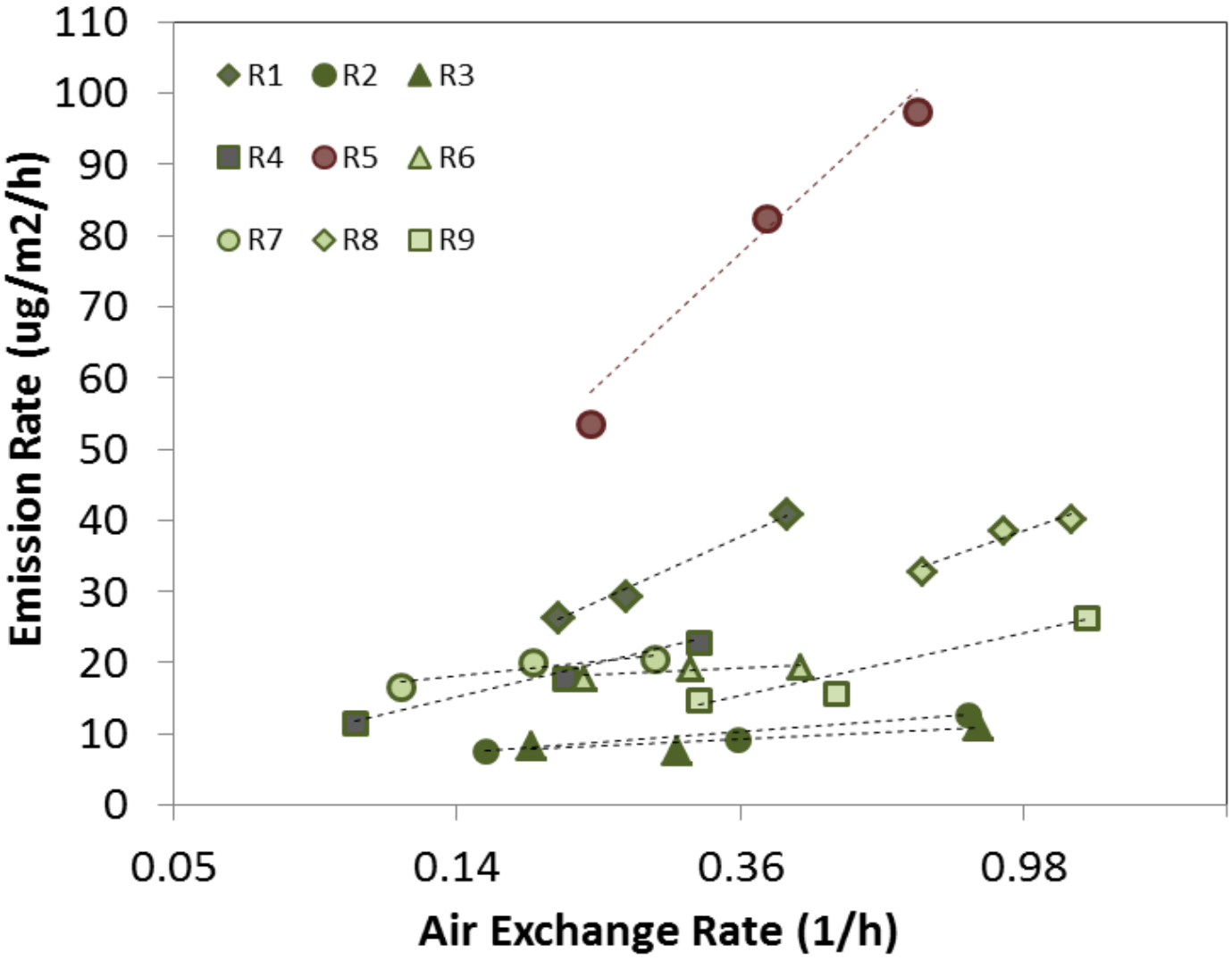
[#]1= Wood products compliant with CA Title 17 or low- or no- formaldehyde standards,
2= Wet surface finishing certified as low-emitting,
3= Carpet materials and backing low-emitting.

Lower concentration achieved with increasing AER in each study home



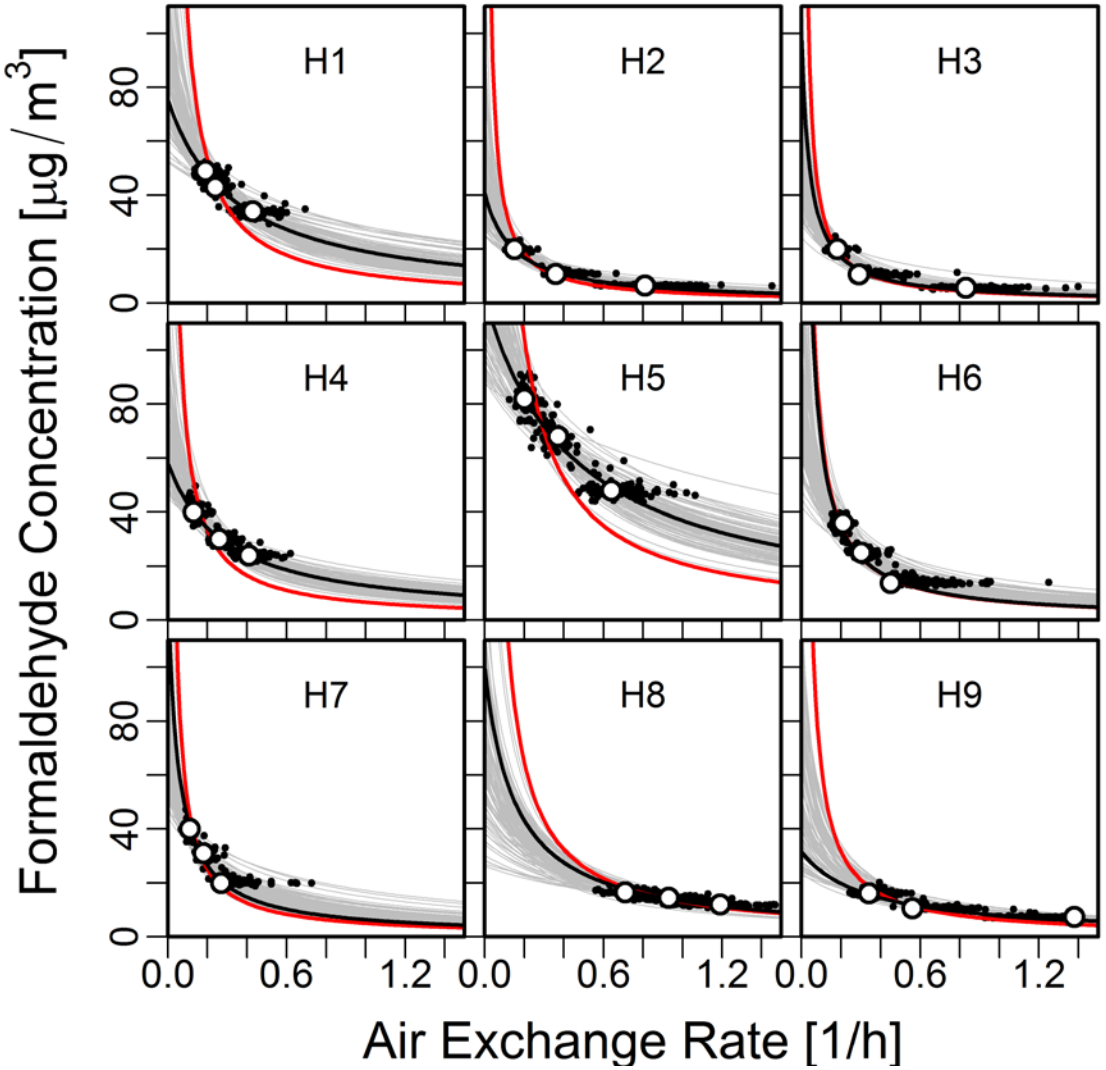
May - Sep 2011
Age: 0.3 - 2.5 y
N = 9 homes

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



Observations

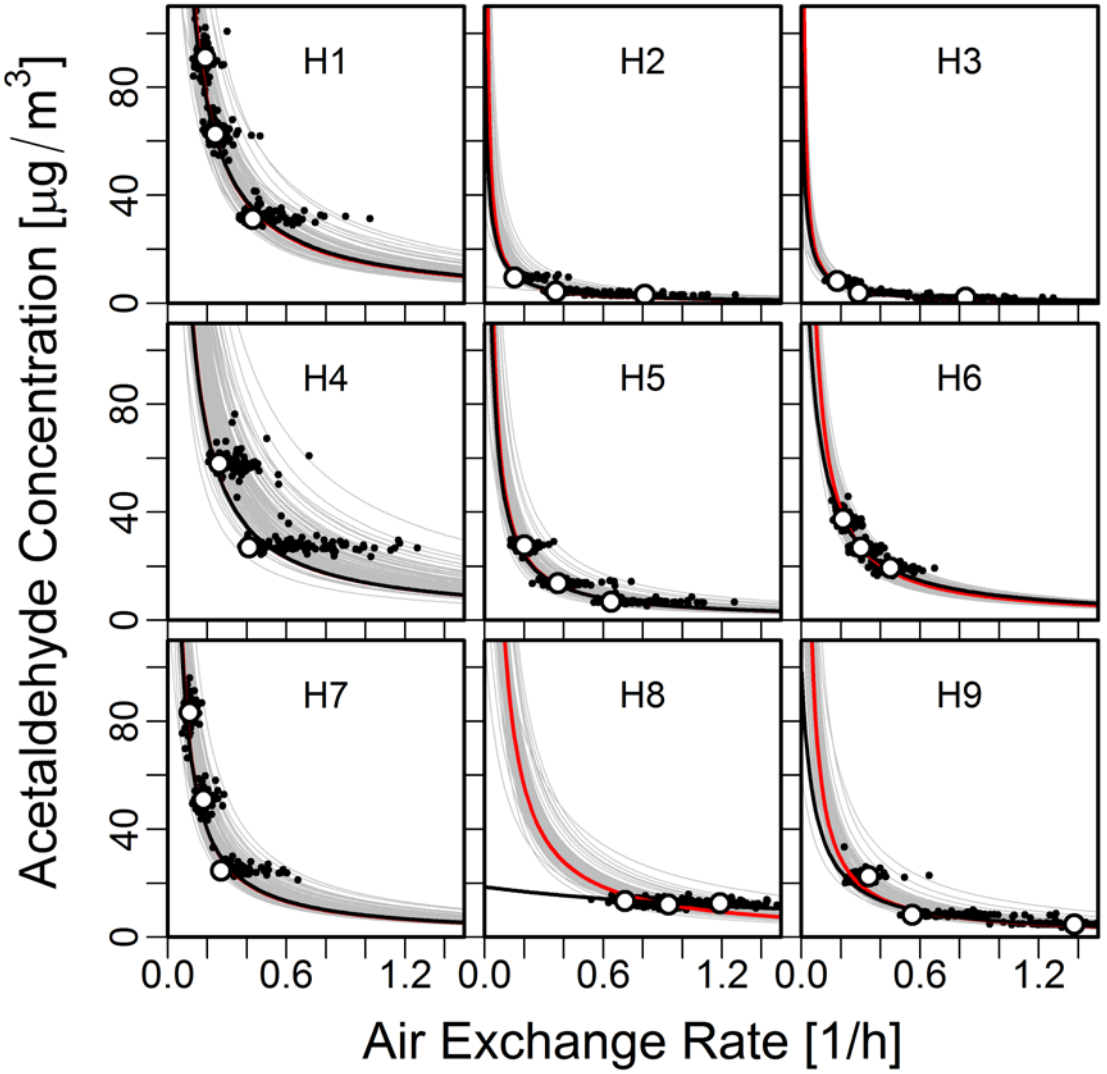
Constant emission model

Concentration dependent emission model

Bayesian simulator 'true' values

Bayesian simulator Conc-dependent emission model

Acetaldehyde response to ventilation consistent with constant emission sources



Observations

Constant emission model

Concentration dependent emission model

Bayesian simulator 'true' values

Bayesian simulator Conc-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

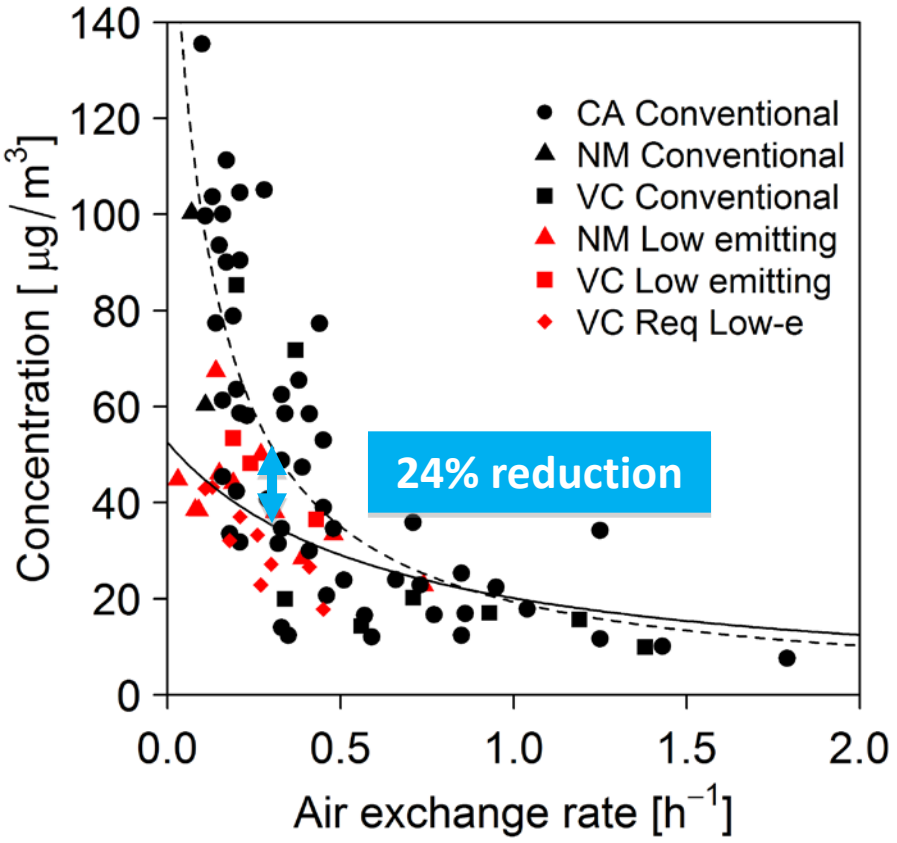
- 11 LEED / EPA Indoor airPLUS homes in NM
  - 0.3 to 3.5 years old
  - ATCM compliant wood products
- 4 low-emitting homes from vent. control study

Compare to homes with conventional materials

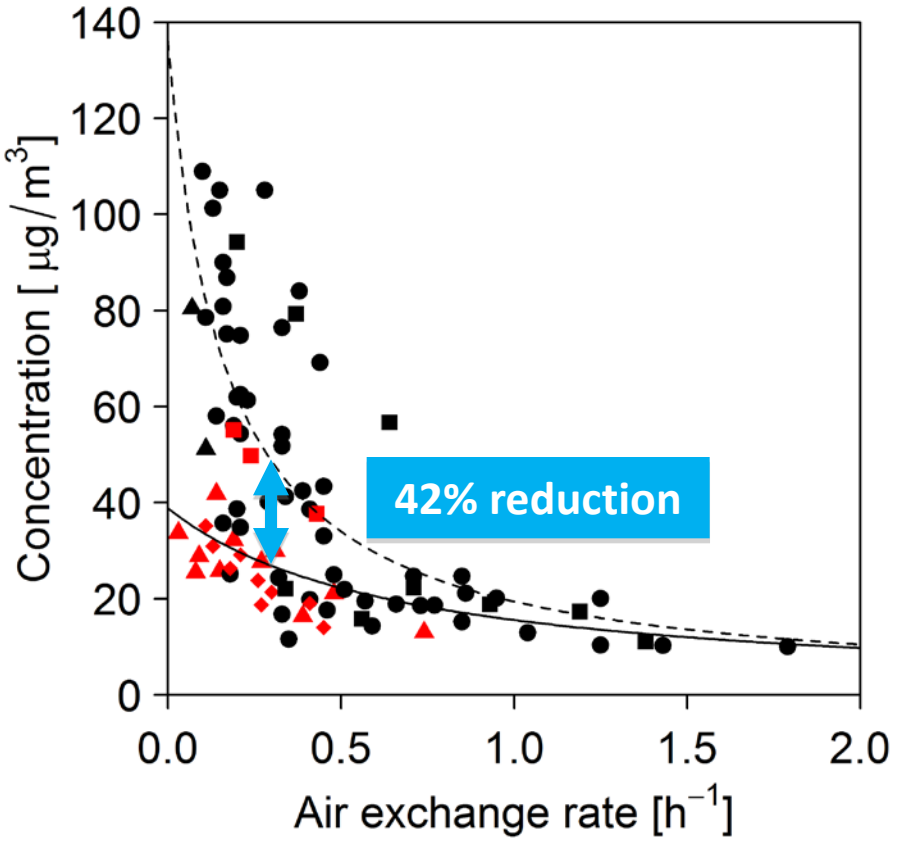
- 54 homes from CNHS (2-5 years old)
- 3 homes from vent. control study
- 2 control homes from New Mexico

Homes with low-emitting materials have lower formaldehyde concentrations

Unadjusted



Adjusted for T, RH, house age



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%

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