Mechanical Outdoor Air Ventilation Systems and IAQ in New Homes

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- **Member of ACGIH Bioaerosols Committee**
- **Member of the Cal-OSHA IAQ Advisory Committee**
- **Published 26 Peer-Reviewed Studies on Building Air Quality**
- **IAQ Diagnostics/Mitigation in over 2,000 Buildings (25 years - 2009)**

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Study Sponsors

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HYPOTHESIS

- Many homeowners never or rarely open their windows.
- As a result, outdoor air exchange rates in these homes are very low (e.g. 0.1 - 0.2 ach)
- These low air exchange rates result in elevated indoor concentrations of air contaminants such as formaldehyde, which is both a potent irritant and a know human carcinogen.

Study Design

- Recruit 108 home

  - 54 each from Northern and Southern California

  - 20 homes with mechanical outside air ventilation systems.

- Summer and Winter Field Sessions (20 home seasonal crossover)

- Measure window/door opening, outdoor air exchange rates, air contaminant concentrations, house characteristics, source activities, and occupant perceptions.

Recruitment

- We utilized a recent mail survey by UCB on window use in new single family homes (random stratified).
- A total of 965 of the 1,515 UCB Mail Survey respondents indicated an interest in participating in the follow up field study.
- We mailed out recruitment letters to the 965 interested UCB Mail Survey participants, as well as 1,798 additional nearby new homes.

Ventilation Measurements

7 Day Monitoring Period

- **Window/door openings**

  - electronic loggers and occupant logs.

- **Exhaust fan usage**

  - electronic loggers, occupant logs, and flowhood measurements.

- **Mechanical outside air and FAU fan usages**

  - electronic loggers and flowhood measurements.

- **Building envelope air leakage**

  - multi-point fan depressurization

Outdoor Air Exchange Rate Measurements - 24 hour

- **Passive tracer gas technique (PFT)**

  - 4-8 tracer gas sources deployed one week in advance to allow for the emission rates to equilibrate.

  - tracer sampler deployed in home for 24 hour period

  - a subset of 30 homes also deployed samplers for a 2 week period

Quiet Active Indoor Air Sampler

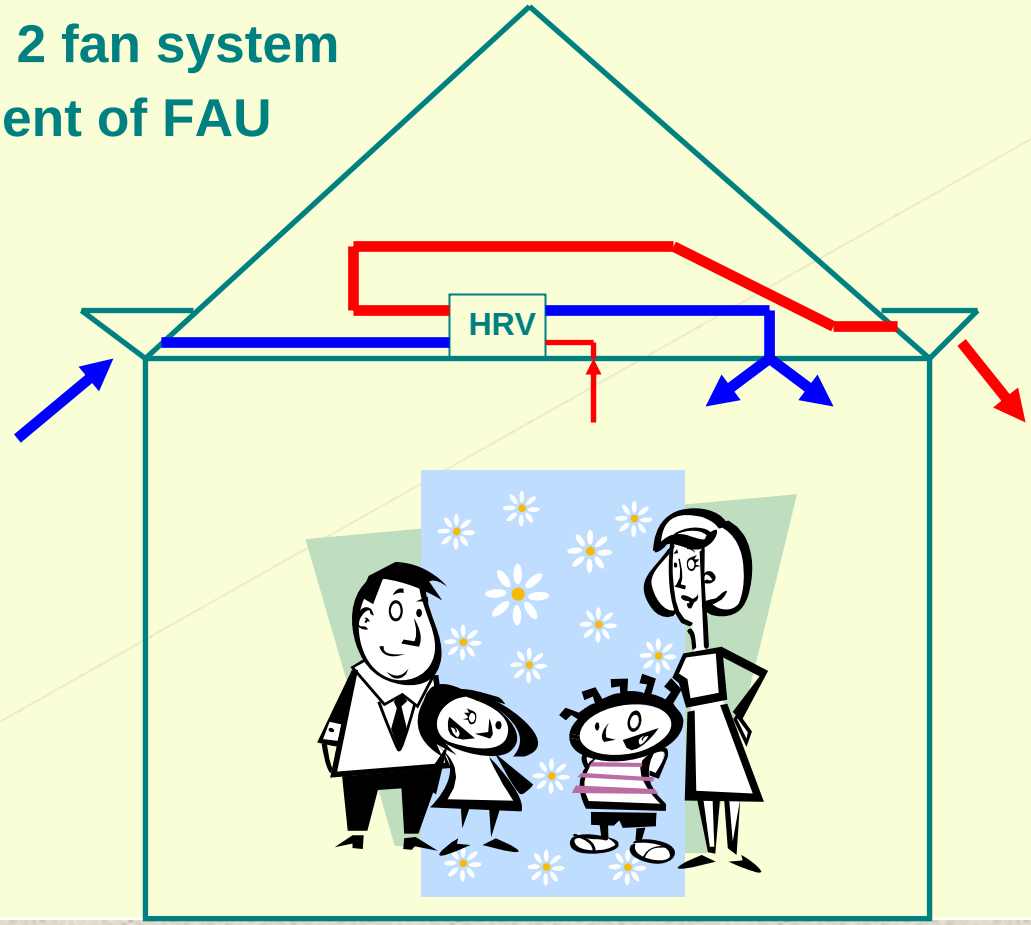
- HCHO
- VOC's
- $PM_{2.5}$
- CO_2
- CO
- T
- RH
- Flow Control
- Power Surveillance

Field Session Recruits

- 108 homes primarily from tract developments
- built 2002 or later, and have been owner-occupied for at least one year (median age 3.4 years)
- typically stucco and slab on grade with attached garages.
- all homes had forced air unit heating systems (94% with AC)
- 35 homes with some type of mechanical outdoor air ventilation system

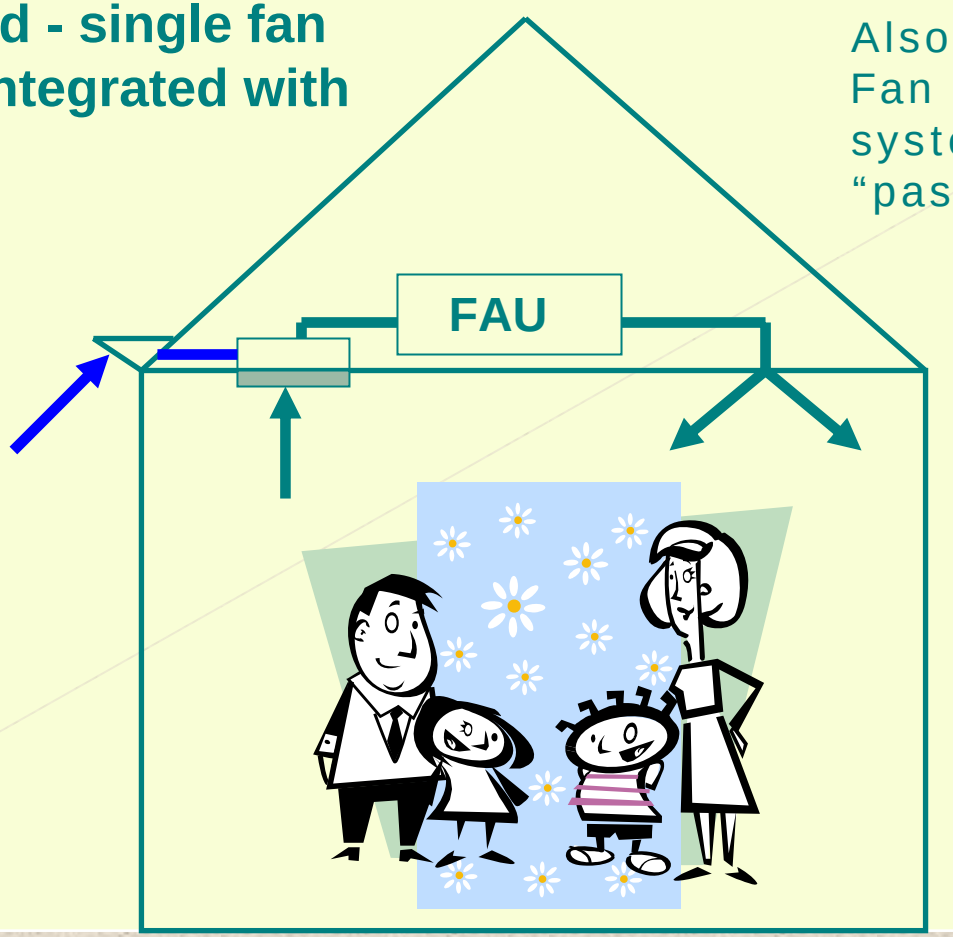
Heat Recovery Ventilator (HRV) System (9 homes)

Balanced 2 fan system independent of FAU



Ducted Outdoor Air (DOA) System (17 homes)

Unbalanced - single fan system – integrated with FAU

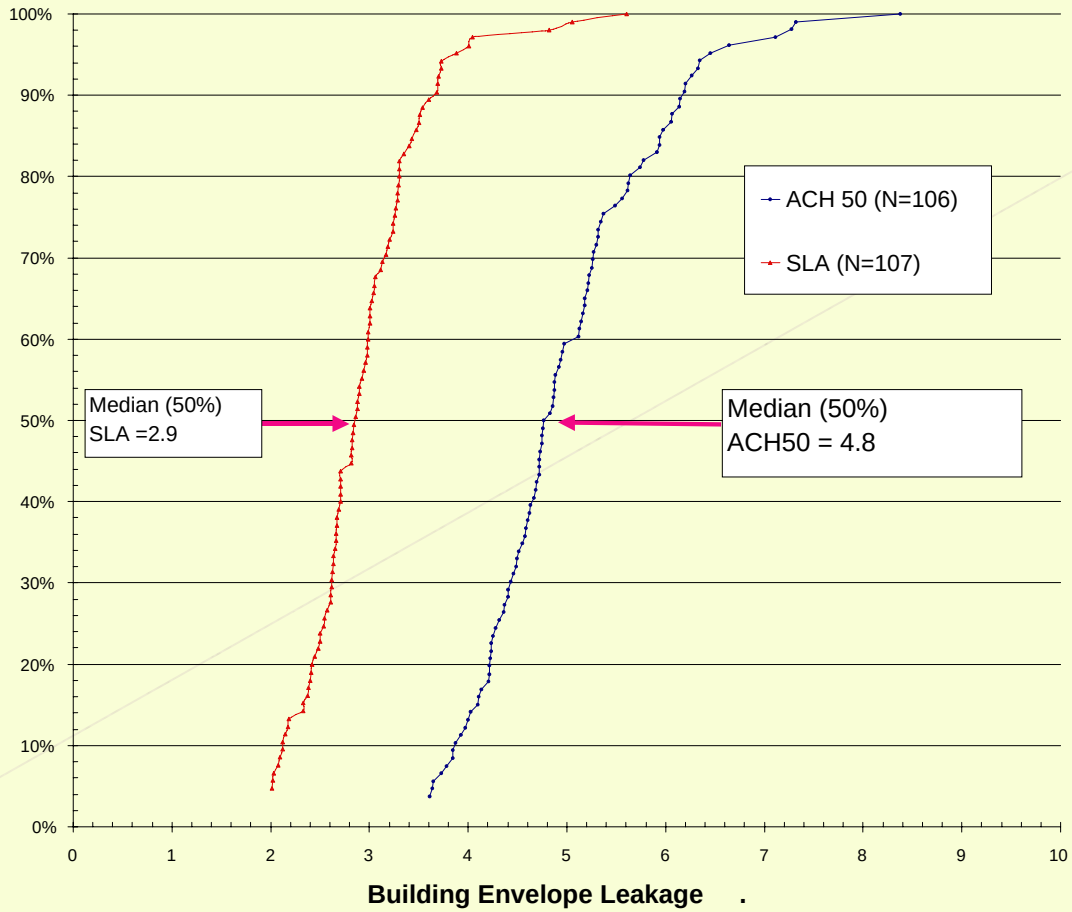


Also called Central Fan Integrated (CFI) systems and "passive inlets".

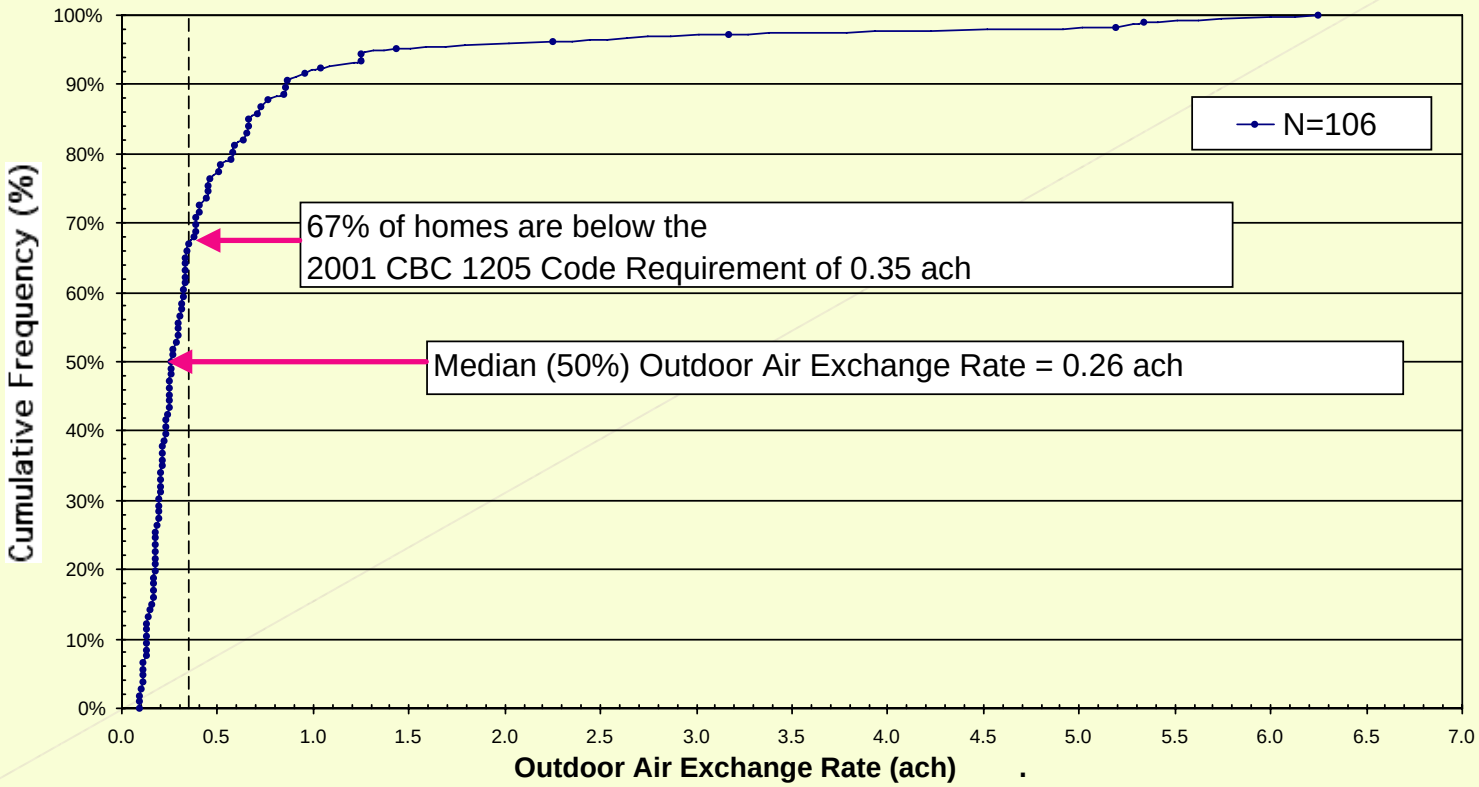
RESULTS - Window/Door Usage

- 32% of the homes never opened windows or doors during the test day and 15% never during the previous week.
- most of the homes with zero window/door usage were in the Winter field session (85%)

RESULTS - Building Envelope Leakage



RESULTS - Outdoor Air Exchange Rates - PFT Measurements



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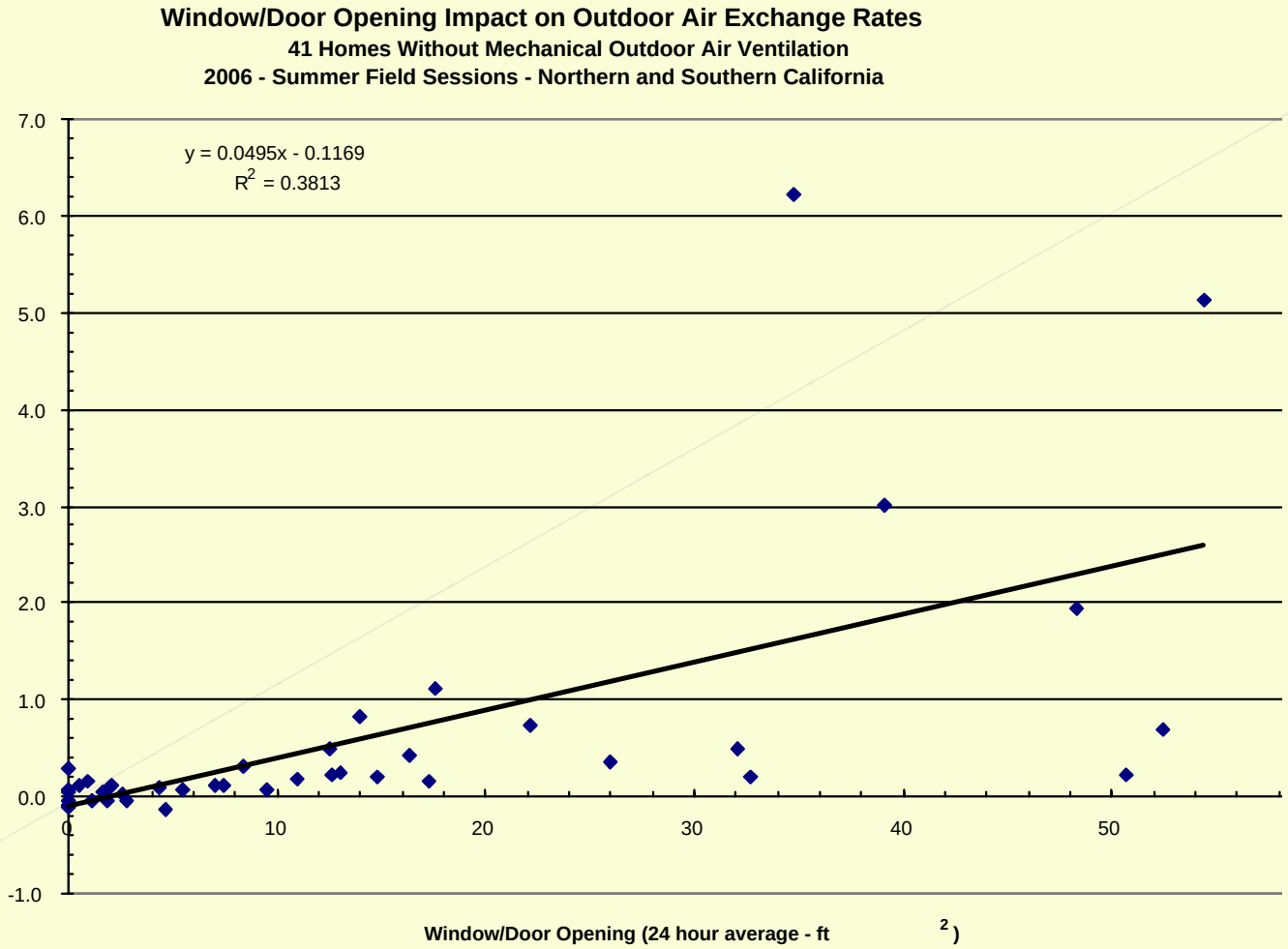


RESULTS - 24-hour Average Outdoor Air Exchange Rates

	Number of Homes Tested	Minimum (ach)	Median (ach)	Maximum (ach)	Percentage [a] of Homes Below CBC Code Requirement
Non-mechanically Ventilated Homes	73	0.09	0.25	5.3	75
DOA-mechanically Ventilated Homes	14	0.10	0.20	0.60	64
HRV-mechanically Ventilated Homes	5	0.33	0.71 *	4.3	64

- 0.35 ach; 2001 California Building Code (CBC), Appendix Chapter 12, Interior Environment, Division 1-Ventilation, Table A-12-A, Outdoor Air Requirements for Ventilation, Living

* statistically significantly higher mean ach (t-test, $p<0.05$)

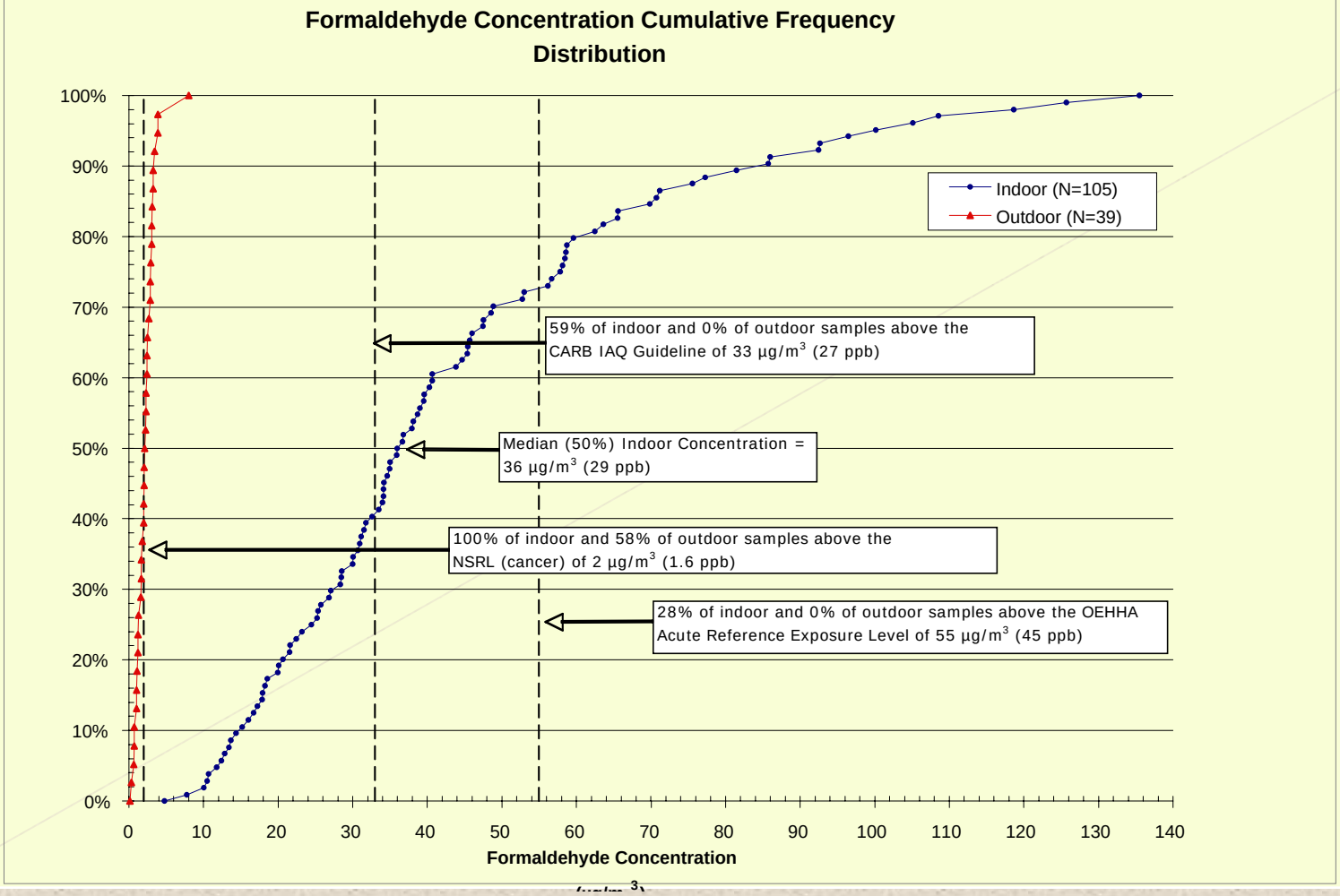
RESULTS - Mechanical Outdoor Air System Performance

	DOA Mechanical Outdoor Air Homes (n=14)			HRV Mechanical Outdoor Air Homes (n=8)		
Quartiles	Ach (h^{-1})	% on time	cfm	Ach (h^{-1})	% on time	cfm
Minimum	0	0	9	0.12	32	66
Median	**0.01**	**10**	**38**	**0.30**	**100**	**128**
Maximum	0.08	75	355	0.47	100	159

RESULTS - Formaldehyde Concentration Guidelines

- Proposition 65 (cancer):
  - NSRL (cancer) - 2 µg/m^3
- OEHHA Reference Exposure Levels (non-cancer, irritant effects)
  - CREL - 9 µg/m^3
  - 8 hour REL - 9 µg/m^3
  - AREL- 94 µg/m^3
- California Air Resources Board
  - Indoor Air Guideline - 33 µg/m^3

RESULTS – Formaldehyde Concentrations

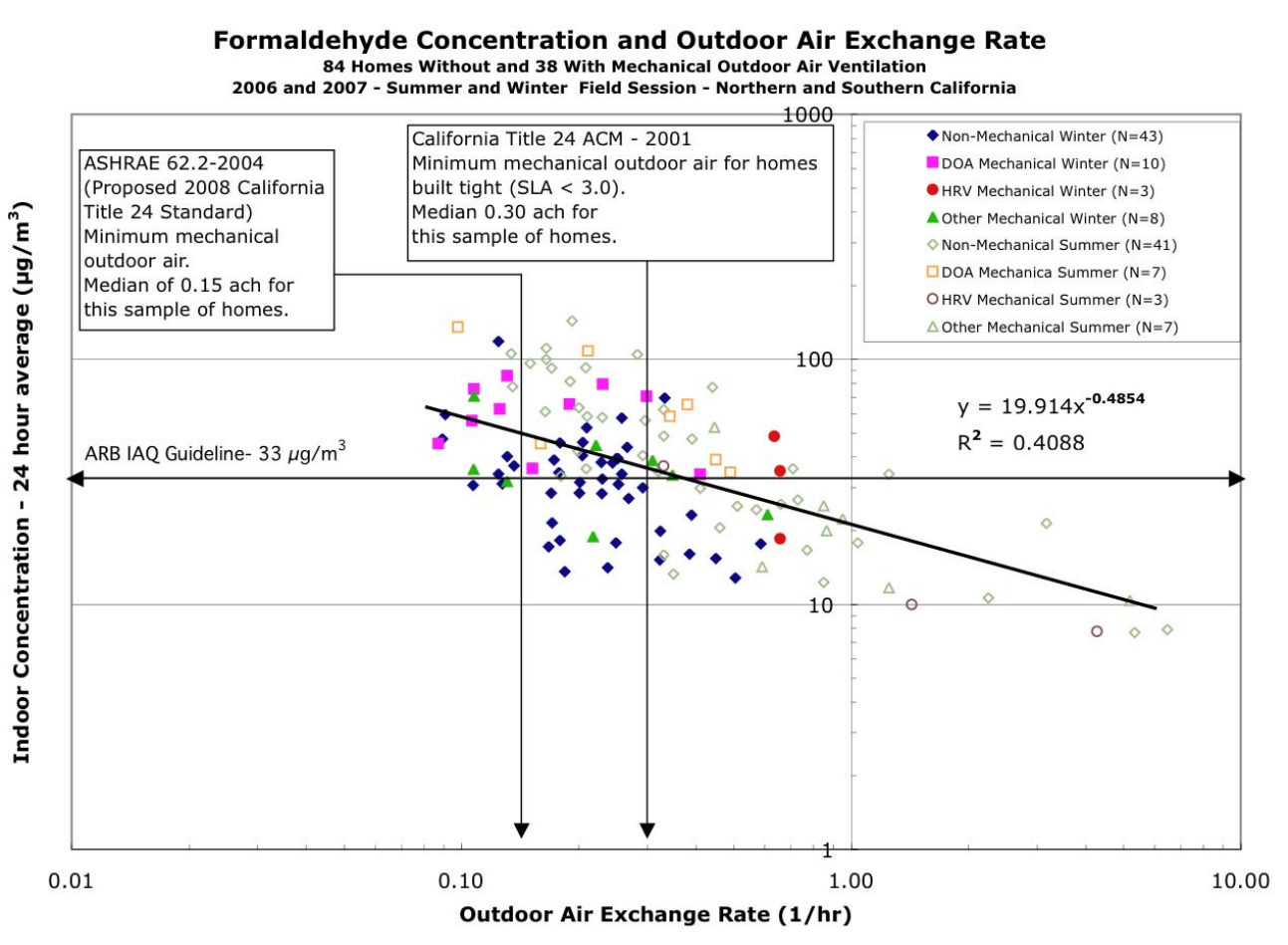


RESULTS - Indoor Concentrations of Formaldehyde

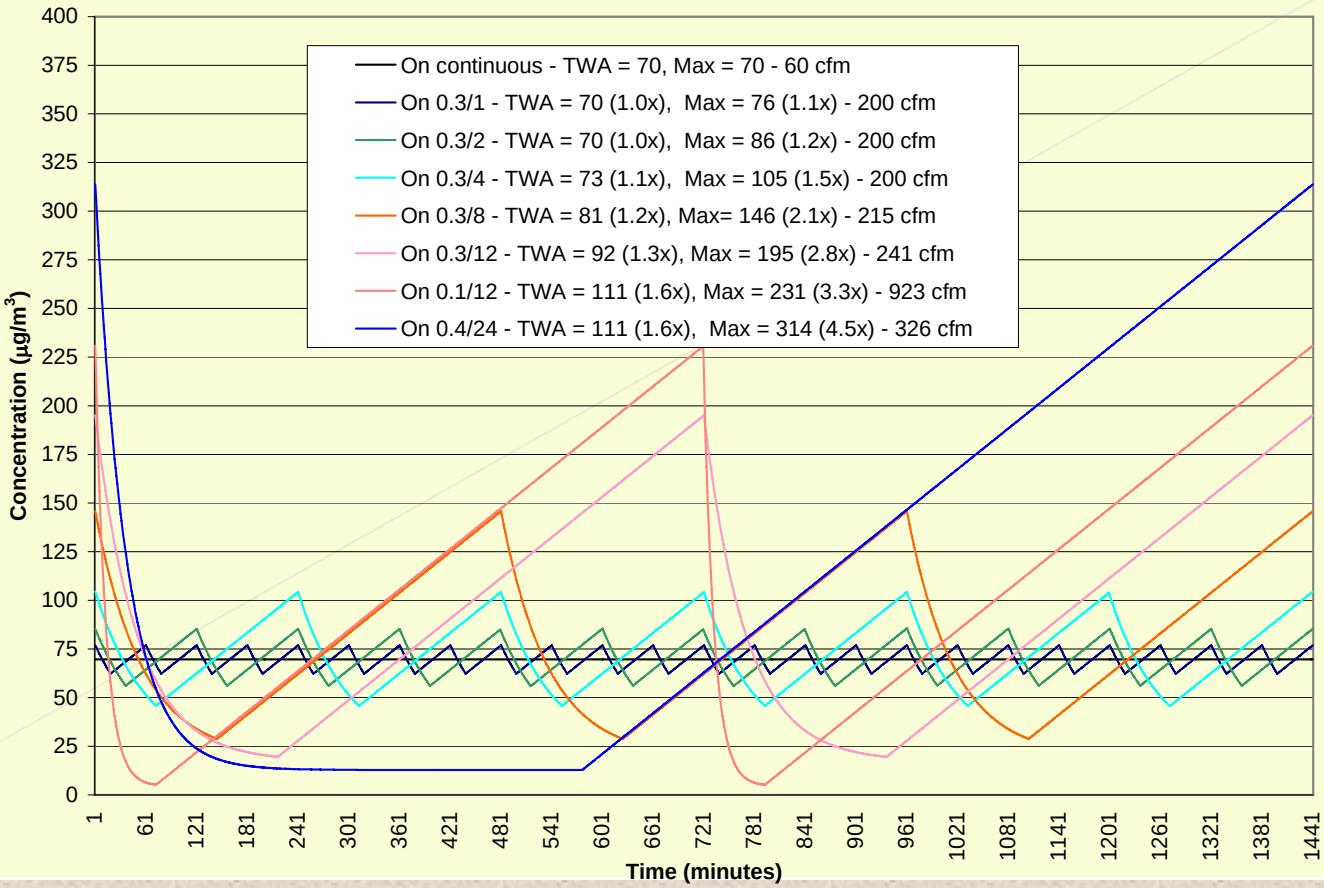
	Number of Homes Tested	Minimum ($\mu g/m^3$)	Median ($\mu g/m^3$)	Maximum ($\mu g/m^3$)	Percentage [a] of Homes Above ARB Indoor Air Guideline
Non-mechanically Ventilated Homes	72	8	35	126	57
DOA-mechanically Ventilated Homes	14	34	68*	136	93
HRV-mechanically Ventilated Homes	5	8	37	63	60

a.) 2005 California Air Resources Board – 33 $\mu g/m^3$.
* statistically significantly higher mean concentration (t-test, $p<0.05$)

RESULTS - Formaldehyde Concentrations and Ventilation



RESULTS - Intermittent vs. Continuous Outdoor Air Ventilation



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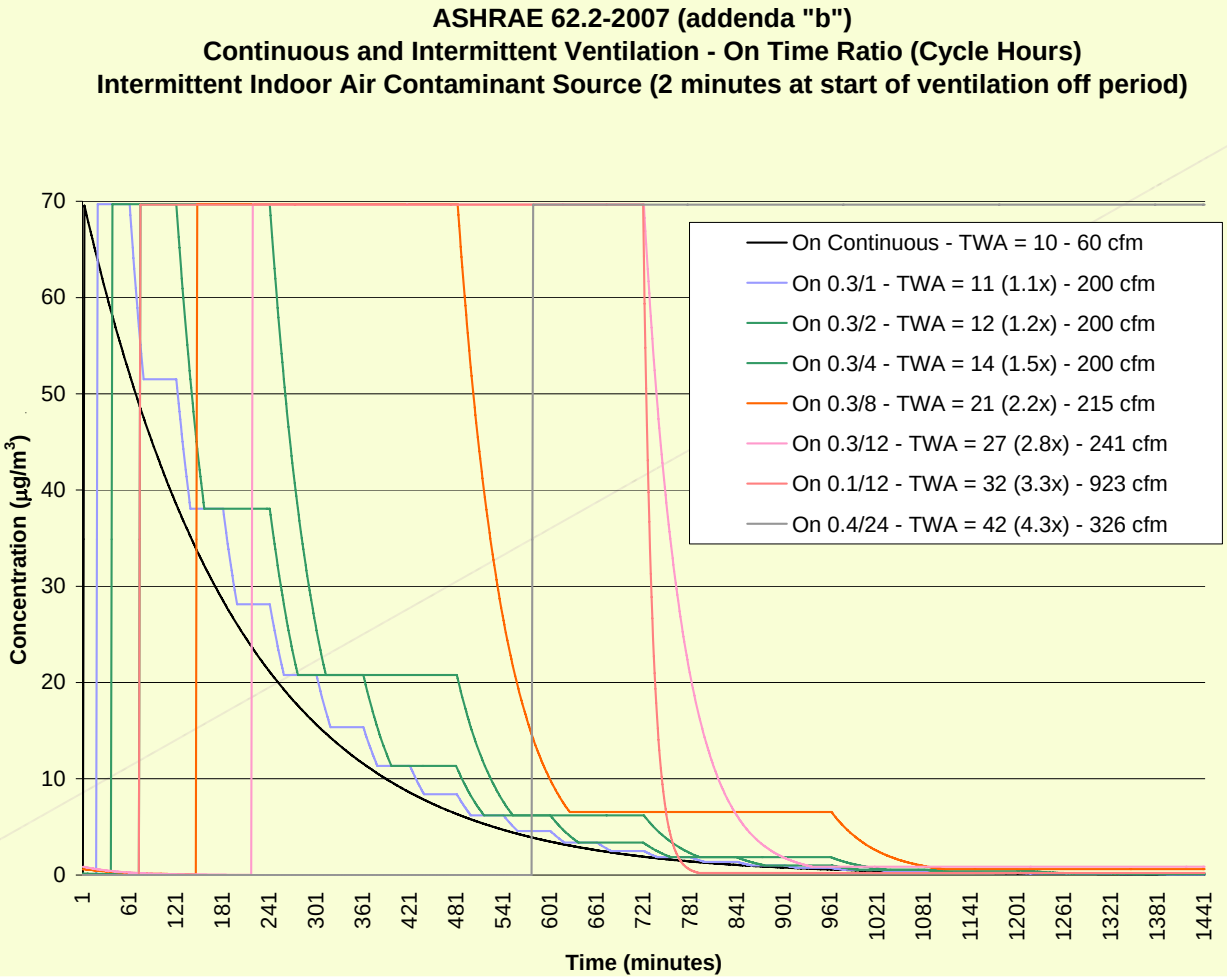

Conclusions

- We conclude that the new single-family detached homes in California are built relatively tight (i.e. 50% of the homes had an $ACH_{50} < 4.8$).

- Many homeowners never open their windows (e.g. 32% in the Winter).

Conclusions

- Homes where the windows/doors are not opened, have low outdoor air exchange rates (e.g. 0.1 - 0.2 ach), and indoor concentrations of air contaminants, such as formaldehyde, can be significantly elevated.

- 67% of the homes had outdoor air exchange rates below 0.35 ach (2001 CBC 1205 code requirement).

- 59% of the homes had indoor formaldehyde concentrations above 33 $\mu g/m^3$ (27 ppb), the California ARB indoor guideline.

Conclusions

- The HRV mechanical outdoor air systems performed well in increasing the home outdoor air exchange rates and reducing indoor formaldehyde concentrations.

- The DOA systems did NOT perform well as a result of a combination of the low outdoor air flow rates and low fan operation times.

Conclusions

- Intermittent mechanical outdoor air systems, such as the DOA systems in this study, can NOT provide IAQ that is equivalent to continuous systems.

- Especially for long cycle times, the ASHRAE 62.2-2007 ventilation effectiveness factors provide ventilation rates that are too LOW to provide equivalent long term average concentrations, which is important for cancer and cardiovascular diseases.

Conclusions

- In addition, intermittent ventilation systems, especially those with long cycle times, allow for air contaminants with indoor sources to increase substantially during the extended outdoor air ventilation off times.

- For some air contaminants, such as those that cause irritation and/or odor, the effects are initiated by the immediate exposure to the indoor concentration rather than the exposure to a concentration over a period of time.

Recommendations

• Consideration should be given to changing Title 24 and the California Building Code to require installation of mechanical outdoor air ventilation systems in new single-family residences to provide a dependable and continuous supply of outdoor air to the residence.

• Too this end, in 2009, Title 24 was revised to require mechanical outdoor air systems in new single family homes, using ASHRAE 62.2 minimum rates (e.g. typically 0.15 ach mechanical). Additional studies of indoor contaminant concentrations in homes with non-continuous mechanical outdoor air systems (i.e. fan cyclers) should be conducted.

Recommendations

- Consideration should be given to regulating the emissions of air contaminants from building materials. To this end, in April 2007, the California Air Resources Board (2007) adopted an airborne toxics control measure (ATCM) to reduce formaldehyde emissions from composite wood products.

- Emission rate reductions from other indoor sources of formaldehyde will also be needed to provide healthful indoor air quality.

Recommendations

- Conduct further studies in additional homes with mechanical outdoor air ventilation systems to confirm the findings identified in this study and with consideration for other building factors. Evaluate both installation and field performance of the mechanical outdoor air ventilation systems.

- Conduct a similar study in multi-family homes.

- Build it TIGHT but ventilate it RIGHT.

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