Compartmentalization Effects in Multifamily Buildings

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Background

- Dwelling unit compartmentalization aims to reduce inter-unit air and contaminant transport as well as envelope leakage for energy purposes
- Some codes/standards, including ASHRAE 62.2, have performance-based compartmentalization targets for multi-family dwellings

Key Questions

1. Is the current compartmentalization requirement in ASHRAE 62.2 adequate for controlling cross-contamination in multi-family buildings?
2. Are different ventilation system types more or less sensitive to compartmentalization?

Building Typology and Climate

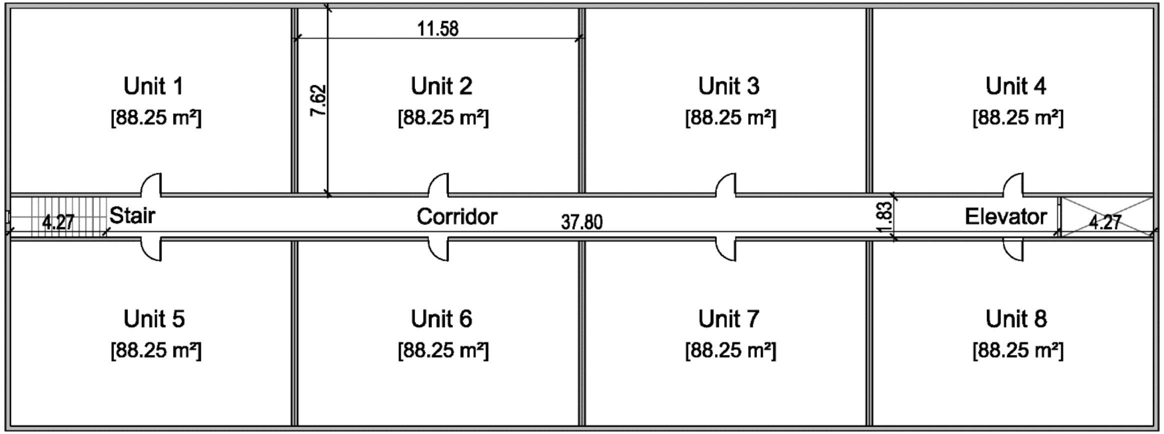
Building Types

- Low-rise: 4 stories
- High-rise: 20 stories

Climate Zones

- 2A Hot Humid
- 2B Hot Dry
- 3C Warm Marine
- 4A Mixed Humid
- 7 Very Cold

Each unit about 900 sq. ft.



Ventilation System Design

1. **Unit-Level Balanced Heat Recovery Ventilators**
2. **Unit Exhaust with Corridor Supply (Pressurized Corridor)**
3. **Unit Supply**
4. **Unit Exhaust with Trickle Vents**
5. **No Ventilation**

Air Flows meet ASHRAE 62.2 minimum requirements

Corridors

- Ventilated to meet ASHRAE 62.1

Local Exhaust Fans

- Sized to meet ASHRAE 62.2
- Kitchen, bath, laundry exhaust fans operated on fixed schedules

Time		Activities	Kitchen Fan L/s (cfm)	Bathroom Fan L/s (cfm)	Laundry Fan L/s (cfm)
Start	End				
7:00	7:30	Showering	0	25 (53)	0
7:30	8:00	Cooking and Showering	50 (106)	25 (53)	0
11:45	12:15	Cooking	50 (106)	0	0
18:00	18:30	Cooking	50 (106)	0	0

Dwelling Unit Air Leakage

Areas are all 6 sides
Blower Door pressurization to 50 Pa
“Unguarded”

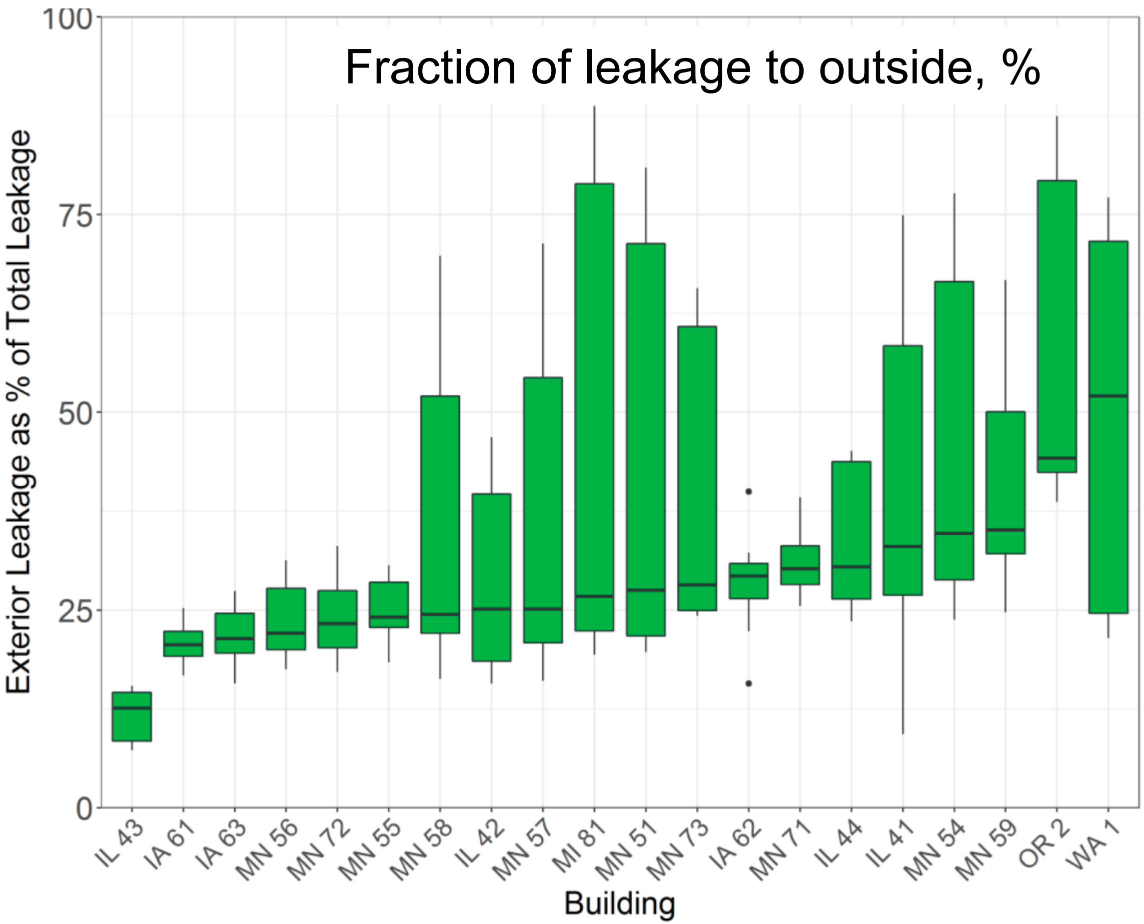
Leakage Class	Leakage ($L/s/m^2$ at 50Pa)	Leakage (cfm_{50}/ft^2)
Typical	5.1	1.0
Current Practice	1.5	0.30
Moderate	1.0	0.20
Tight	0.50	0.10
Super Tight	0.25	0.05

ASHRAE 62.2 - 2019 *optional* Compartmentalization Requirement and EPA ENERGY STAR (→ Current Practice)

ASHRAE 62.2 - 2022 Compartmentalization Requirement (→ Moderate)

Leakage Distributions: Indoors and outdoors

Highly variable between buildings and between units (in some buildings and not in others)….

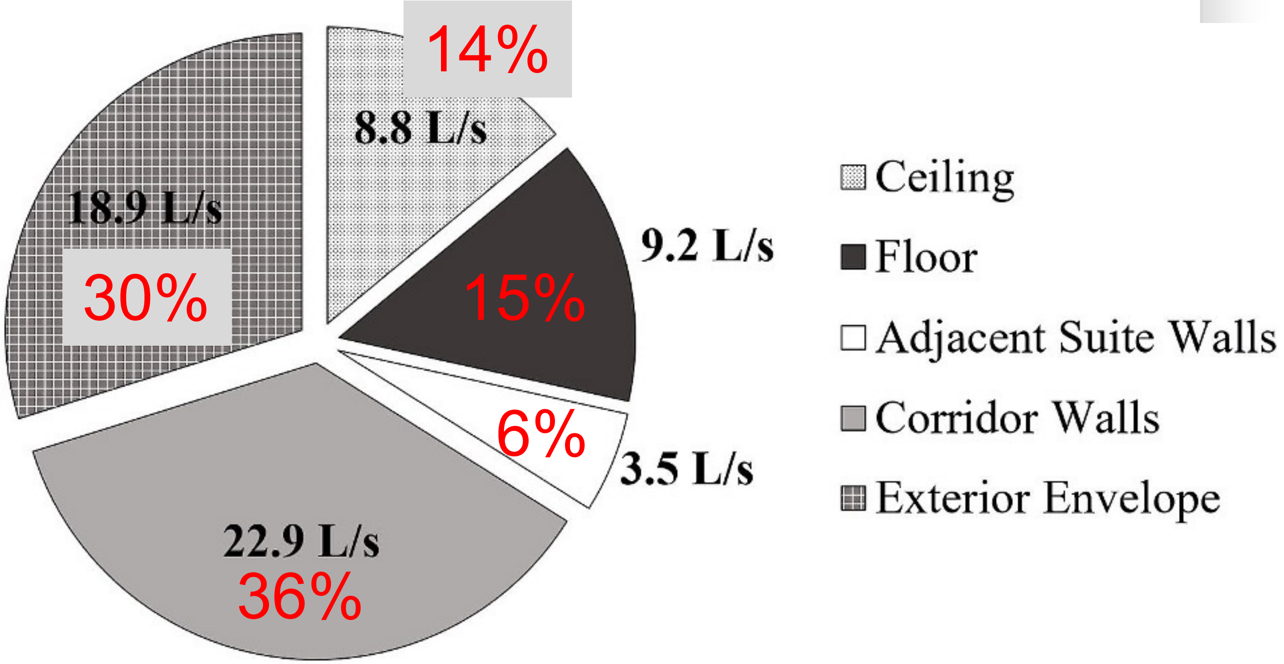


Bohac 2020

Leakage Distribution – all 6 sides

Most leaks to outside or corridor

Not much leakage to adjacent suites on the same floor

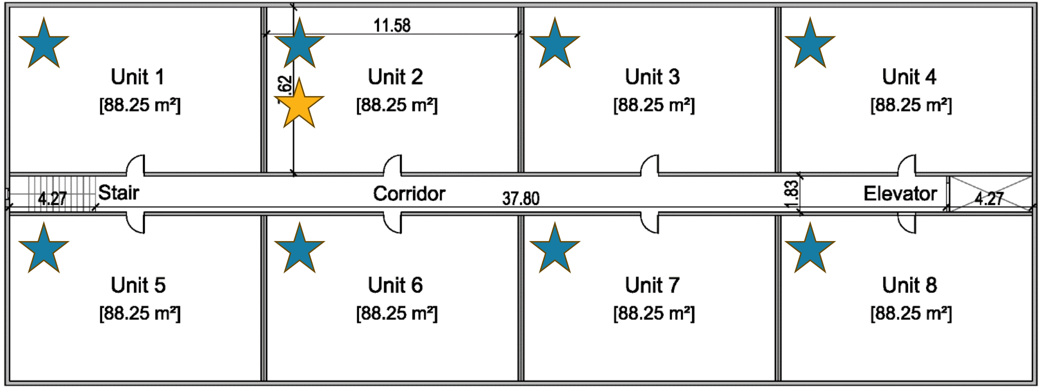


Cfm ~ L/s X 2

Lozinsky & Touchie 2021

Indoor Contaminants

- Carbon Dioxide from NIST
- Formaldehyde
- $PM_{2.5}$
- Moisture
- Emission rates from field studies
- Contaminant Types
  - Global contaminants (ALL dwelling units)
  - Shadow contaminants (Unit 2 on Levels 1, 11, 20)



Results

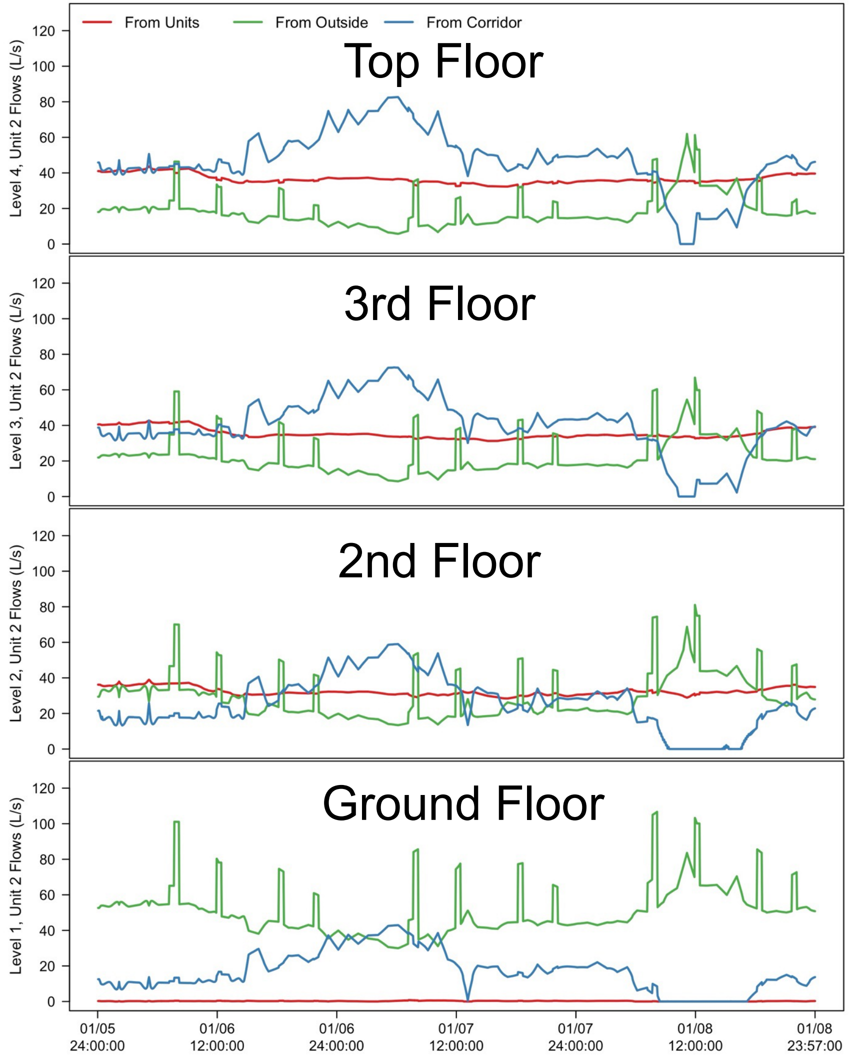
Example Air Flows for a Leaky Building

Unit Exhaust, Corridor Supply ventilation
Three days in January in CZ 7

At this “typical” poor leakage level – flows not controlled by mechanical ventilation system

Significant flow from other units(except ground floor)

Flow from outside depends on weather – less on mechanical ventilation system



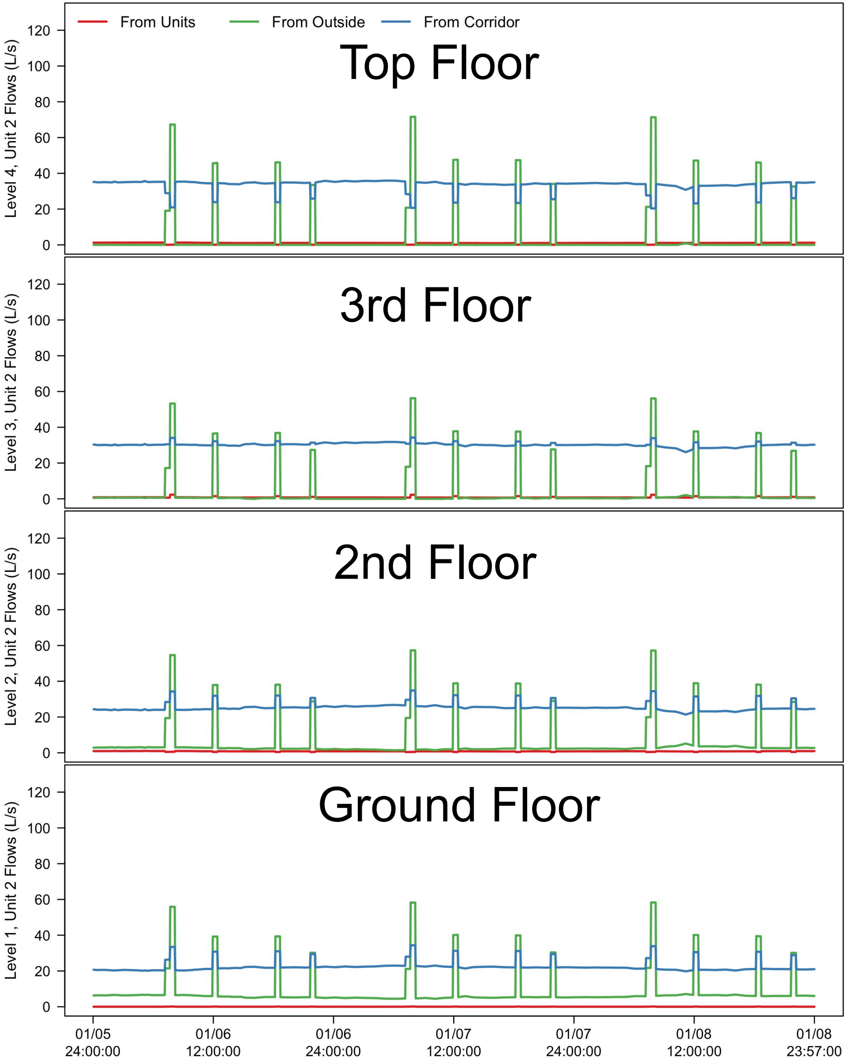
Example Air Flows for a Tight Building

Unit Exhaust, Corridor Supply ventilation
Three days in January in CZ 7

At this “tight” leakage level – flows are controlled by mechanical ventilation system

No flow from other units

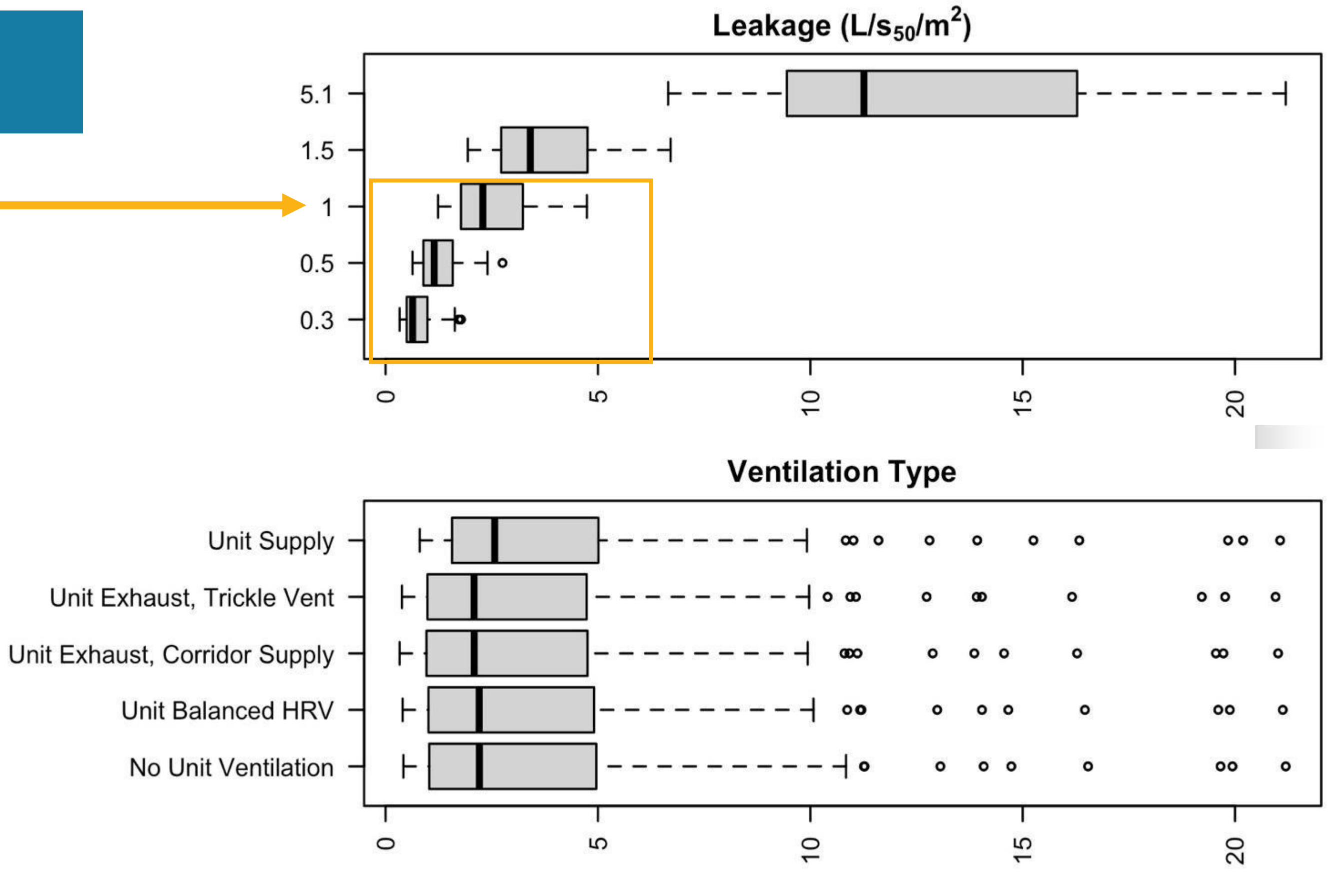
No weather dependence



Inter-Unit Air Flow Summary

1. Diminishing returns for air leakage rates below current ASHRAE 62.2 compartmentalization requirement

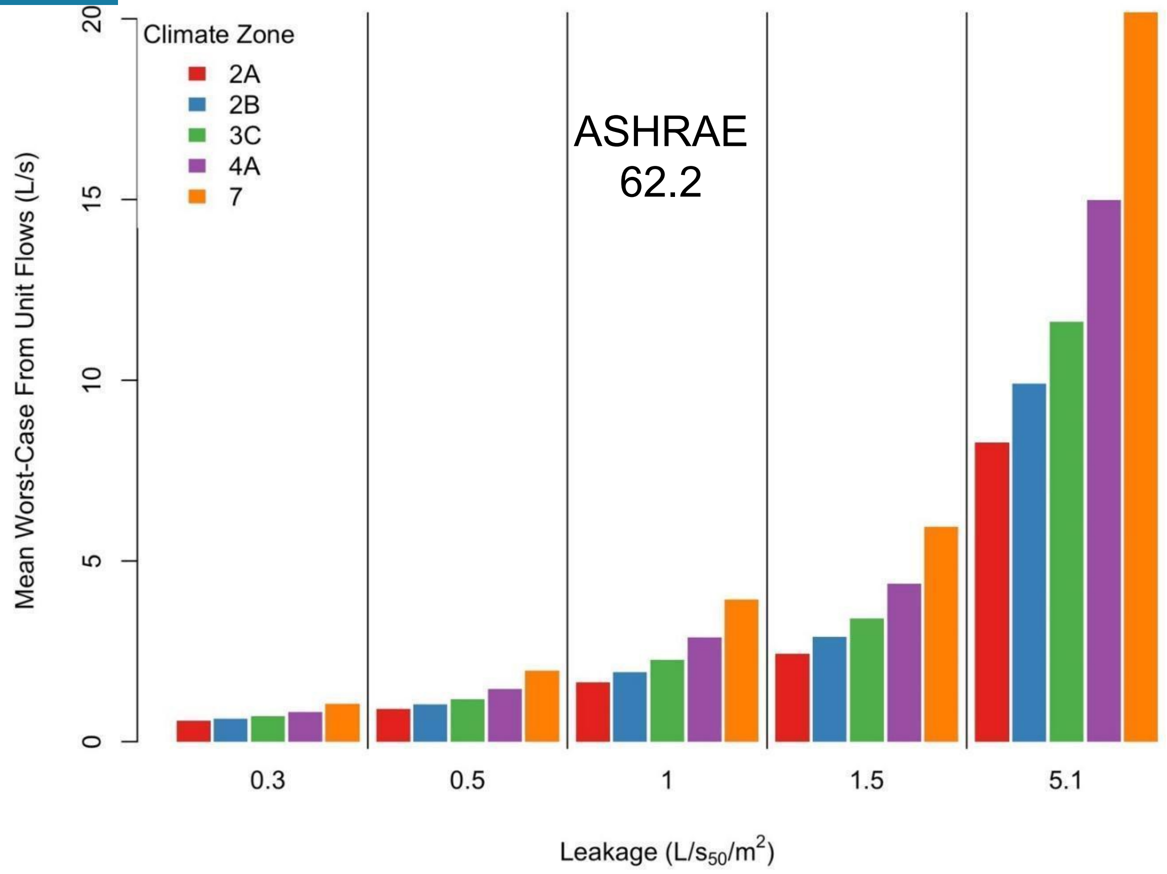
2. No significant difference between ventilation system types



Worst case: Building-Level **Maximum** "From Unit" Air Flows (L/s)

Inter-unit air flow: Climate

Tight buildings have very small climate effects



Contaminant Transport (shadow contaminants)

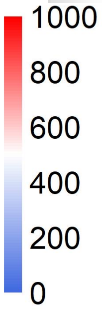
Annual Average Zone CO_2 Concentration (ppm) from Source Unit

Very little transport for tight construction for CO2, formaldehyde and even less for PM

Highest Non-Source Unit <10%

Most units – no measurable difference

	Apt 1	Apt 2	Apt 3	Apt 4	Elv	Cor	Str	Apt 5	Apt 6	Apt 7	Apt 8
Level 20	0.3	0.3	0.3	0.3	0.7	0.4	0.7	0.3	0.3	0.3	0.3
Level 19	0.3	0.3	0.3	0.3	0.7	0.3	0.7	0.3	0.3	0.3	0.3
Level 18	0.3	0.3	0.3	0.3	0.7	0.3	0.7	0.3	0.3	0.3	0.3
Level 17	0.3	0.3	0.3	0.3	0.7	0.3	0.7	0.3	0.3	0.3	0.3
Level 16	0.3	0.2	0.2	0.3	0.7	0.3	0.7	0.3	0.3	0.3	0.3
Level 15	0.2	0.2	0.2	0.2	0.7	0.3	0.7	0.3	0.3	0.3	0.3
Level 14	0.2	0.2	0.2	0.2	0.7	0.3	0.7	0.2	0.2	0.2	0.2
Level 13	0.2	0.2	0.2	0.2	0.7	0.2	0.7	0.2	0.2	0.2	0.2
Level 12	0.1	0.1	0.1	0.1	0.7	0.2	0.7	0.1	0.2	0.2	0.2
Level 11	0.1	0.1	0.1	0.1	0.7	0.1	0.7	0.1	0.1	0.1	0.1
Level 10	0	0	0	0	0.7	0	0.7	0	0	0	0
Level 9	0	0	0	0	0.7	0	0.7	0	0	0	0
Level 8	0	0	0	0	0.8	0	0.8	0	0	0	0
Level 7	0	0	0	0	0.9	0	0.9	0	0	0	0
Level 6	0	0	0	0	0.9	0	0.9	0	0	0	0
Level 5	0	0.1	0	0	1.1	0	1.1	0	0	0	0
Level 4	0	0.7	0	0	1.3	0	1.3	0	0	0	0
Level 3	0	5.5	0	0	1.7	0	1.7	0	0	0	0
Level 2	0.2	46.9	0	0	2.4	0.4	2.4	0.2	0.2	0.2	0.1
Level 1	1.7	618.6	0	0.3	4.3	4.3	4.3	0.9	1.1	1.1	0.8



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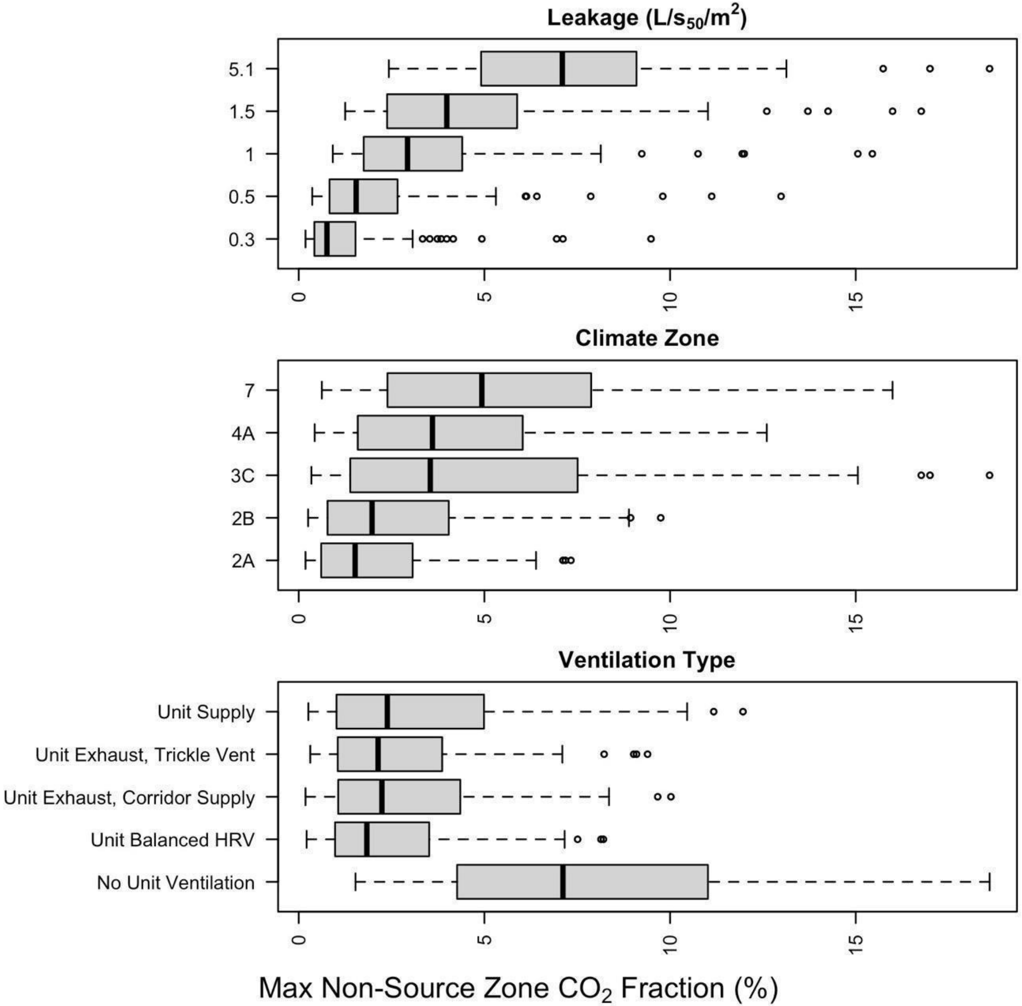
ASHRAE Tightness ($1.0 L/s/m^2$ ($0.2 cfm_{50}/ft^2$))

Highest fraction of CO_2 from other units (%)



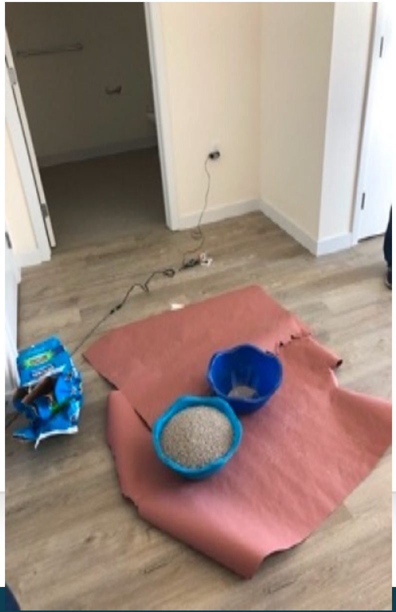
Tight construction = very low transfer

Colder climates = more transfer

Doesn't matter HOW you ventilate, so long as you ventilate!

UCDavis Field Study

- Field Measurements in California buildings – leakage about 0.15 cfm50/ft^2 (0.75 L/s/m^2)
- No measurable PM transfer
- Very little CO_2 transfer unless kitchen exhaust operating [1-3% of CO2 from source unit]



(Modera et al. 2023)

Conclusions

1. **Is the current compartmentalization requirement in ASHRAE 62.2 adequate for controlling cross-contamination in multi-family buildings? YES**
    - **Maximum** From-Unit Flows typically 1-2 cfm (did not exceed 10 cfm) for current 62.2 compartmentalization target – **typical** flows even smaller
    - No measurable PM transfer
    - Increasing compartmentalization provided diminishing returns
    - Limiting wind and stack flows allows mechanical ventilation to operate as designed

2. **Are different ventilation system types more or less sensitive to compartmentalization?**
    - No significant differences between ventilation systems for reasonable (EPA EnergyStar or ASHRAE 62.2) tightness

“Build Tight, Ventilate Right”

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Contaminants – CO_2 & $PM_{2.5}$

CO_2

From NIST (8 hours sleeping 16 hours awake)

- Adult: 10 mg/sec (awake); 6.5 mg/sec (asleep)
- Child: 6.5 mg/sec (awake); 4 mg/sec (asleep)

$PM_{2.5}$

Cooking source measured in homes (Chan et al. 2020)

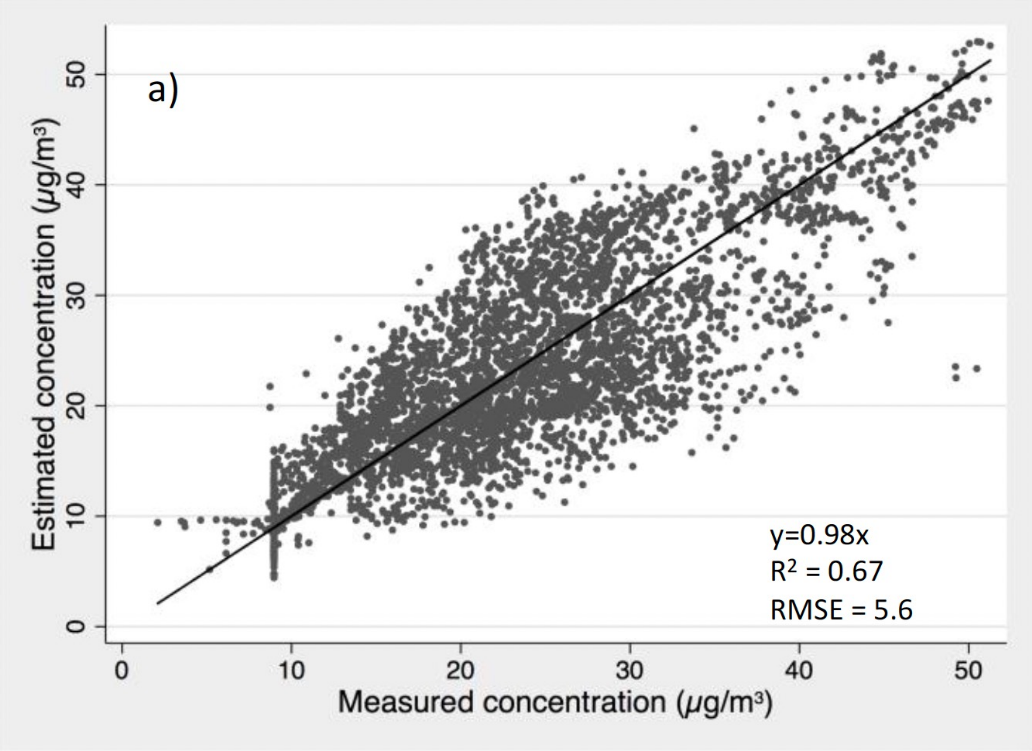
- PM2.5 cooking: 0.0208 mg/sec (assumes a 50% CE range hood), otherwise 0.0416 mg/sec)
- PM2.5 other sources: 0.00007 mg/sec.

Outdoors from EPA – tracked as a separate contaminant

Included removal mechanisms for interunit transport and through exterior walls based on measured data in homes (an insulated wall is about MERV 11/13 – Singer et al. 2016)

Contaminants: Formaldehyde

- From measured formaldehyde in 70 test homes (Zhao et al. 2022).
- Complex function of temperature, humidity and ventilation rate



Does construction type matter?... Not consistently

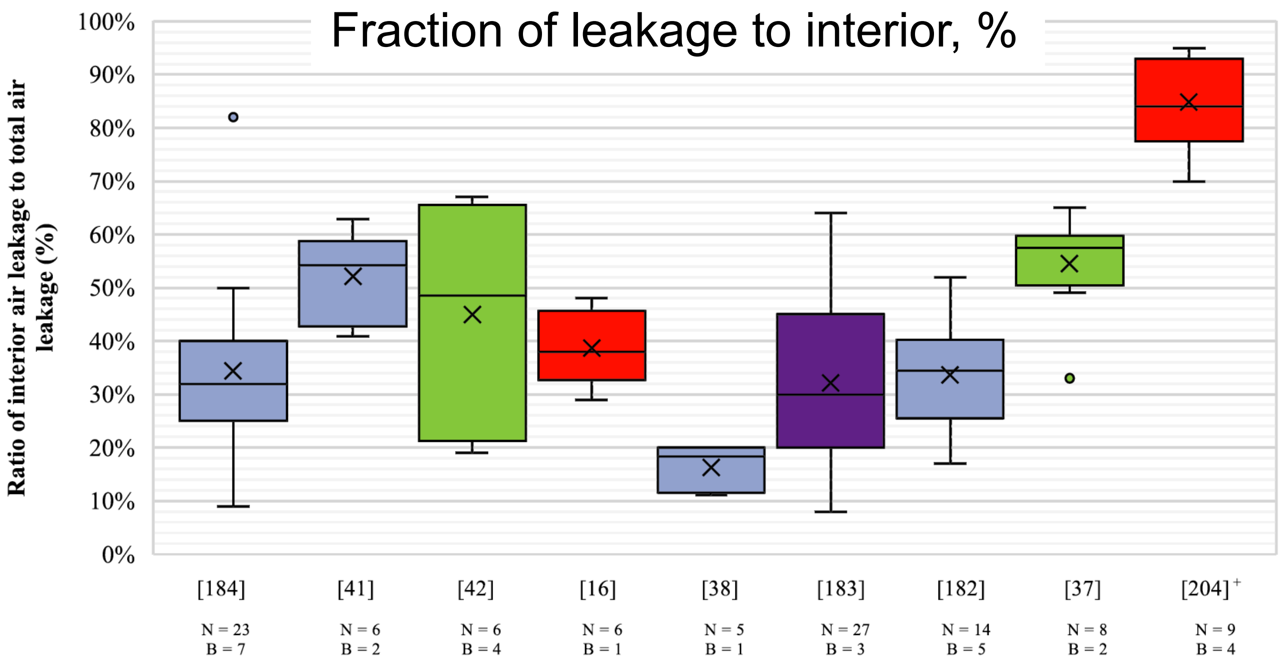


FIGURE 3 Contribution of interior air leakage paths to total suite air leakage from previous studies

Lozinsky and Touchie 2020

Indoor Contaminant Example
PM from cooking

Tightening increases in-unit concentration but decreases PM from other units