Major Sources of Personal Exposure to Airborne Particulate Matter

Seminar at EPA Region IX

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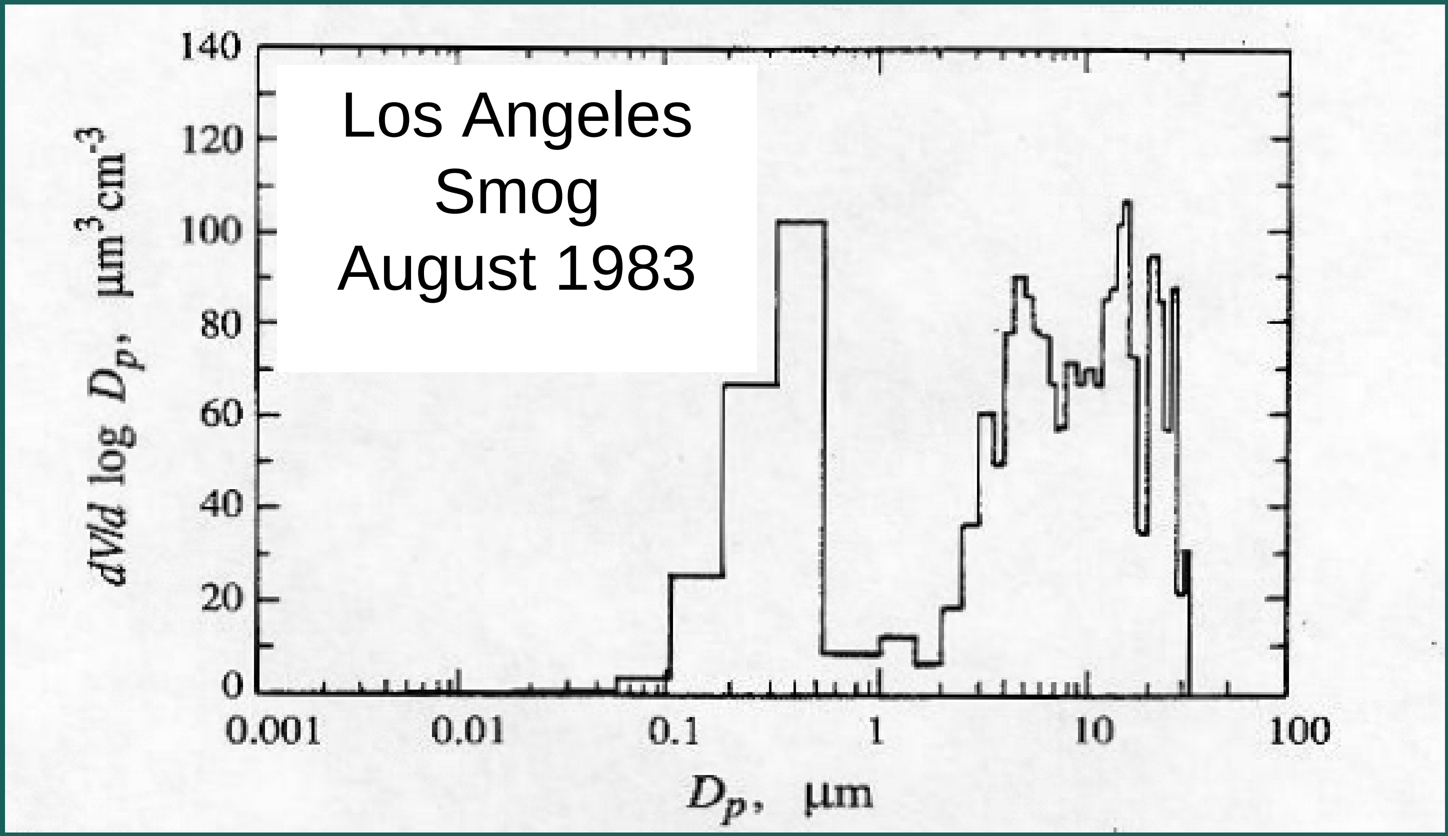
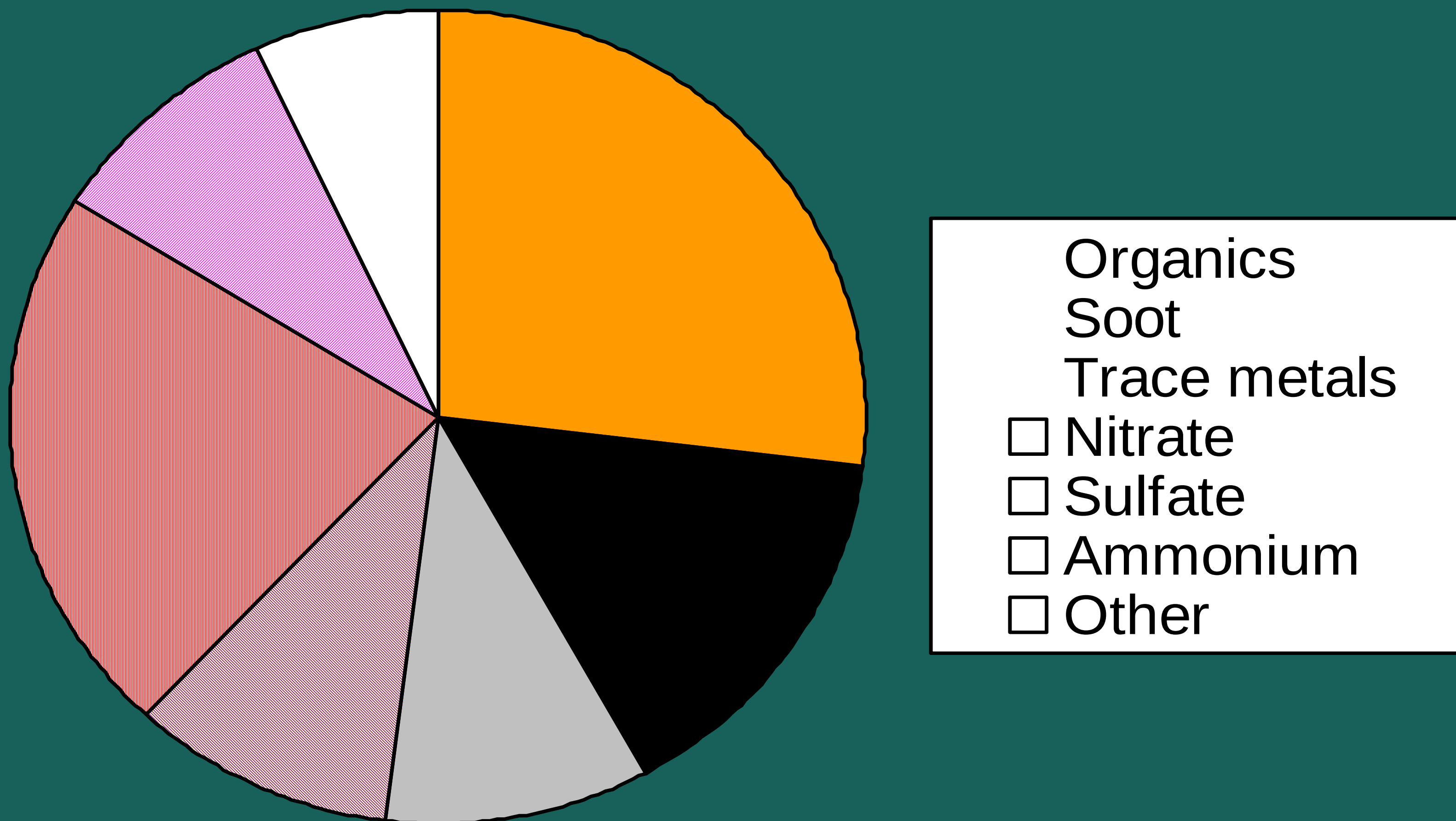
Airborne Particulate Matter (PM) Exists in a Wide Range of Particle Sizes . . .

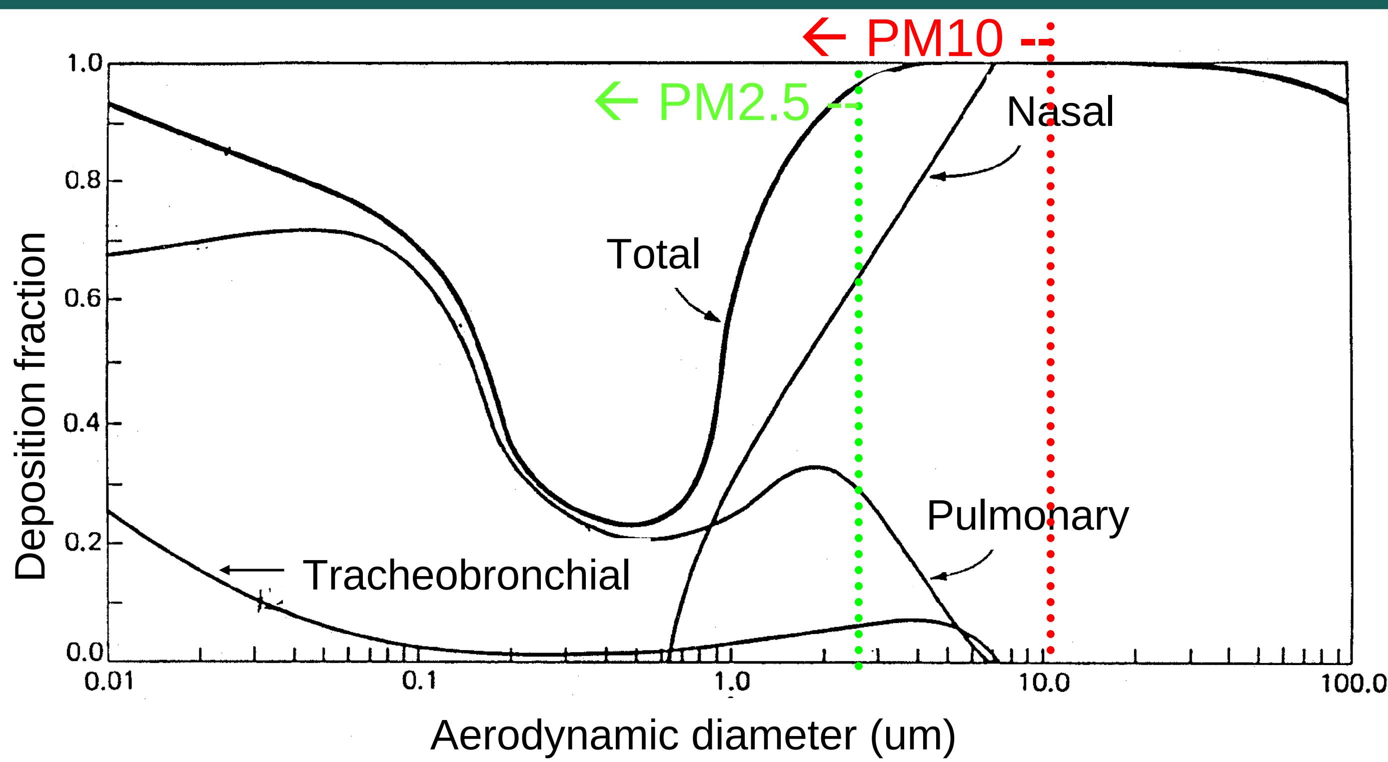


. . . and the PM Has a Complex Chemical Composition

EXAMPLE: Los Angeles Fine PM



PM Deposition in Respiratory Tract Varies with Particle Size



From Seinfeld, John H. *Air Pollution. Physical and Chemical Fundamentals*, McGraw-Hill, NY, 1975

How Does Airborne PM Cause Health Impacts ?

→ Three Popular Hypotheses:

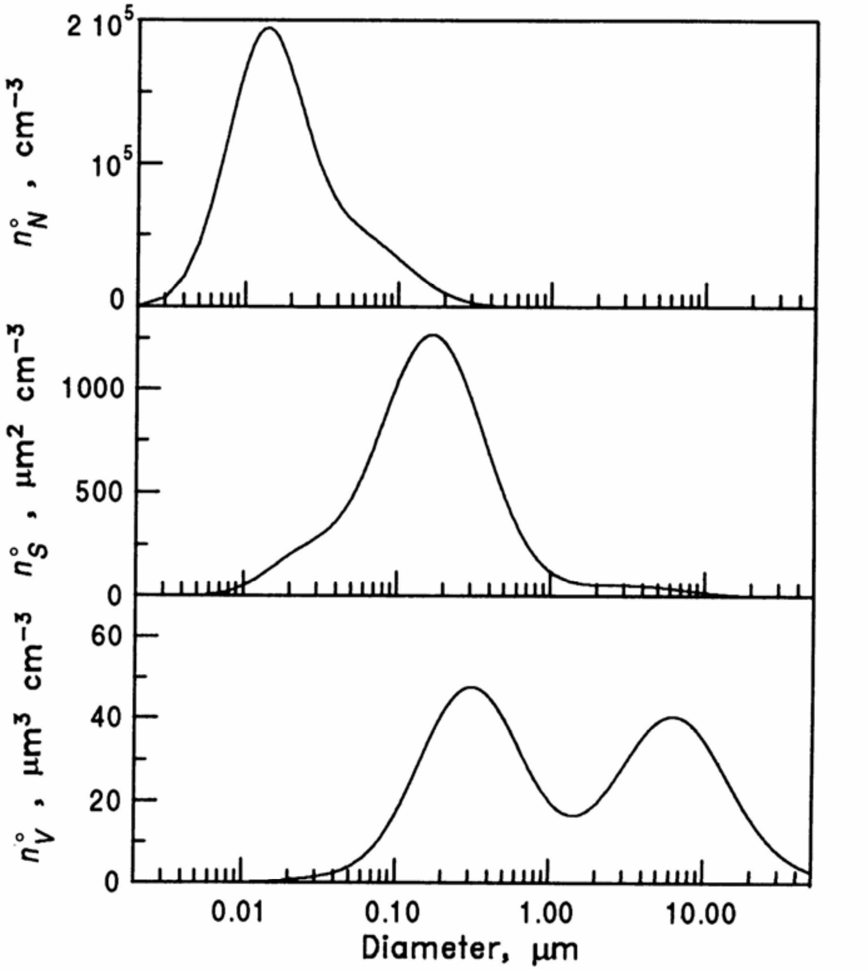


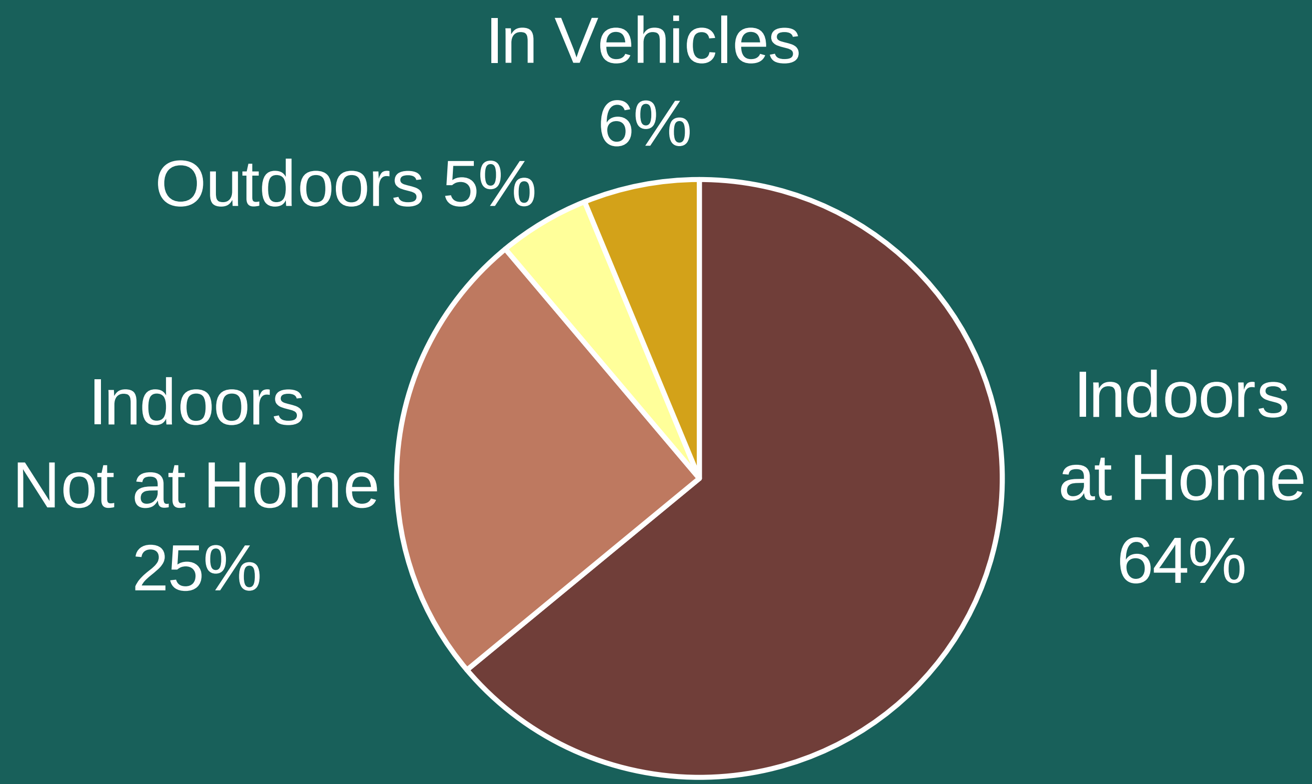
FIGURE 7.12 Typical urban aerosol number, surface, and volume distributions.

(from Seinfeld & Pandis, "Atmospheric Chemistry and Physics," Wiley-Interscience, 1997)

1. Each particle depositing in lungs represents an "insult", so focus on PM < 0.05 µm
2. Chemical coatings on particle surfaces are important, so focus on submicron PM (0.01-1 µm) and consider chemical composition.
3. Impact depends on mass of deposited particles, so continue focusing on PM10 and/or PM2.5

Percentage of Time Spent Indoors, Outdoors and in Vehicles in the United States

(Robinson et al., 1991)

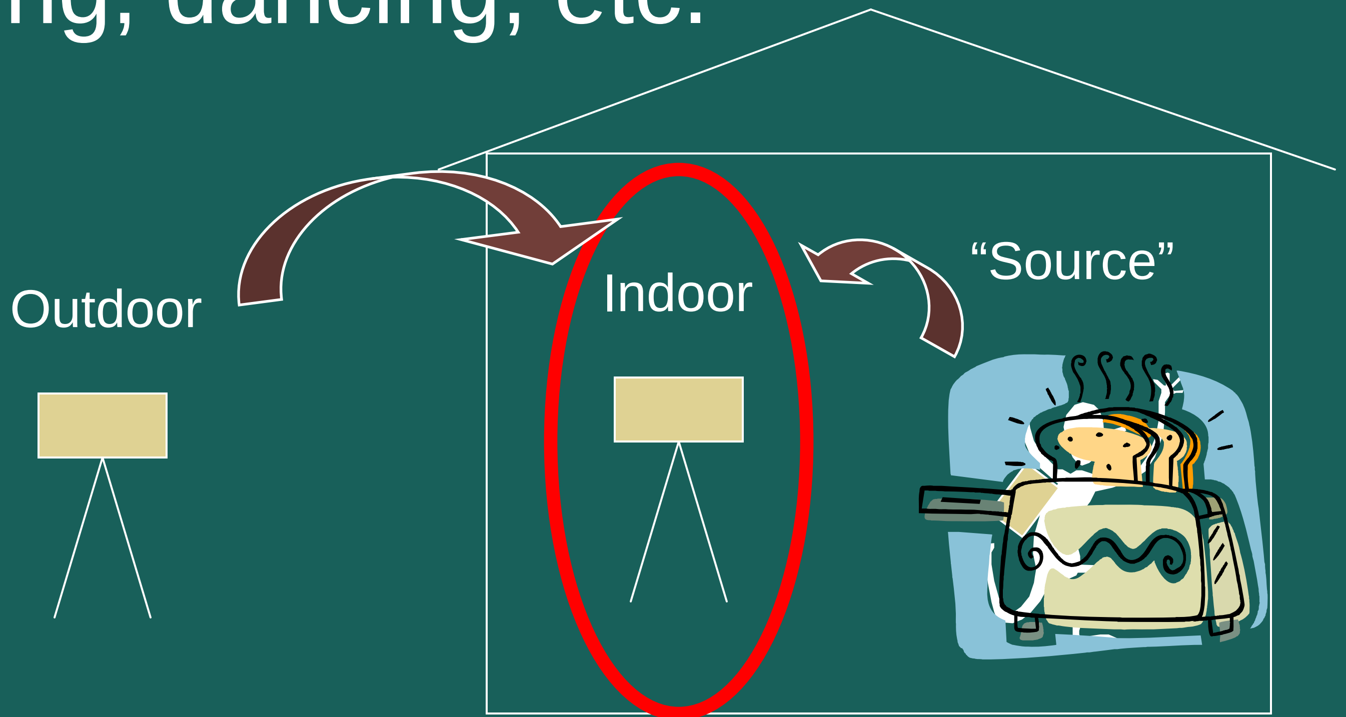


Where Does Near-Roadway PM Come From?

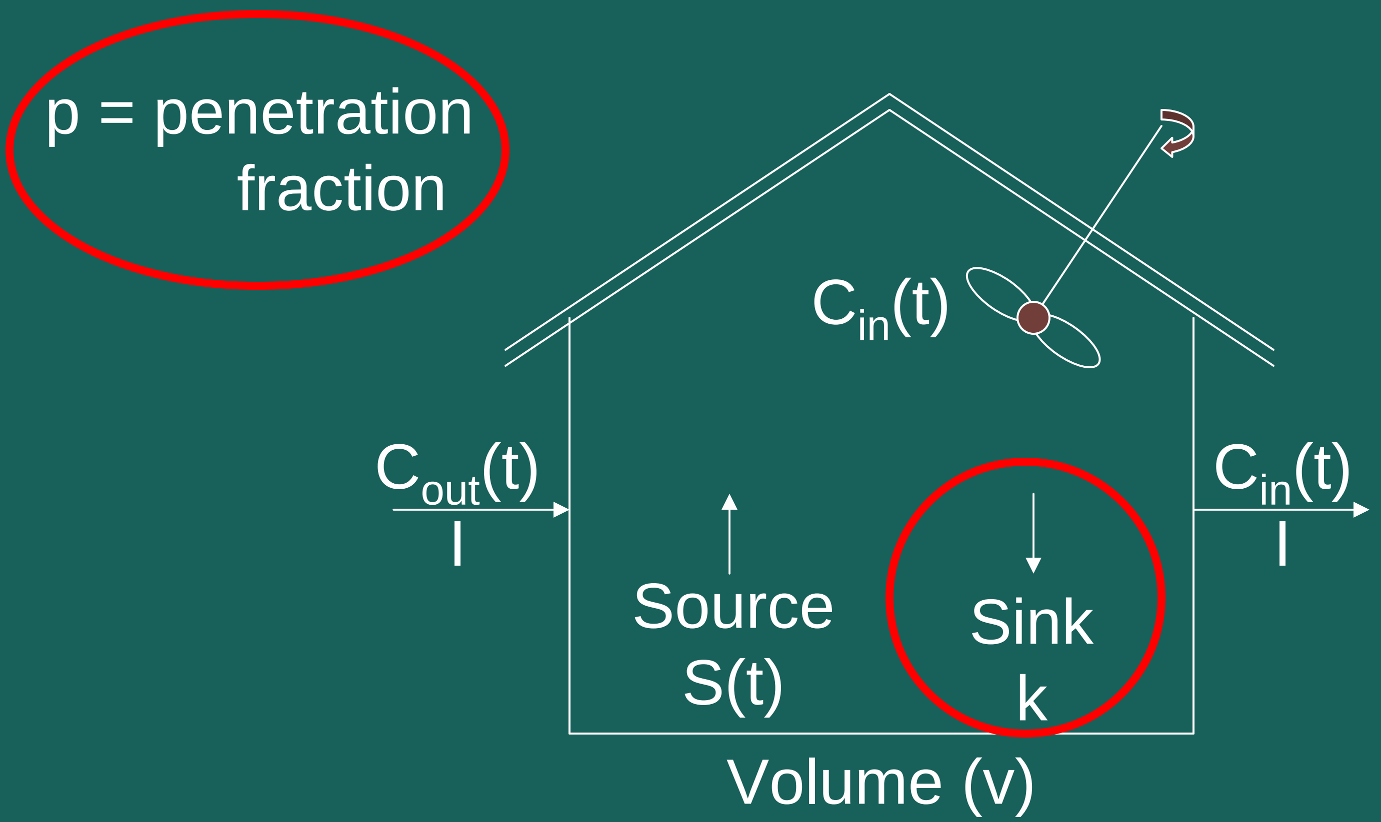
- Consists of ambient outdoor PM, <u>plus</u>
  - Tailpipe emissions
  - Brake wear and tire wear
  - Resuspended road dust

Where Does Indoor PM Come From?

Some infiltrates from outdoors, but can also have indoor “sources” like cooking, cleaning, dancing, etc.



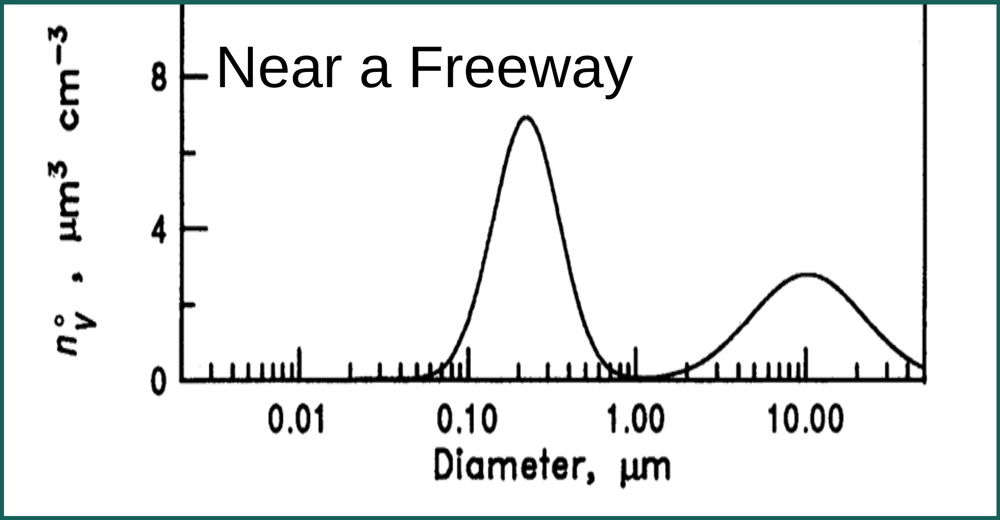
Contribution of Outdoor Air vs Indoor Sources to Indoor PM



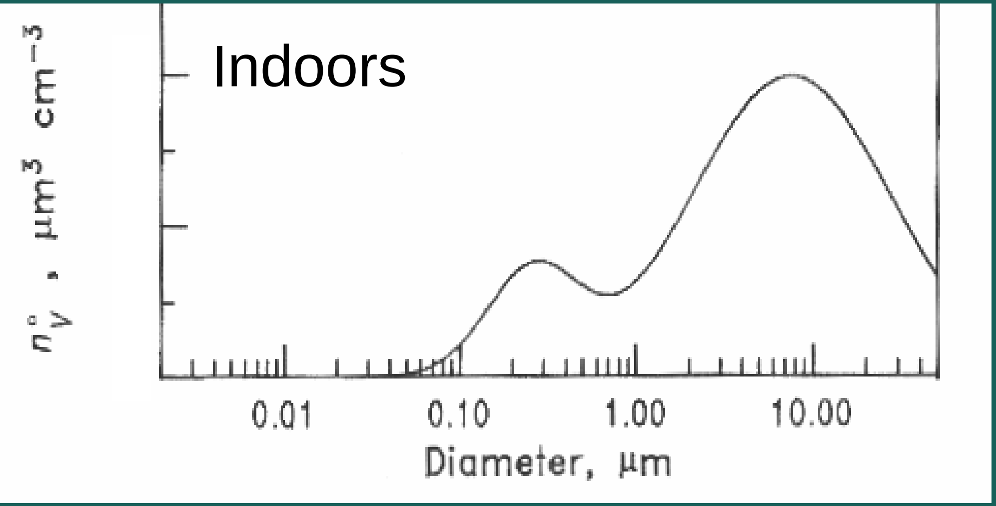
$$C_{in}(t)= C_{out}(t)[pI/(I+k)] + S(t)/[(I+k)v]$$

How Do Sizes of PM Near Roadways and Indoors Differ from Urban Outdoor Levels?

<u>Near busy roadways</u>:
-- fine PM ↑↑ (from tailpipe emissions)
-- coarser PM ↑ (from road dust resuspension)



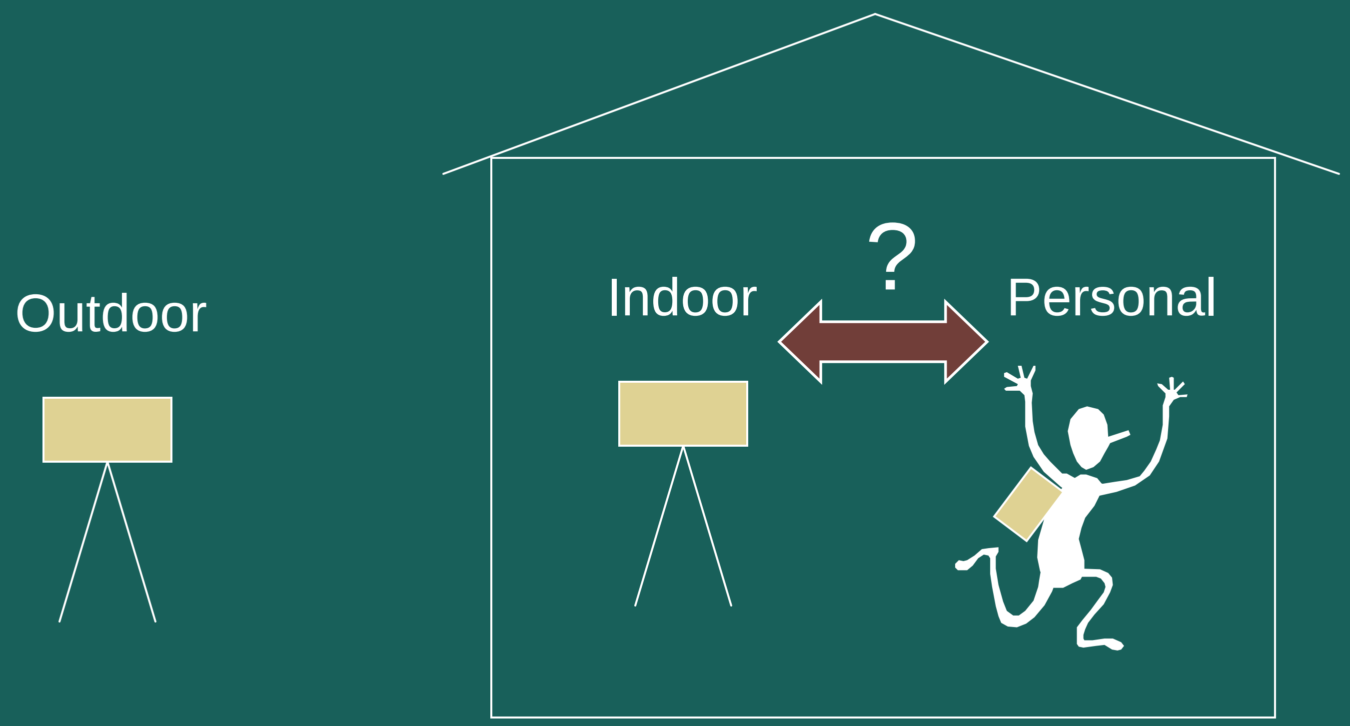
<u>Indoors</u>:
-- fine PM usually ↓;
-- coarser PM may go ↑ (shown) or ↓ depending on human activities



How Does PM Composition near Busy Roadways and Indoors Differ from Urban Outdoors?

- Near busy roadways, see elevated levels of:
  - -- soot and organics (from tailpipe emissions)
  - -- trace elements like Si, Al, and Fe (from paved road dust)
- Indoors, see a larger fraction of:
  - -- organics
  - -- soil tracers like Si and Fe
  - -- other trace metals like Al and Pb
  - -- pesticides and allergens

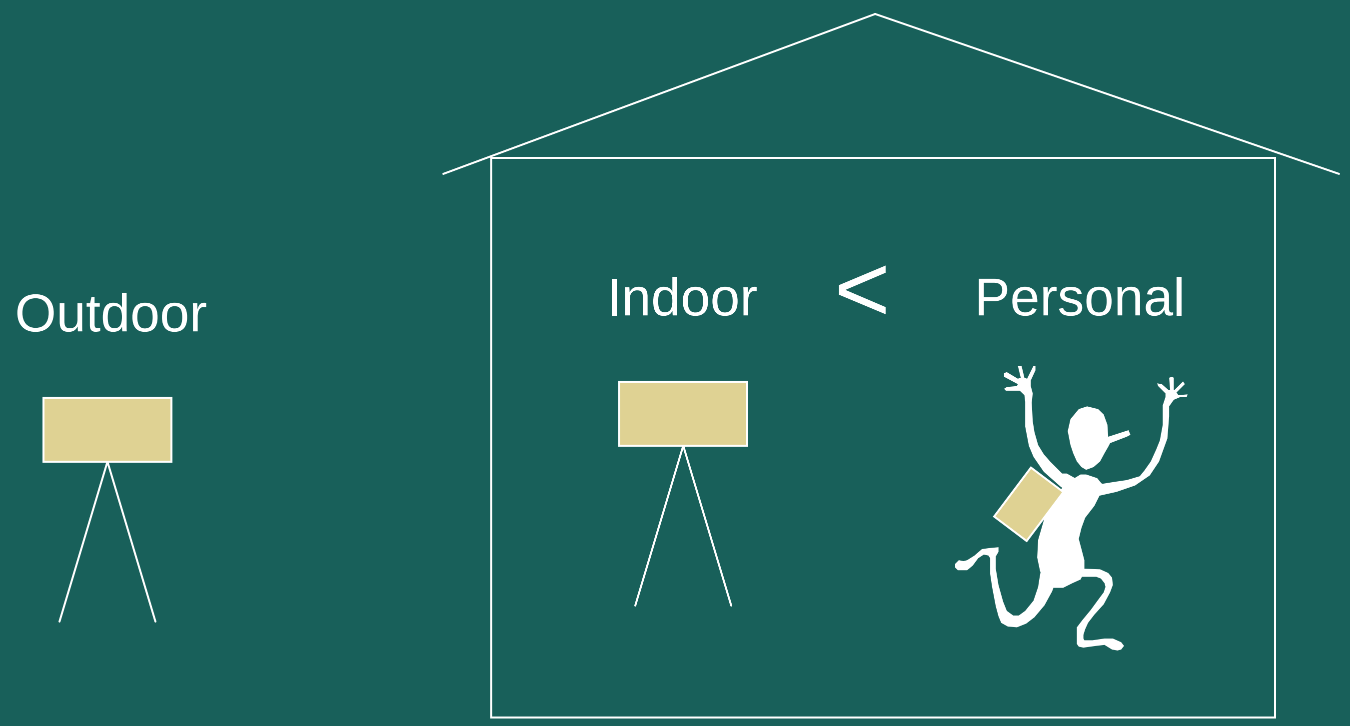
Do Indoor Monitors Accurately Measure Personal Exposure to PM?



The Personal Cloud

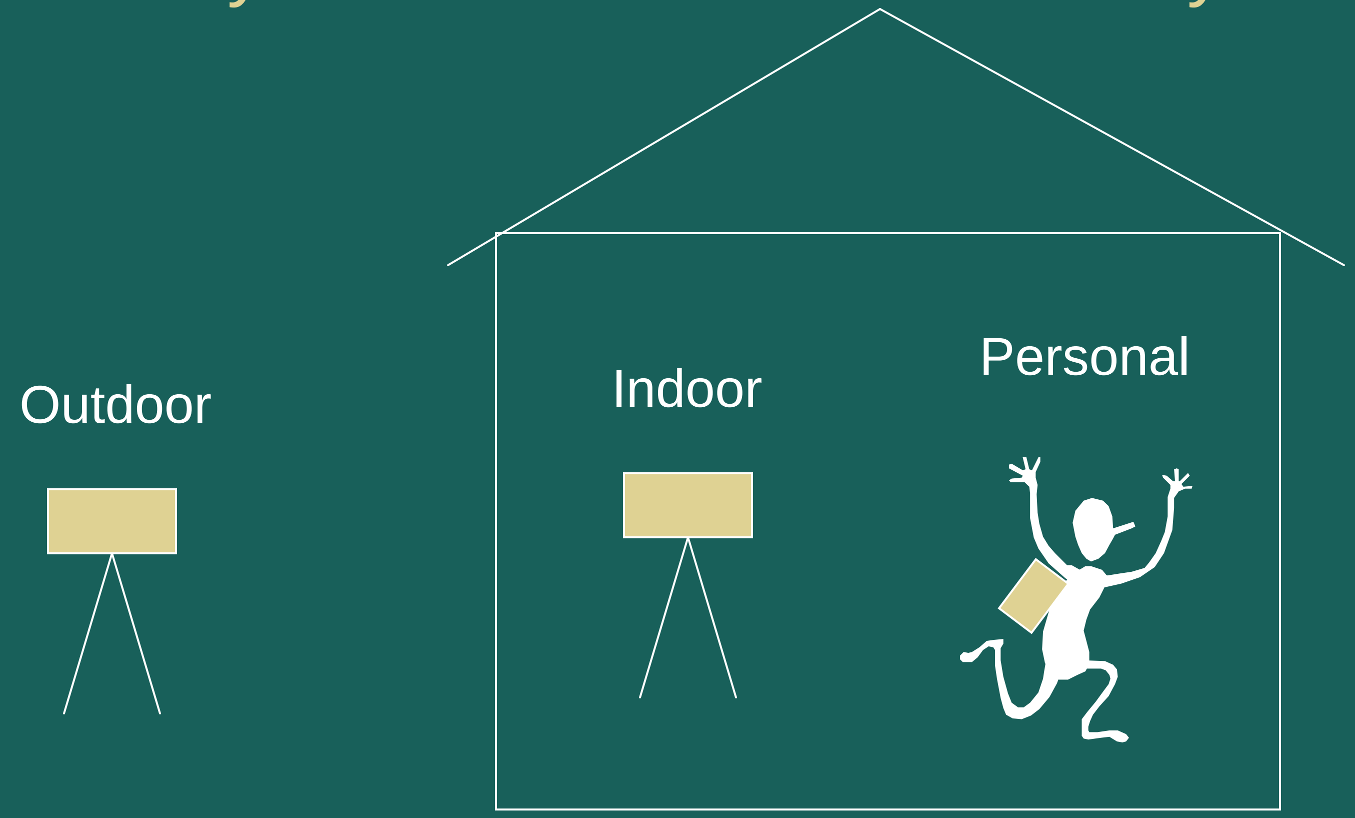
- Personal / Indoor concentration ratio > 1
- Median ratios for 5 studies ranged from 1.6 to 13.4

  (Rodes et al, 1991)



Re-suspension Study Set-up

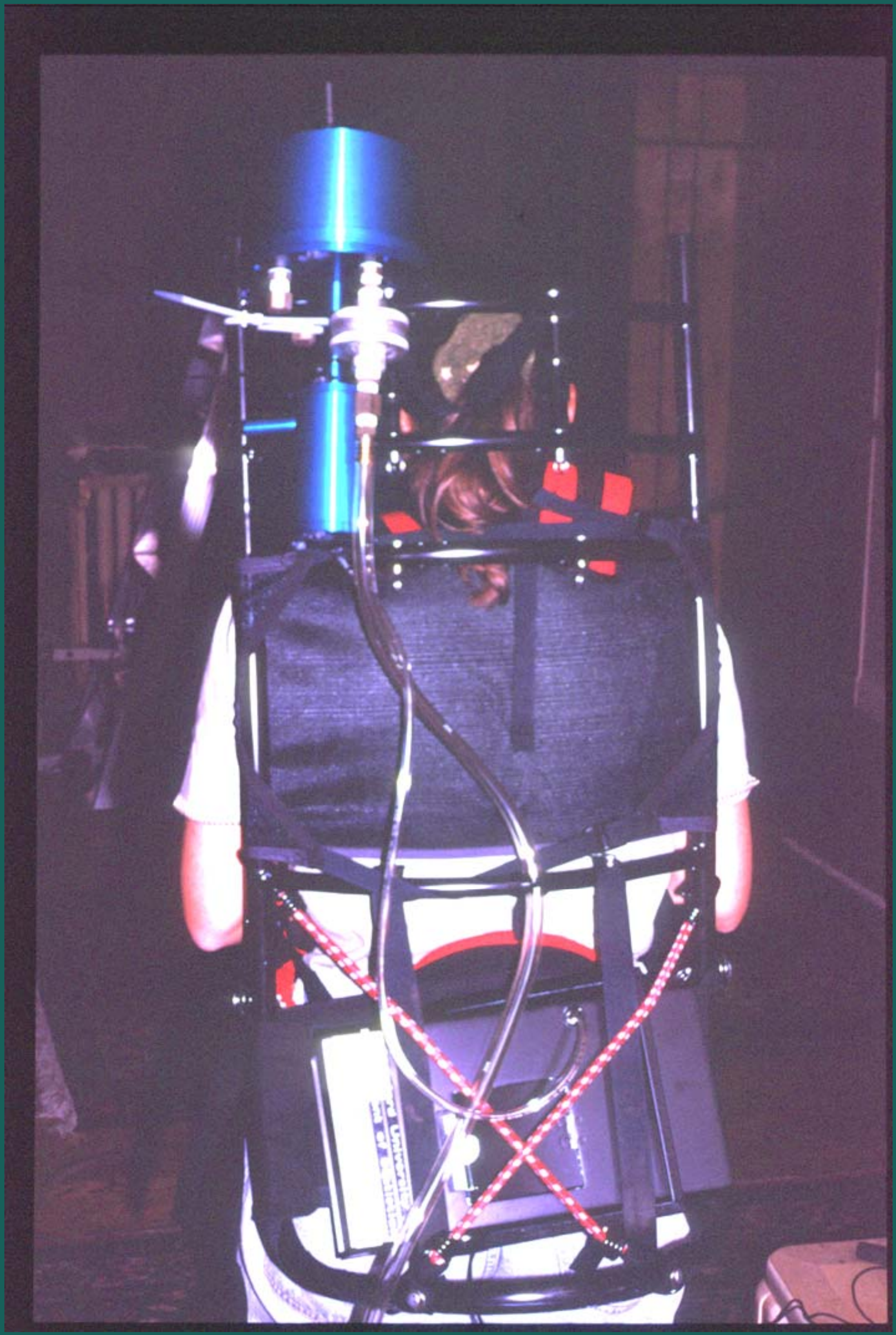
3 Days with Prescribed Human Activities
2 Days with Minimal Indoor Activity



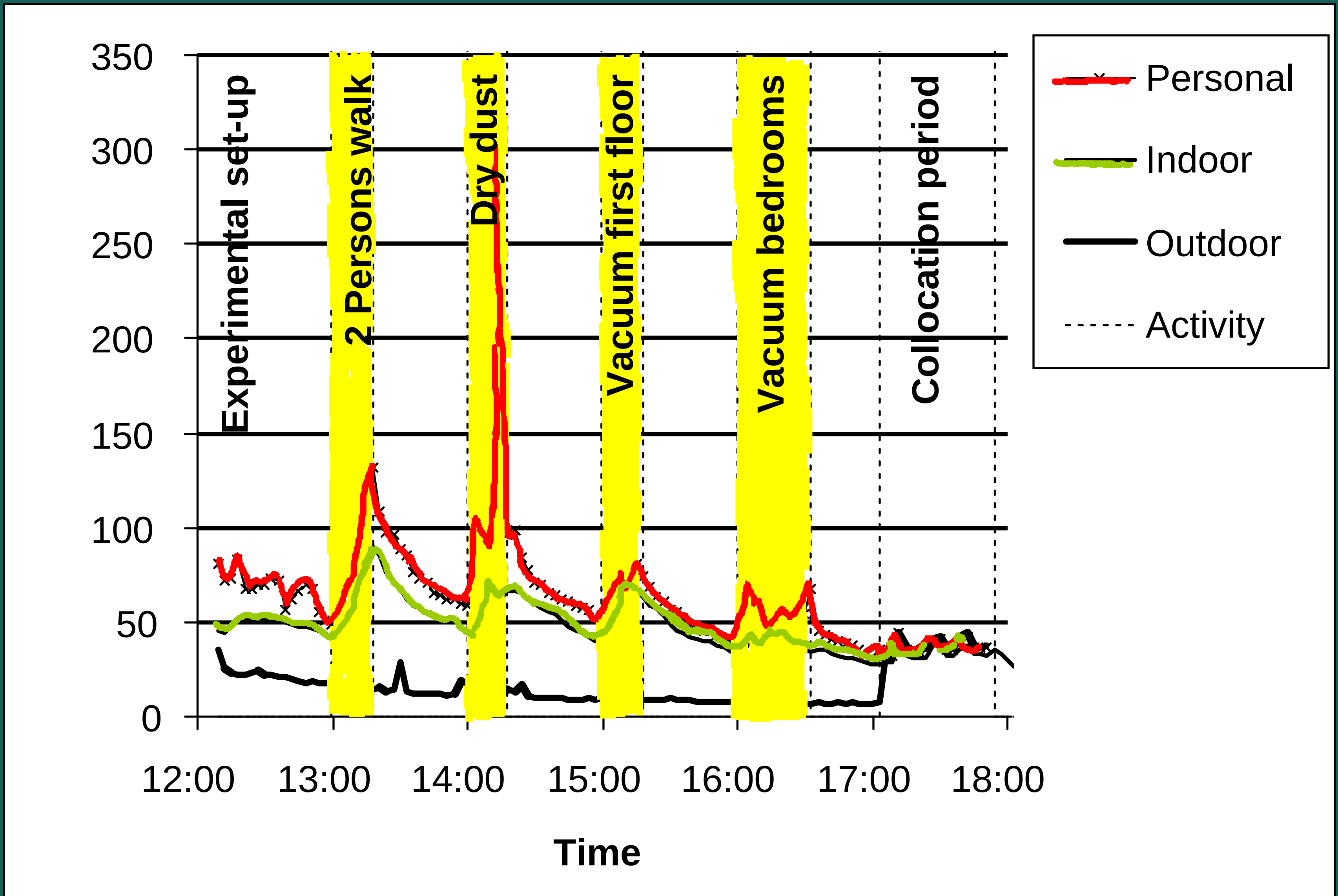
General Methodology

- Real-time instruments for temporal and size resolution of PM
- Filter samples for mass concentrations and trace elemental compositions
- Trace gas release (SF_6) to measure air exchange rate

Personal Exposure Monitor (PEM)

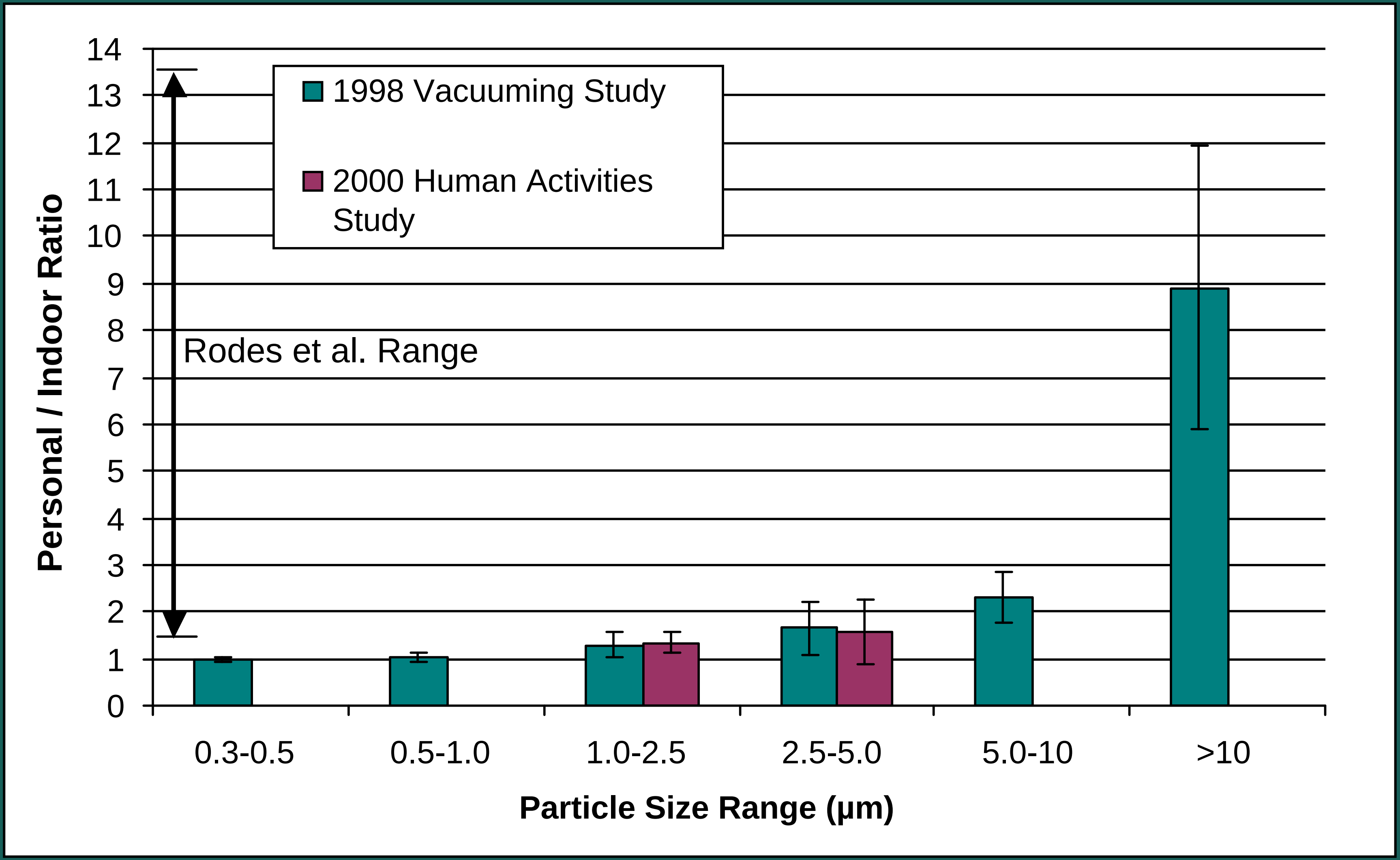


PM-5 Time Series



Re-suspension Effect by Particle Size

(Mean and St. Dev.)



Resuspension Effect Findings

- Resuspension of PM from human activity produces a measurable personal cloud
- For PM of 2.5-10 µm, personal/indoor concentration ratios during human activity are ~1.5-2.5
- Personal/indoor ratios from human activity increase with particle size

How Much Does Resuspension of House Dust Contribute to Indoor PM?

- Model contribution of re-suspended house dust to indoor PM using 2 completely independent models:

  -- infiltration model

  -- CMB model

First Modeling Approach: Indoor-Outdoor (I-O) Model*

The indoor PM concentration due just to infiltration of outdoor air is:

$$C_{in(i)} = C_{in(i-1)}\, e^{-[k+I]\delta} + C_{out(i-1)}(pI/k+I)(1- e^{-[k+I]\delta})$$

where $i = 1,2,\ldots,n$

I = infiltration rate [h^{-1}]

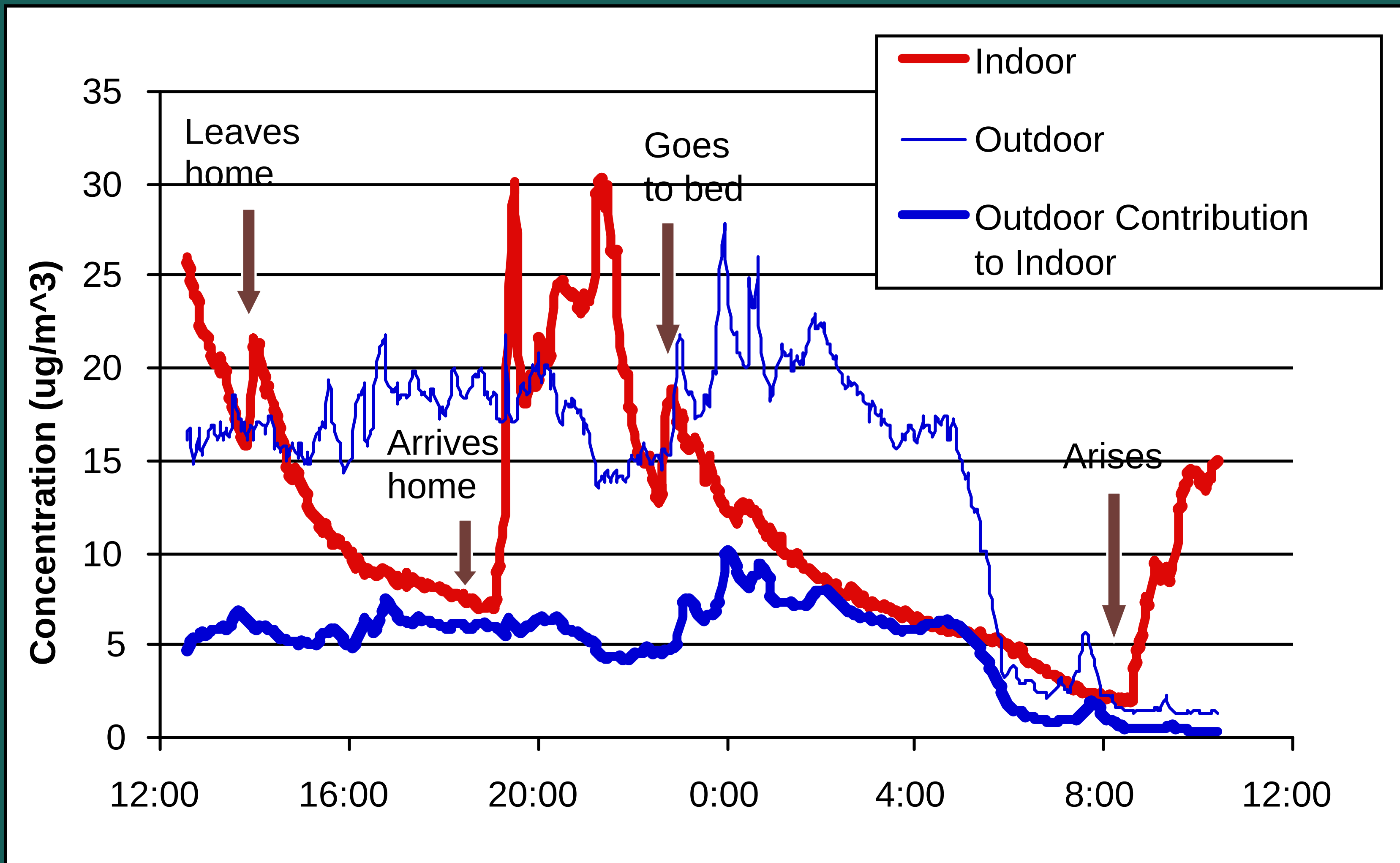
k = removal rate [h^{-1}]

p = penetration fraction [-]

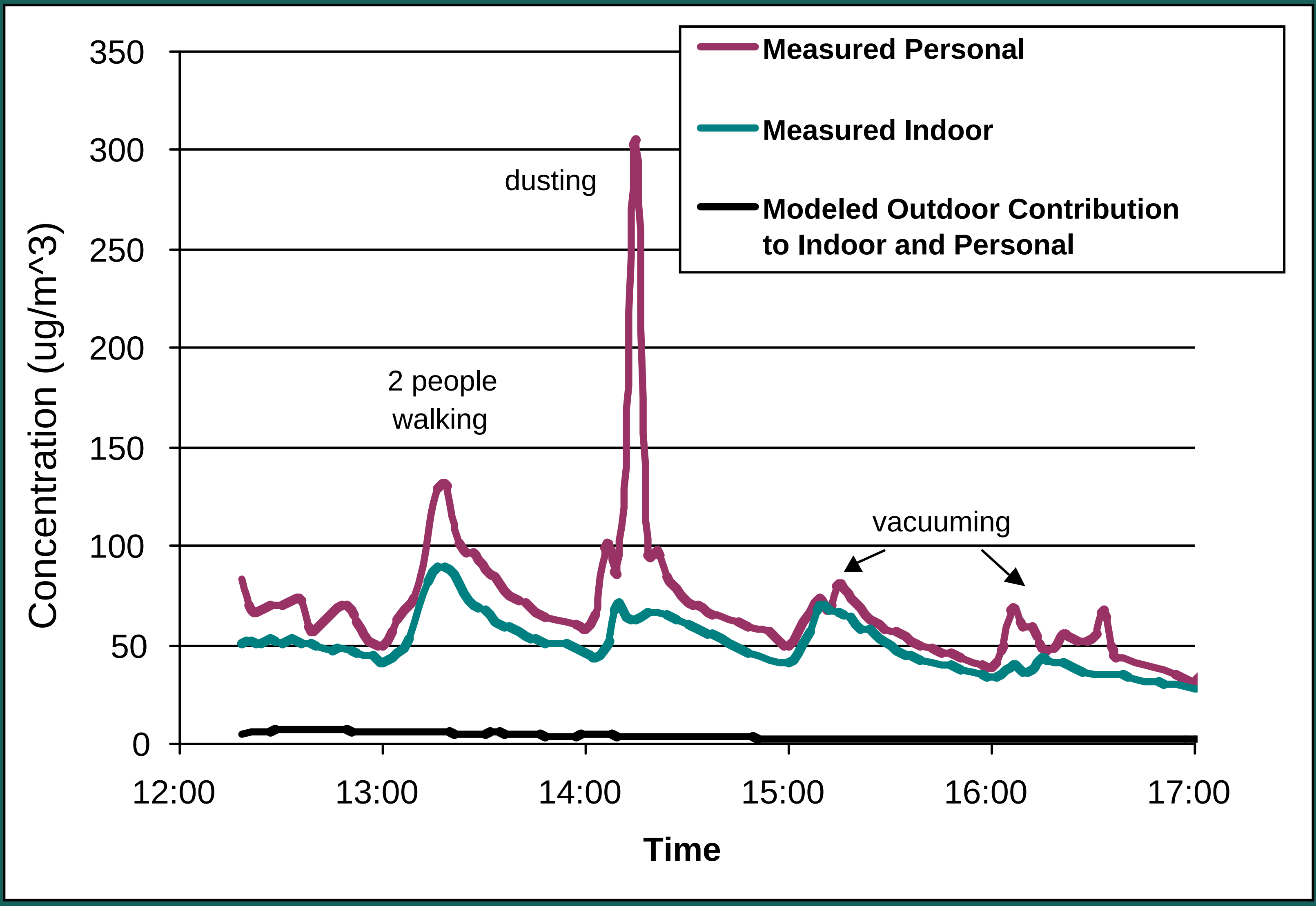
δ = equally spaced time interval [h]

*Switzer and Ott (1992)

Indoor-Outdoor Model Results
PM-5, Low-Activity Day (Day 5)



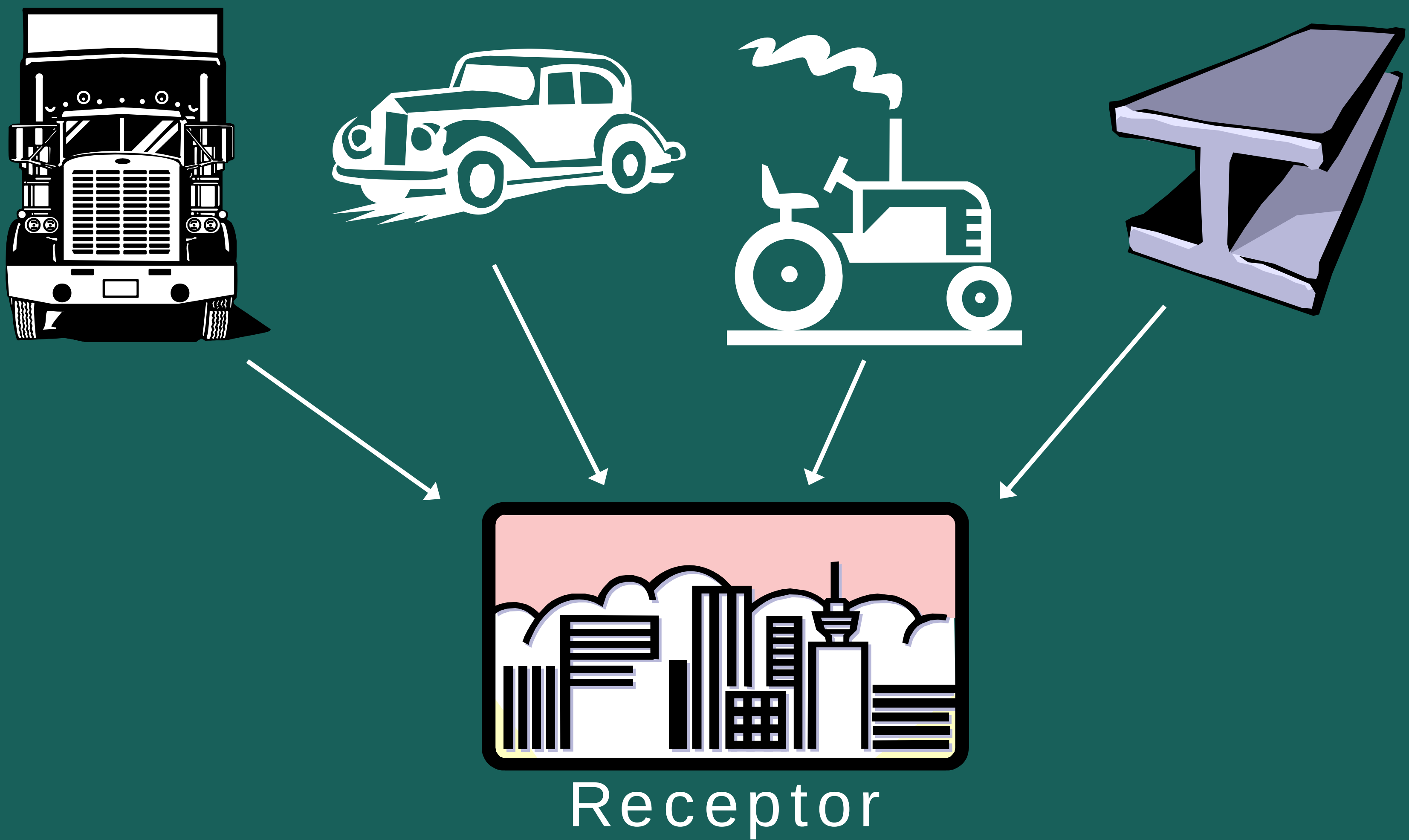
Indoor-Outdoor Model Results
PM-5, Day with Activities (Day 3)



Summary of I-O PM-5 Model Results

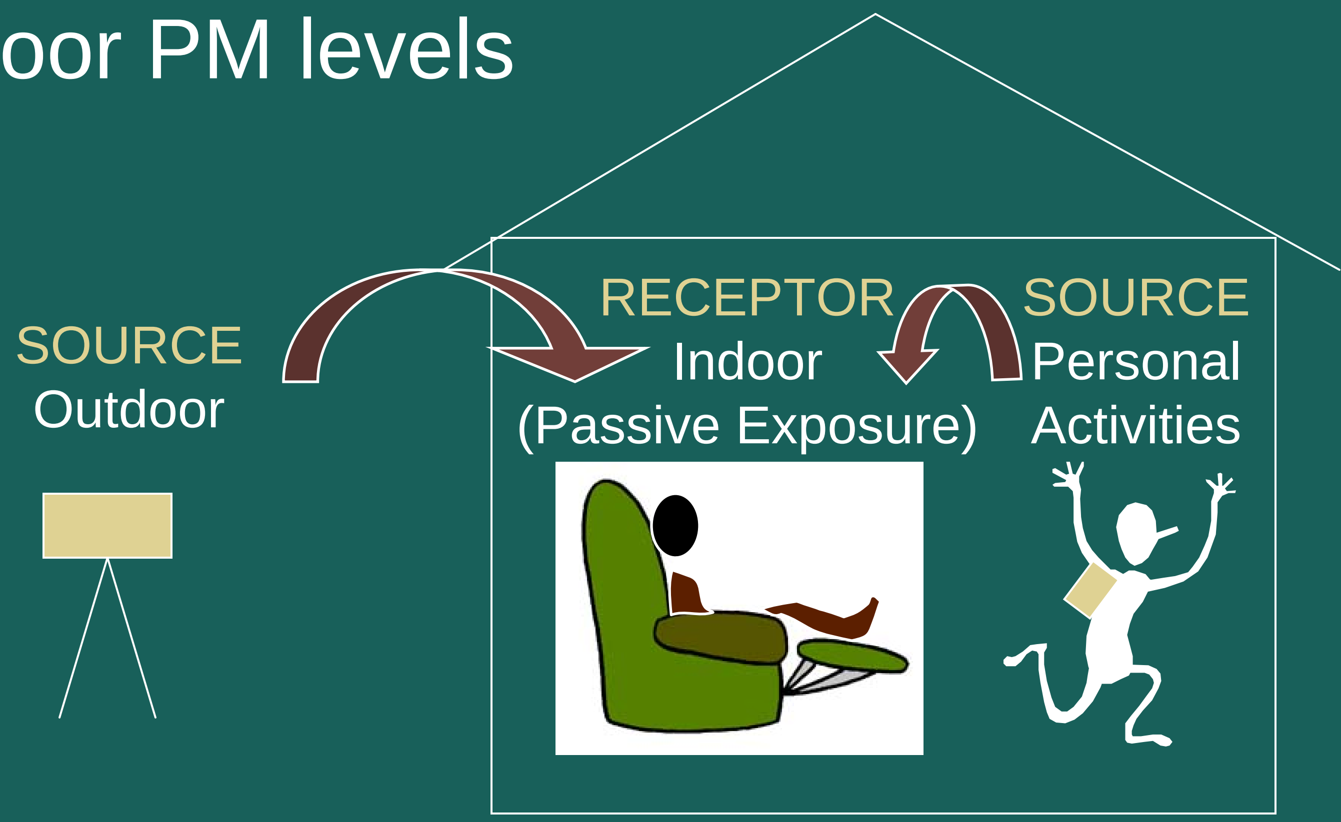
	Indoor Conc. µg/m^3	Outdoor % Contribution	Activities % Contribution
•Prescribed Activities:			
Day 1 (5-hr)	89	4	96
Day 2 (5-hr)	41	10	90
Day 3 (5-hr)	48	8	92
•Minimal Activity:			
Day 4 (23-hr)	10	37	63
Day 5 (7-hr)	12	49	51

Second Approach: Chemical Mass Balance (CMB) Receptor Model



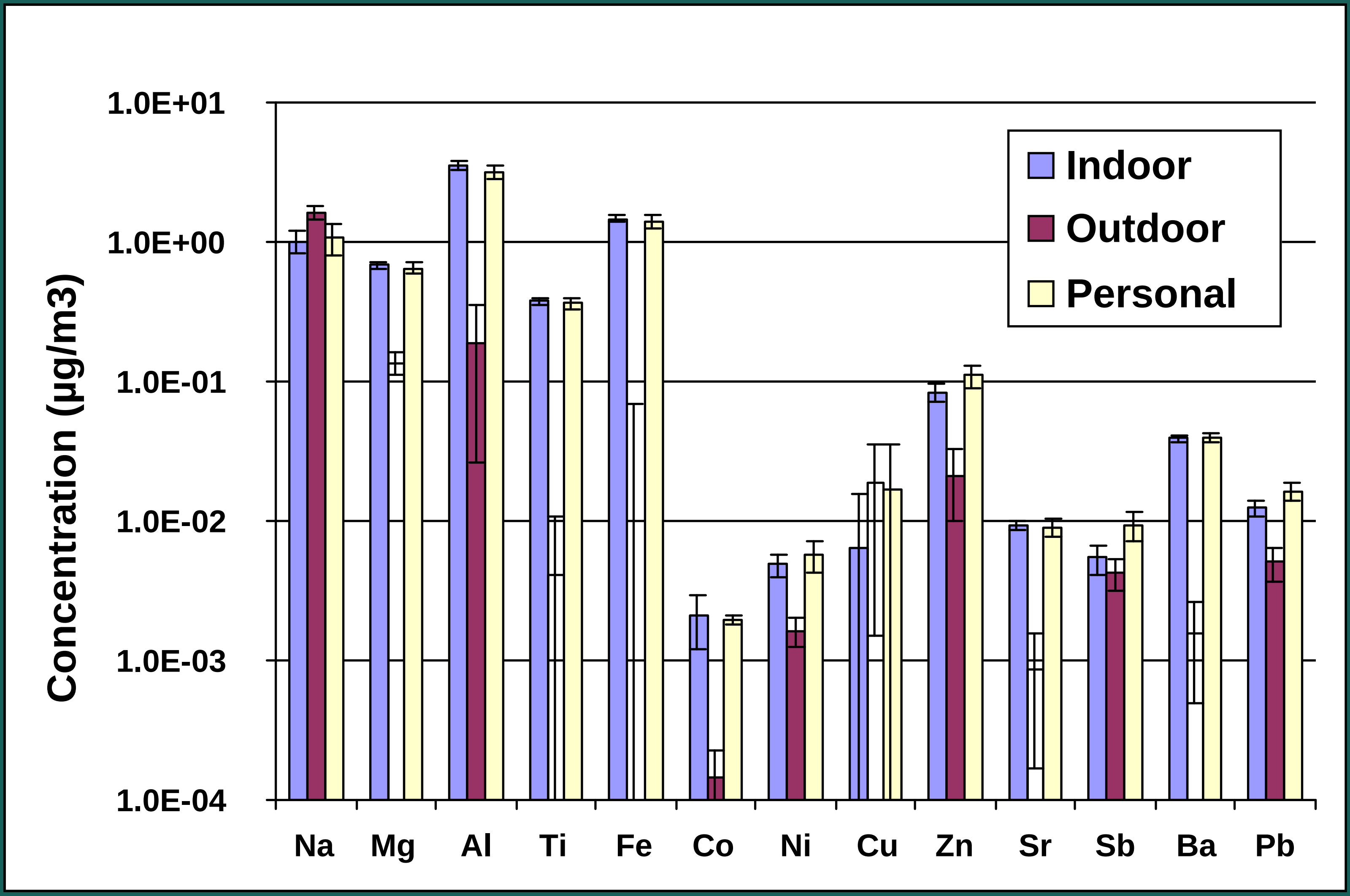
Indoor Receptor (CMB) Model

Outdoor air and personal activities are assumed to be the 2 “sources” contributing to indoor PM levels



For each elemental tracer:

Indoor Conc. = Outdoor Contribution + Contribution from Activities



Comparison of I/O and CMB Models for PM-5

	Indoor (µg/m3)	Outdoor % Based on CMB	Outdoor % Based on I/O
Prescribed activity periods (5 hour samples):			
Day 1	89	0 ± 2	4
Day 2	41	2 ± 5	10
Day 3	48	4 ± 4	8
Low-level activities (23 hour samples):			
Day 4	10	40 ± 4	37
Day 5	12	38 ± 6	51

Re-suspension / Indoor Air Findings

- During the 5 hour periods of prescribed activities, >90% of indoor PM5 was from re-suspension of house dust (for PM2.5, was 60-90%)
- During minimal activity days, 44-63% of indoor PM5 was from re-suspension of house dust (for PM2.5, was 27-45%)

Limitations of Study

- Scripted activities
- Only one week of data
- Only one home
- No dust loading information

Conclusions

The concentration of re-suspended house dust from human activities is large enough:

- To represent ~1/2 of the total PM5 (and >1/4 of the total PM2.5) present indoors on a low-activity day, and
- To substantially increase human exposure to PM

Thank you!

Acknowledgements:

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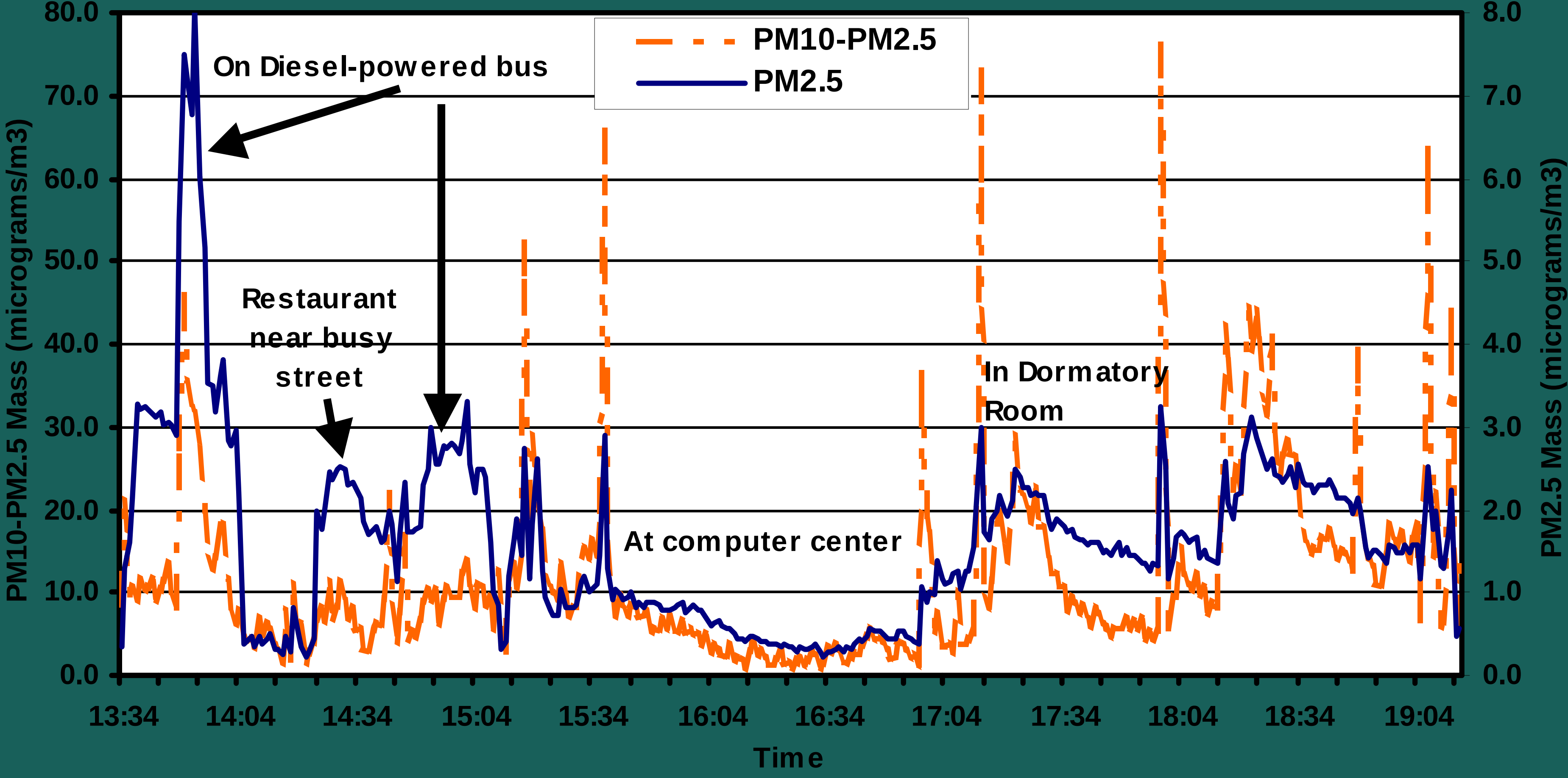
Example of Personal Exposure to Coarse vs Fine PM for Different Locations



- Combustion PM emissions are mainly fine; indoor activities tend to generate coarse PM.

Vacuuming Study

6 vacuuming experiments

- Each experiment was performed 6-8 days after study home was last vacuumed
- Same person vacuumed each time for 30 mins, wearing comparable clothing
- Same region was vacuumed each time, using a fresh vacuum bag and the same vacuum
- Real-time PM monitors collected PM counts in 6 size ranges on a minute-by-minute basis

Summary of Vacuuming Study Results (Personal / “Background” Ratios)

Particle Size Range	Vacuum On	Vacuum Off	No Vacuum
0.3-0.5 um	1.4	1.1	1.0
0.5-1.0 um	2.1	1.6	0.9
1.0-2.5 um	5.6	2.5	1.2
2.5-5.0 um	11	9.7	2.4
5.0-10 um	18	23	5.6
> 10 um	250	210	20

Source Strengths for Human Activities (mg/min)