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Assessment of the Toxicity of Coal-Fired Power Plant Emissions: Preliminary Results from the TERESA Study

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Air Quality V

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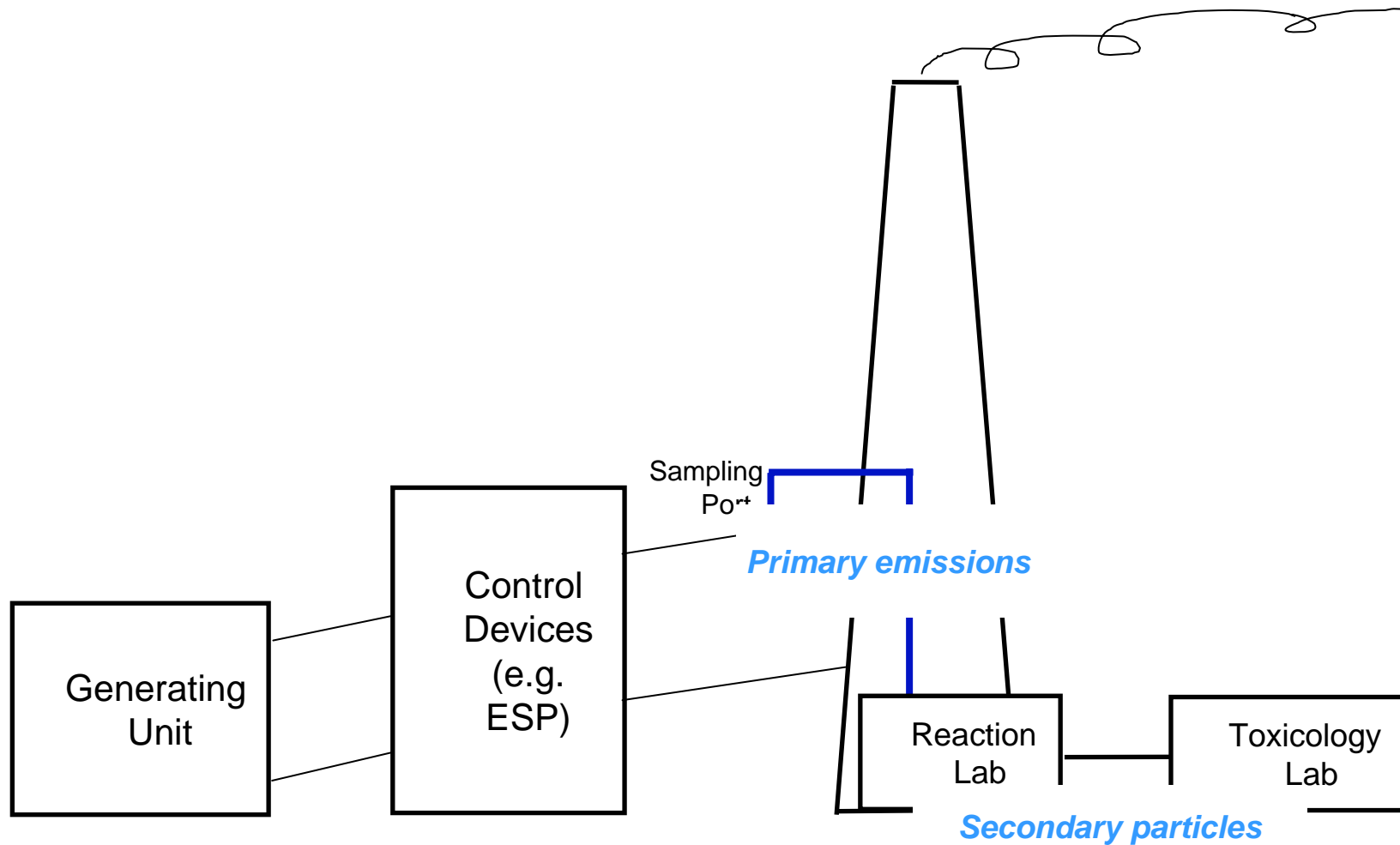
TERESA: Overview

TERESA: Toxicological Evaluation of Realistic Emissions of Source Aerosols

Approach:

- Evaluate toxicity of *secondary* particles from power plants, at power plants
- Expose rats to multiple simulated atmospheric conditions
- Examine mobile source emissions using same methods

Study Schematic



Objectives

- Evaluate the relative toxicity of coal-fired power plant emissions, mobile source emissions, and ambient particles
- Assess the effect of atmospheric conditions on particle formation/toxicity
 - Oxidants (OH radicals) convert SO_2 to sulfuric acid
 - NH_3 neutralizes strong acidity
 - Secondary organic aerosol (α -pinene + ozone)
- Evaluate the impact of coal type and pollution control technologies on toxicity

Why Is TERESA Important?

- Highly innovative and ground-breaking
 - First study to evaluate secondary particles at power plants
- Previous studies have significant limitations:
 - Studies using collected primary coal fly ash
 - Inhalation exposure studies using emissions from pilot combustors
- TERESA addresses these limitations

Three Plants in Program

1. Upper Midwest: Powder River Basin coal, no SCR, no FGD. Fieldwork completed November 2004.
2. Southeast: Low sulfur (<1%) eastern bituminous coal, SCR, no FGD. Fieldwork nearing completion.
3. Midwest: Medium-to-high sulfur (>2-3%) eastern bituminous coal, SCR, FGD. Fieldwork in summer 2006.

Field Operations at Plant 1



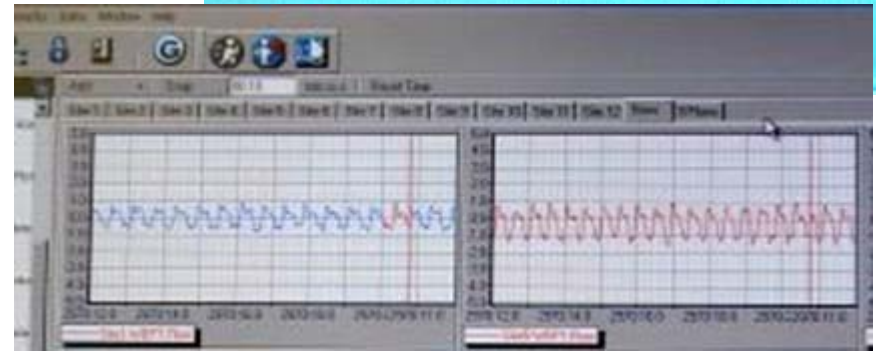
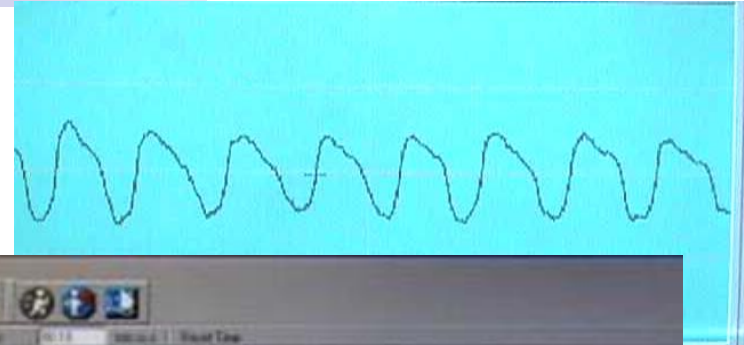
Exposure Characterization

	Parameter	Medium and Method
Integrated	PM _{2.5} mass	47 mm Teflon filter; gravimetric
	Elements	Teflon filter; XRF
	Sulfate, nitrate, NH ₄ , NH ₃ , SO ₂ , HNO ₃ , HONO	Diffusion denuder + Teflon filter; ion chromatography
	Strong acidity	Teflon filter; pH analysis
	EC/OC	47mm Quartz filter; TOR method
	SOA species (pinonic acid, pinic acid, etc.)	47mm teflon filter
	α-Pinene	Tenax Tubes
	Ketones and aldehydes	DNPH cartridges
Continuous	PM _{2.5} mass	R&P TEOM
	Particle number	CPC TSI 3022
	O ₃	UV absorbance method
	NOX	Chemiluminescence method
	SO ₂	Pulsed fluorescence method
	RH and T	Omega

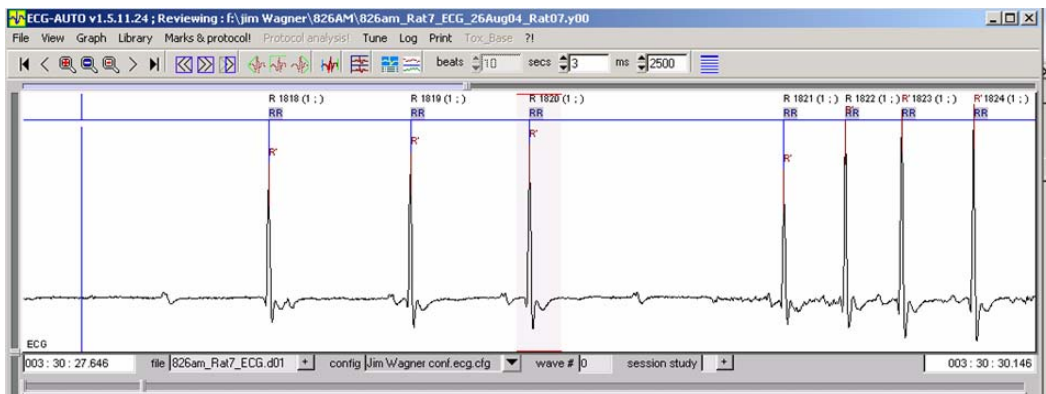
Toxicology Assessment

Breathing Pattern

- Pulmonary function/breathing pattern
- *In vivo* oxidative stress
- Blood cytology (CBC/differential)
- Bronchoalveolar lavage
- Pulmonary histopathology
- Blood chemistry
- ECG monitoring (subset of “susceptible” [MI – heart attack] animals)



Electrocardiogram (ECG)



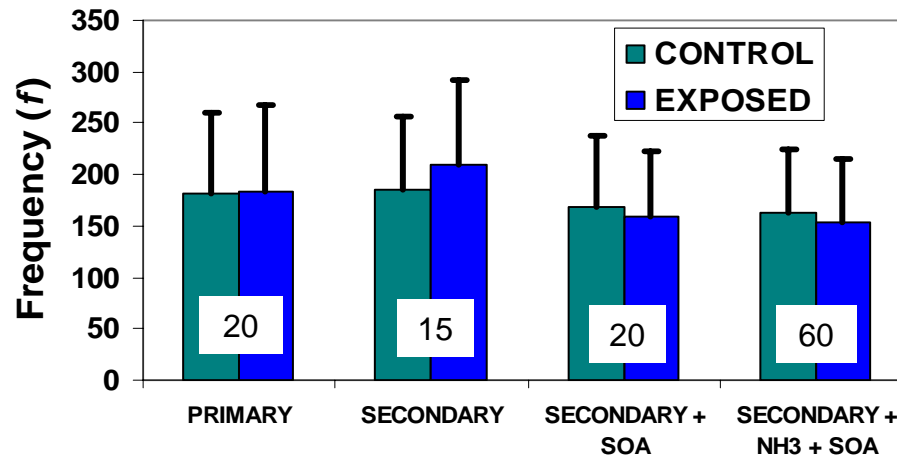
Exposure Data, Plant 1, Fall 2004

Values shown as mean (SD)

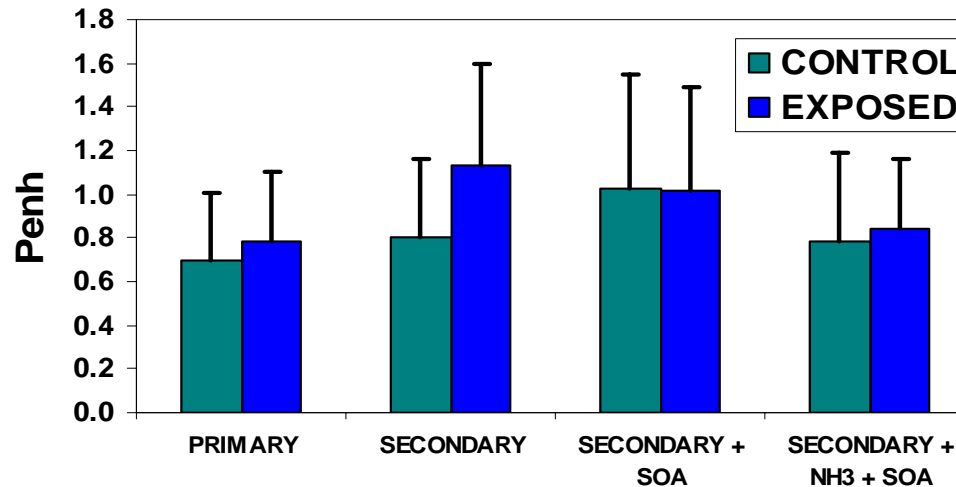
	Round 1: October 4-7 (secondary + SOA)	Round 2: October 11-14 (secondary, neutralized + SOA)	Round 3: November 3-5 (secondary only)
	<i>n</i> =4	<i>n</i> =4	<i>n</i> =3
Mass ($\mu\text{g}/\text{m}^3$)	193 (73)	141 (16)	69 (10.4)
SO ₄ ($\mu\text{g}/\text{m}^3$)	57.1 (24)	38.7 (11)	31.8 (1.3)
NO ₃ ($\mu\text{g}/\text{m}^3$)	1 (0.4)	37.7 (6.2)	1.1 (1.2)
NH ₄ ⁺ ($\mu\text{g}/\text{m}^3$)	3.1 (1.2)	14.7 (4.1)	3.3 (1.7)
Acidity ($\mu\text{g}/\text{m}^3$ H ₂ SO ₄)	49.1 (22.7)	1.6 (1.7)	22.5 (4)
SO ₂ (ppb)	17.5 (4.4)	16 (3)	9.3 (3.5)
HNO ₃ (ppb)	1.6 (0.3)	2.3 (0.6)	0.6 (0.1)
HONO (ppb)	11.2 (5.1)	7.8 (1.5)	5 (1)
NH ₃ (ppb)	20.8 (3.8)	16.1 (6.2)	9.9 (6.2)
Organic carbon ($\mu\text{g}/\text{m}^3$)	130.7 (7.1)	100.6 (6.6)	54.9 (6.9)
Elemental carbon ($\mu\text{g}/\text{m}^3$)	12.1 (9.4)	4.3 (0.7)	2.8 (1.6)
Formaldehyde ($\mu\text{g}/\text{m}^3$)	16.1 (3.6)	18.1 (3.9)	N/A
Acetaldehyde ($\mu\text{g}/\text{m}^3$)	5.2 (1)	4.8 (0.6)	N/A
Acetone ($\mu\text{g}/\text{m}^3$)	15.5 (5.2)	13 (2.9)	N/A
Pinene ($\mu\text{g}/\text{m}^3$)	0.6 (0.1)	0.8 (0.3)	N/A

Plant 1: Respiratory Effects

Respiratory
Frequency:
Indicator of Airway
Irritation

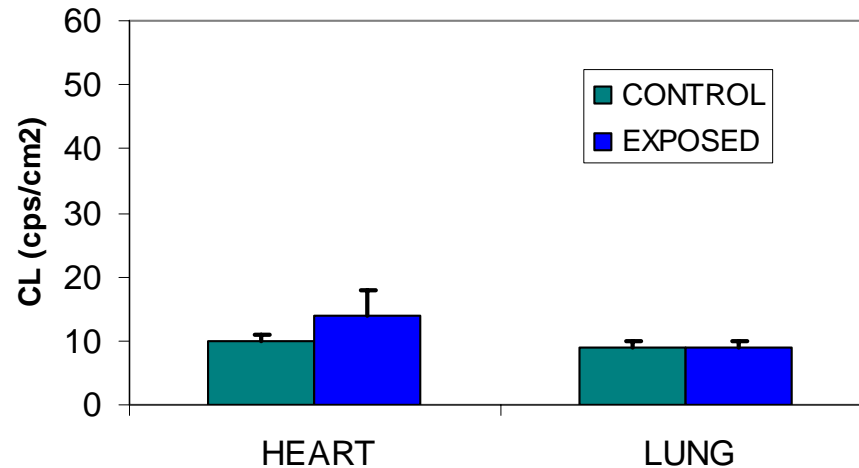


Enhanced Pause:
Indicator of
Airway
Restriction

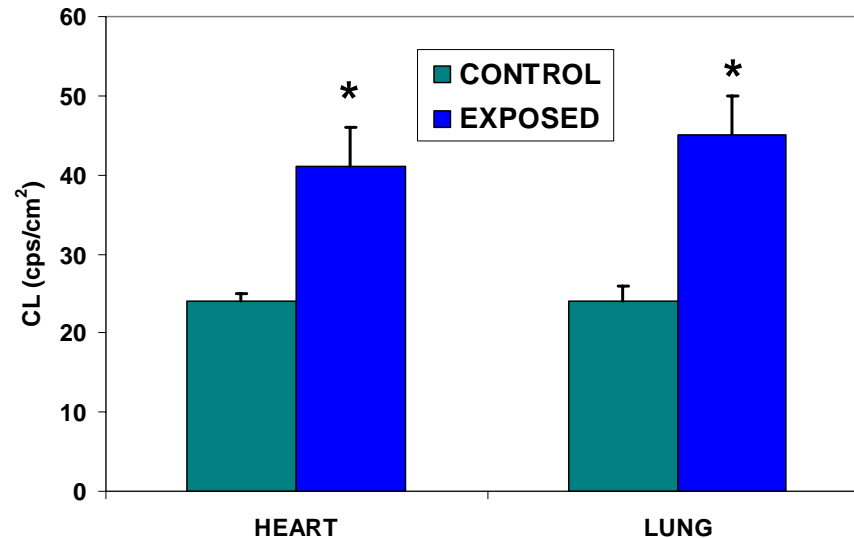


Plant 1: Oxidative Stress in Heart and Lung Tissue

Secondary + SOA
(*n*=8 in each group)



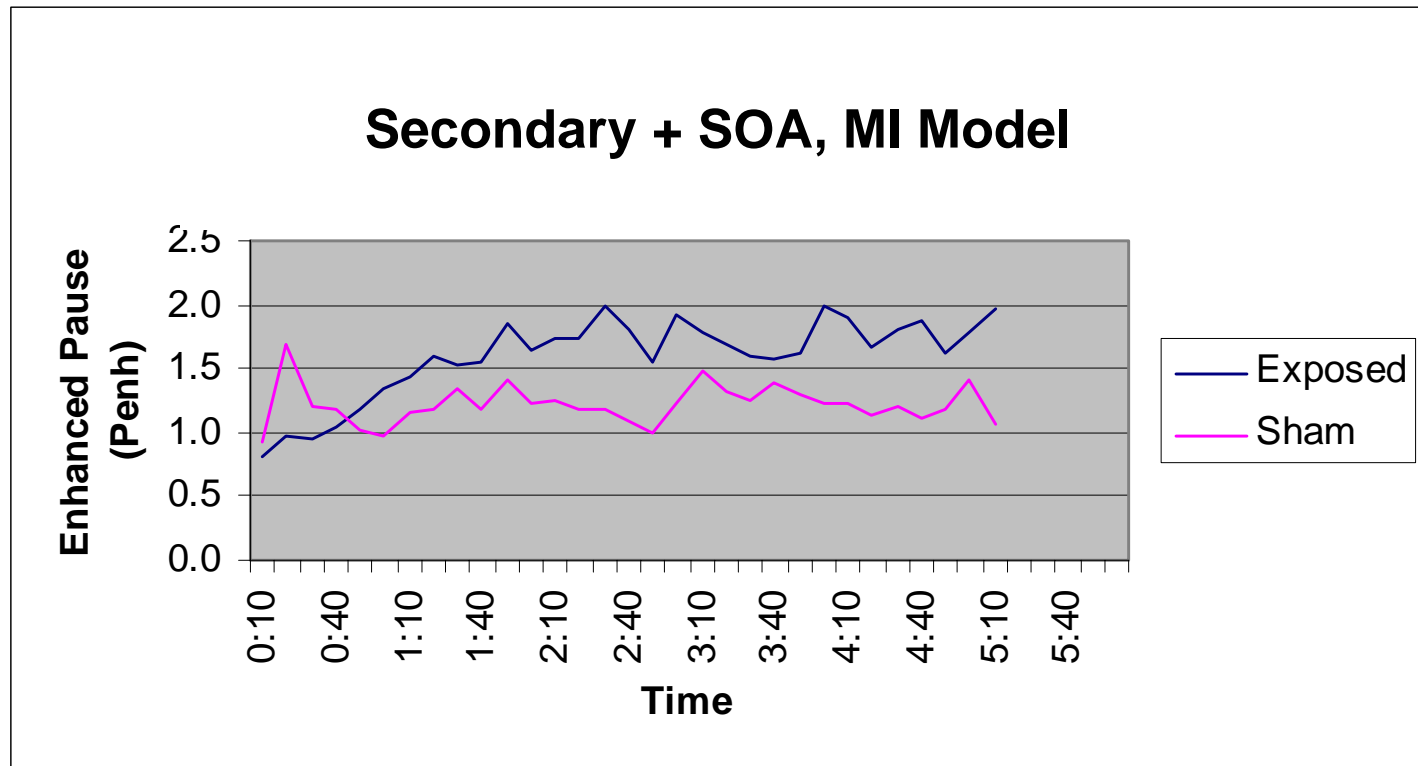
Boston Particles
(Gurgueira *et al.*, 2002)
(*n*=4-6 in each group)



Plant 1: Summary of Results

- No changes in breathing pattern or pulmonary function
- No evidence of lung inflammation or injury
- No changes in blood parameters
- No evidence of oxidative stress in lung or heart tissue
- No changes in lung tissue

Plant 2: Respiratory Effects



Plant 2: Respiratory Effects

Scenario	Respiratory Frequency	Tidal Volume	Inspiratory Time	Expiratory Time	Penh
Secondary, unneutralized + SOA #1	↑ ns	↓ p=0.003	NC.....ns	NC ns	↓ ns
Secondary, unneutralized + SOA #2	↑ ns	NC.....ns	NC.....ns	NC.....ns	↓ p=0.001
Secondary, unneutralized	↑ ns	↓ p=0.04	↓ p=0.02	↓ ns	↓ p=0.01
Secondary, unneutralized (MI model)	↑ p=0.024	NC.....ns	NC.....ns	↓ p=0.005	↑ p=0.03
Secondary, neutralized + SOA	↓ ns	↓ p=0.002	NC.....ns	NC.....ns	↓ p=0.001
Primary particles	↓ ns	↓ p=0.001	NC.....ns	NC.....ns	↓ p=0.003

Airway restriction: ↑ Penh, ↑ expiratory time

Sensory irritation: ↓ frequency

Pulmonary irritation: ↑ frequency, ↓ tidal volume, ↓ insp/exp time

Plant 2: Summary

- Some biological effects observed: breathing pattern, oxidative stress
- Respiratory results don't tell a clear story
- Most effects with unneutralized scenarios

Conclusions and Future Directions

- TERESA results to date suggest few/inconsistent effects of power plant emissions on laboratory rats
- But...we don't have all the data yet
- Awaiting ECG data from Plant 2 animals
- Need to understand how exposures at Plants 1 and 2 differ
- Plant 3 fieldwork next summer
- Mobile source component to begin in 2007 (funded through the Harvard/EPA PM Center)