

Source-Oriented Toxicity to Inform Toxicity-Oriented Emissions Regulations

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Which Sources are more Toxic?

Is all PM created equal?

Is some PM more equal than others?

(apologies to George Orwell)

- Do sea spray and diesel exhaust have same toxicity?
- Current mass-based NAAQS treats them the same
- Can we differentiate sources by their toxicity?

Which Sources are more Toxic?

Epidemiologically

- High risk near freeways
- High risk downwind of coal fired power plants
- Many other studies
- But correlative, not causative

Toxicologically

- Well how about those nasty secondary compounds?
- And how about the atmosphere changing the toxicity?
- Can we collect source-oriented PM from the atmosphere?
- Isn't the atmosphere well mixed?

Source-Oriented Sampling

The atmosphere is not well mixed on short time scales

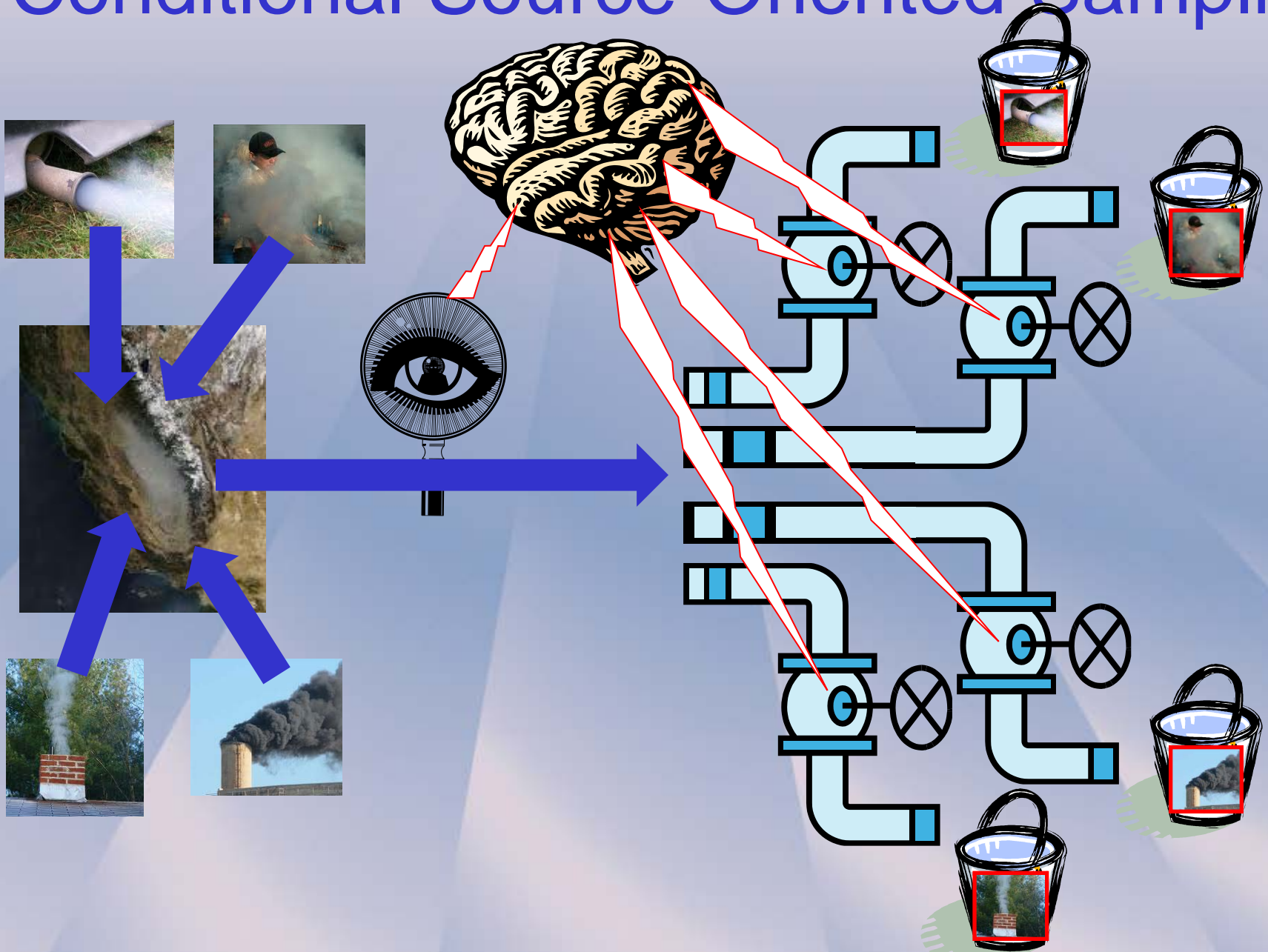
- Consider plumes hitting a sampling site
- Single particle mass spectrometer observations in Atlanta, Houston, Baltimore and Pittsburgh

Source-Oriented Sampling

So what's the big idea?

- Run a single particle mass spectrometer to characterize the mixing state of the atmosphere
- Assign prevailing sources or source combinations to each of 10 high-volume ChemVol samplers
- Use single particle mass spectrometer to select which ChemVol samples
- Collect enough PM for tox studies
- Examine source-differentiated toxicity

Conditional Source-Oriented Sampling



Sampling Train



Source-Oriented Sampling

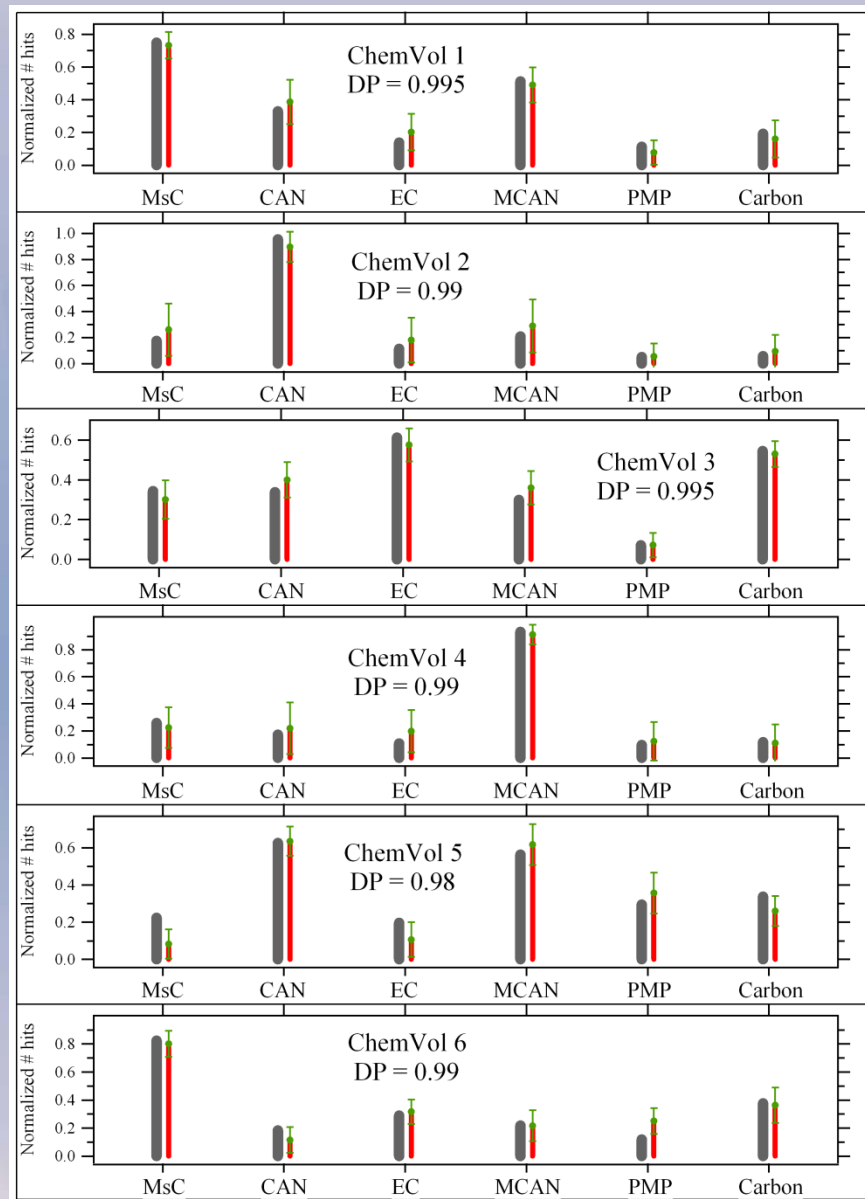
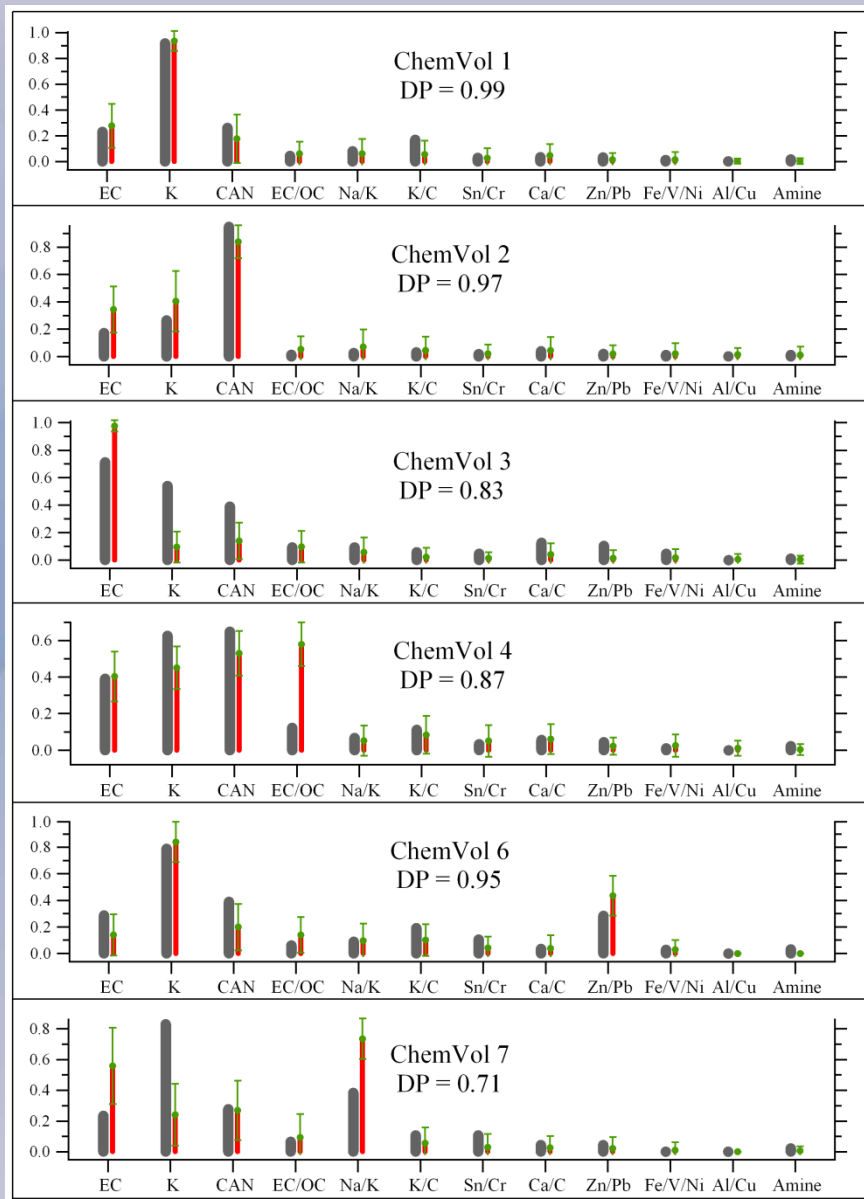
What did we do?

- ❑ Collected source-oriented PM from Fresno
- ❑ Two seasons: Summer '08 and Winter '09
- ❑ Two size ranges
 - ❑ Ultrafine (UF): smaller than 170 nm
 - ❑ Submicron Fine (SMF): 170 nm to 1 μ m
- ❑ Sufficient sample in most sources/sizes for tox studies
- ❑ Samples represent major sources in Fresno
- ❑ Good separation of sources in the samples

Summer 2008

Fidelity

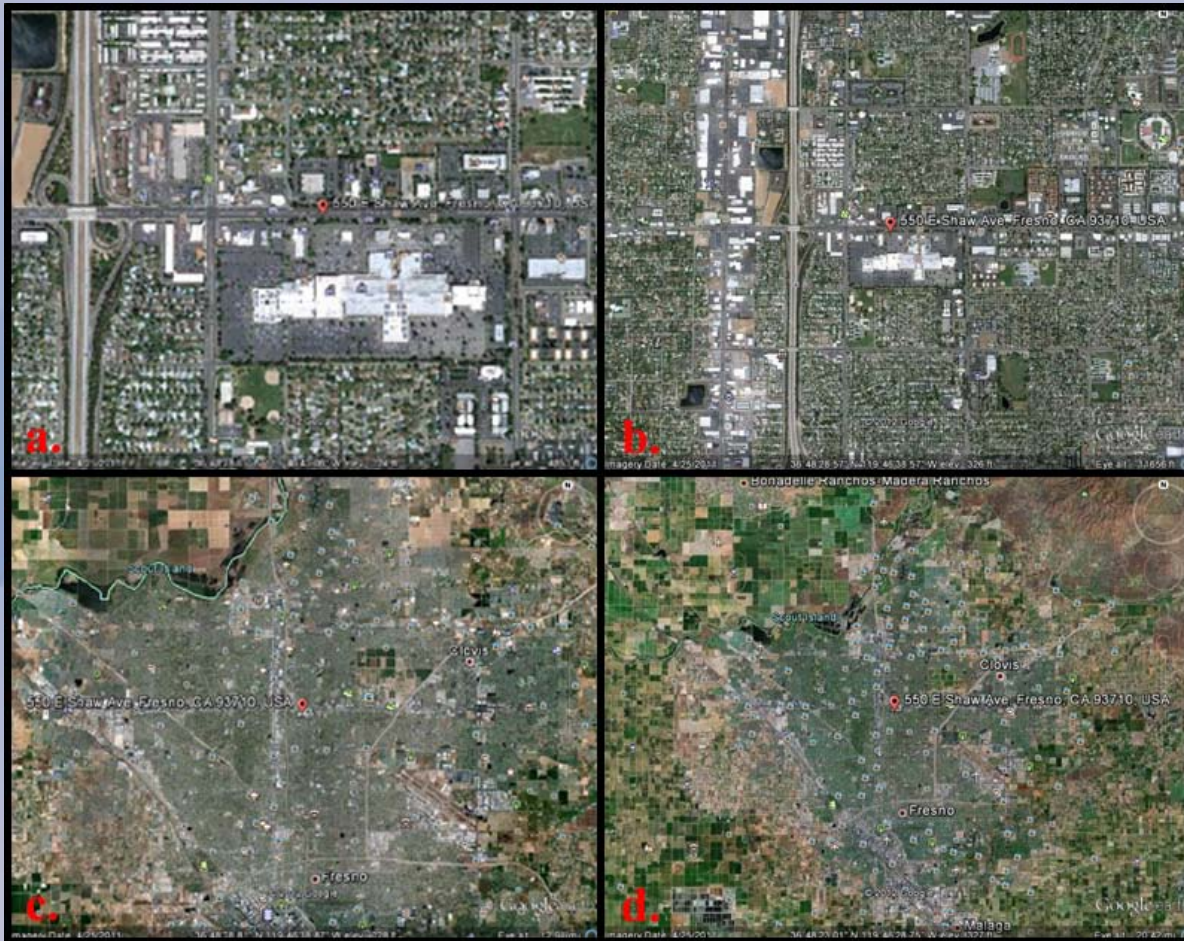
Winter 2009



Source Attribution – Site-Source Relation

Emissions Sources

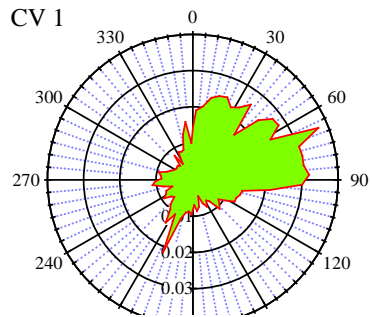
- Vehicular
 - Gasoline and diesel
 - Highways and residential
- Residential and Commercial
 - Cooking
 - Space heating
 - Construction/landscaping
- Agricultural
 - Ranching
 - Agricultural machinery
 - Waste/debris burning
 - Product transportation
- Regional Processing
 - Ammonium nitrate
 - Secondary Organic Aerosol
- Long-range Transport
 - Wildfires
 - Trans-Pacific transport



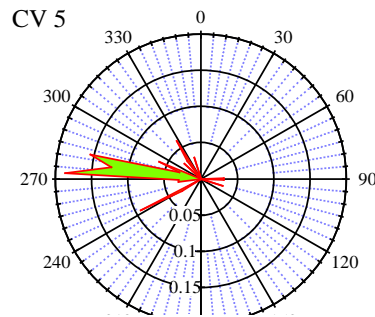
Source Attribution – Spatial Relations

Summer 2008

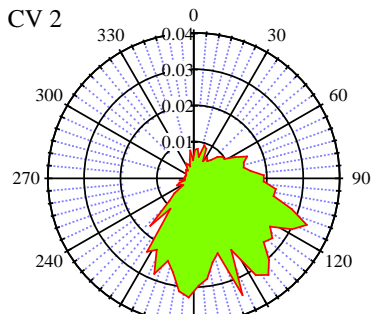
Winter 2009



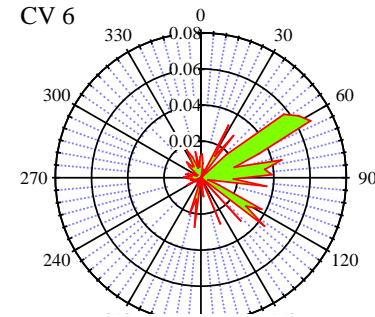
a. Residential Cooking



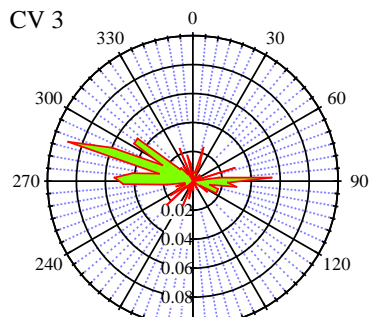
Vehicular – Gas + Diesel



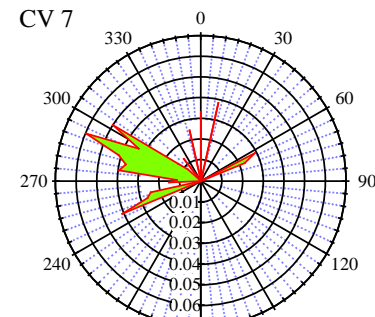
b. Regional Background



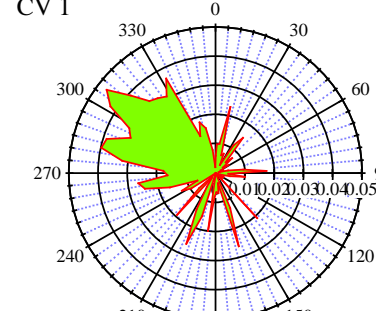
e. Metals – Unknown



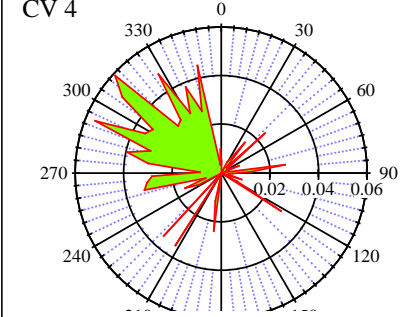
c. Vehicular – Diesel



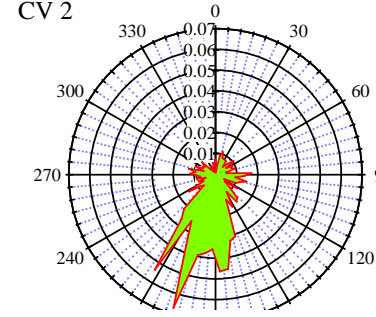
f. Commercial Cooking



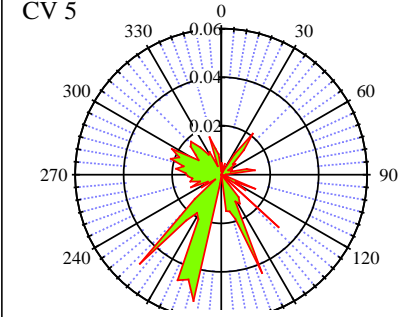
a. Residential Heating



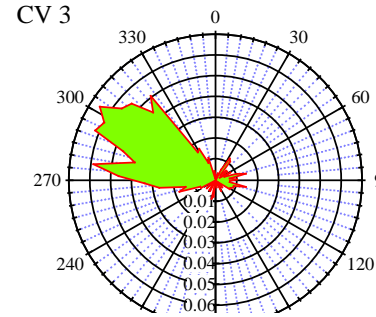
d. Processed Biomass



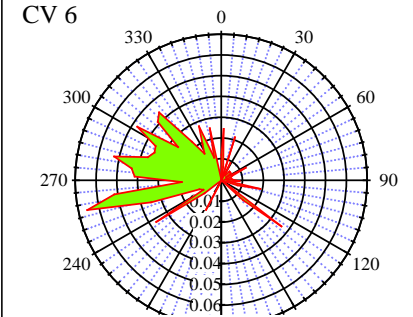
b. Regional Background



e. Regional Mixture



c. Vehicular – Gas + Diesel

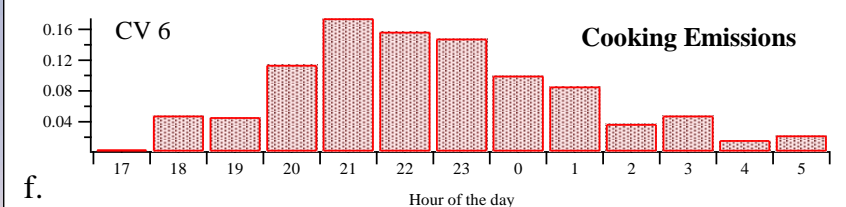
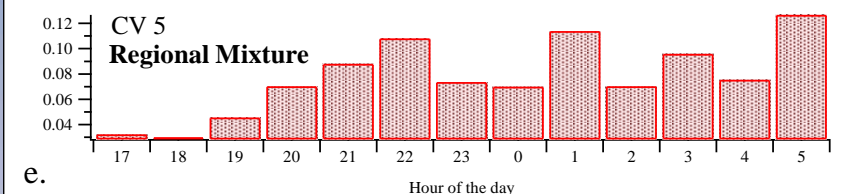
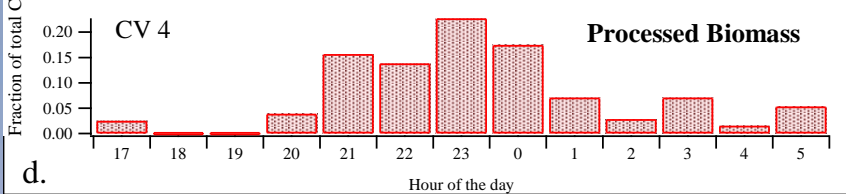
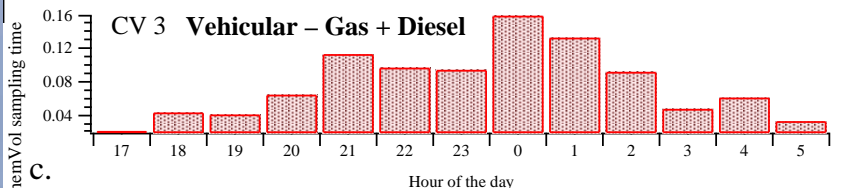
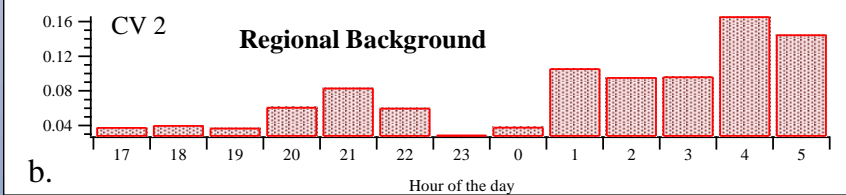
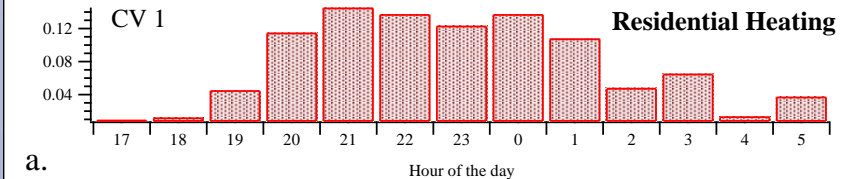
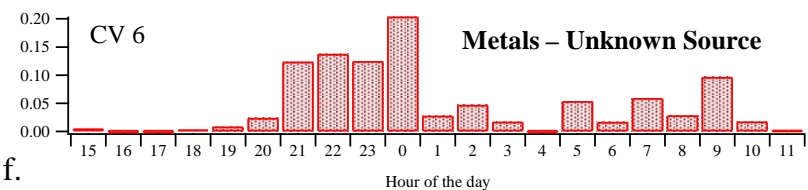
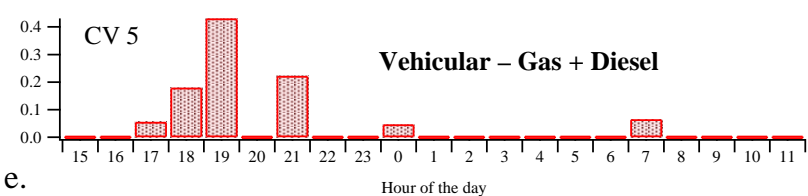
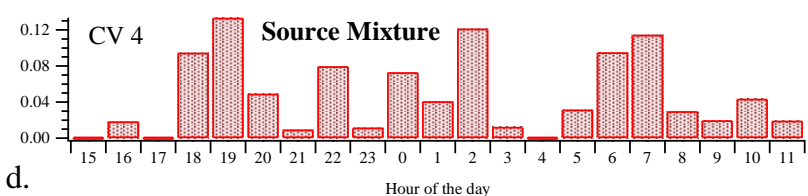
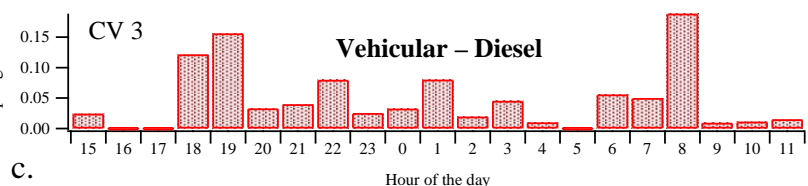
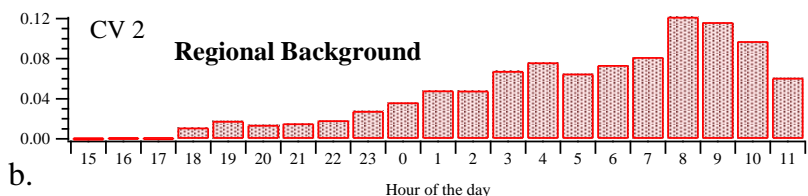
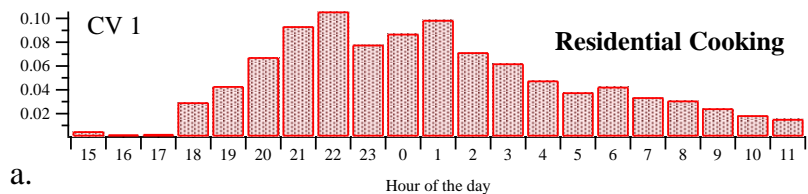


f. Cooking Emissions

Source Attribution – Temporal Relations

Summer 2008

Winter 2009



Source-Oriented Toxicity

Study Design



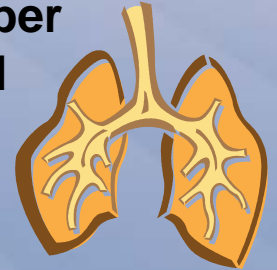
50 μ g
Source-
Oriented
PM



24 hours
post-
exposure

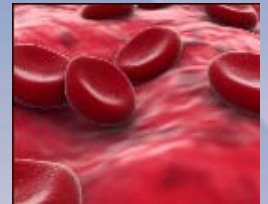
Bronchoalveolar Lavage (BAL)

- Total Cell Number
- Cell Differential
- Cell Viability
- Cytotoxicity
- Cell Damage



Blood (CBC)

- Total Cell Number
- Cell Differential
- Hematology

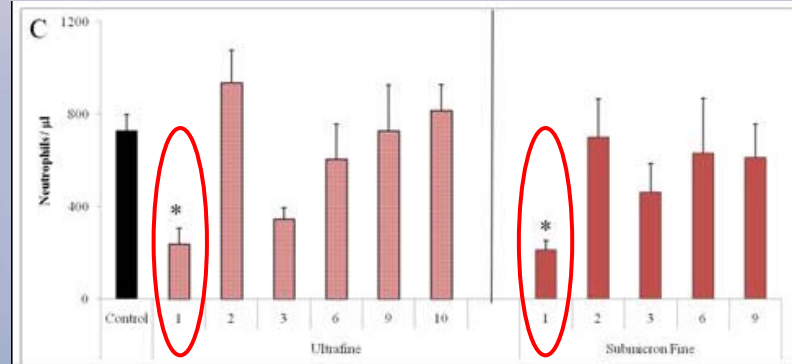


Reactive Oxygen Species

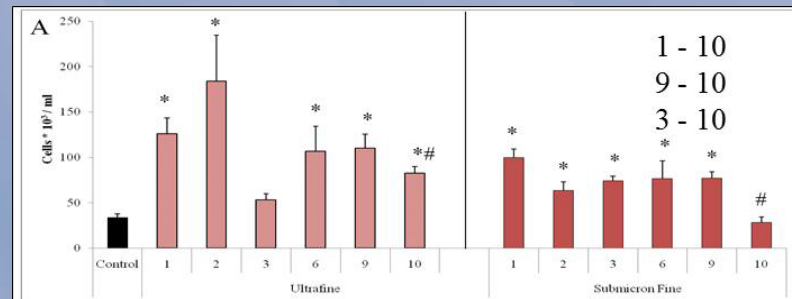
- Hydrogen peroxide
- Hydroxyl radical

Summer Residential Cooking

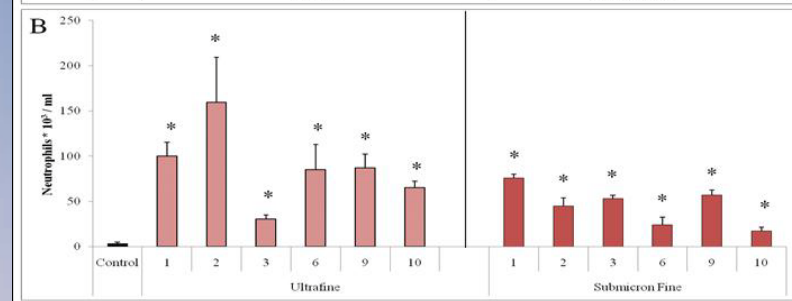
Circulating Neutrophils



Lung BAL:
Total Cells



Neutrophils



Lung BAL protein:

Significant elevation in Summer Commercial Cooking

Winter Cooking

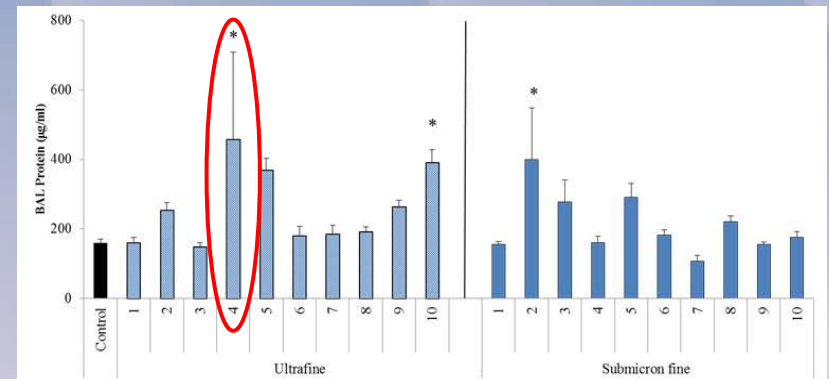
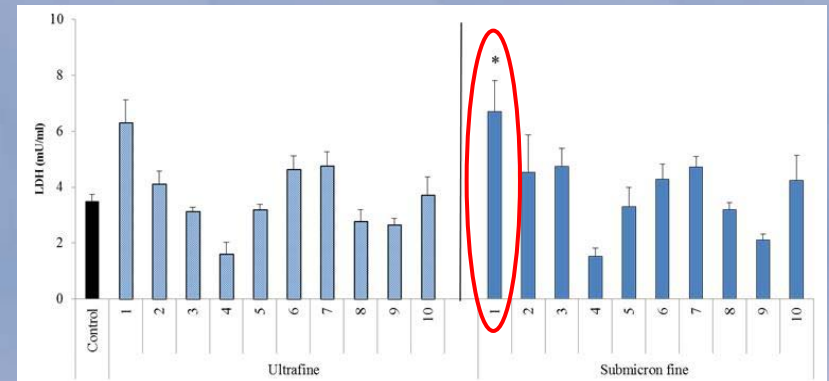
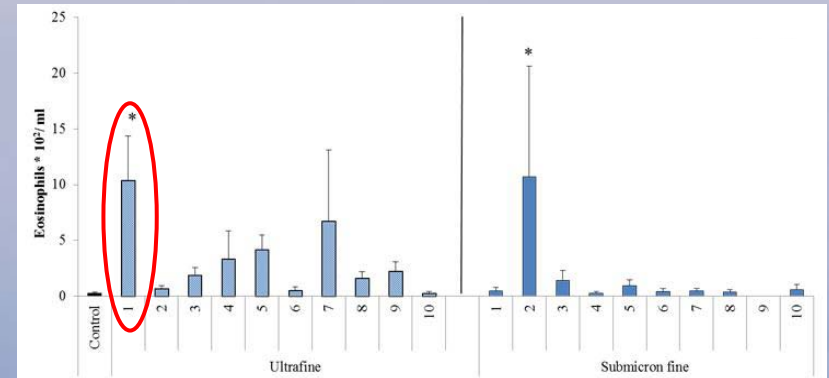
Relatively Little Pulmonary or Systemic Effects Found

Winter Biomass Combustion

Lung BAL:
Eosinophils

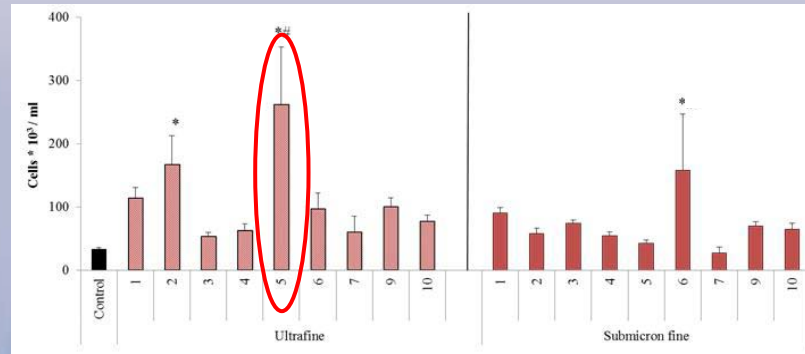
LDH

Protein

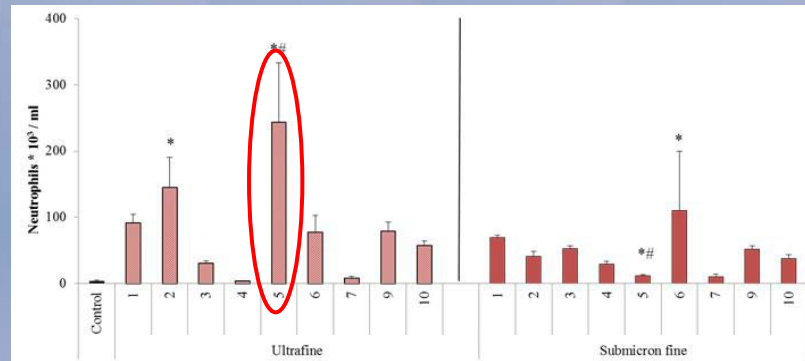


Vehicles in Summer

Lung BAL:
Total Cells



Neutrophils



Eosinophils

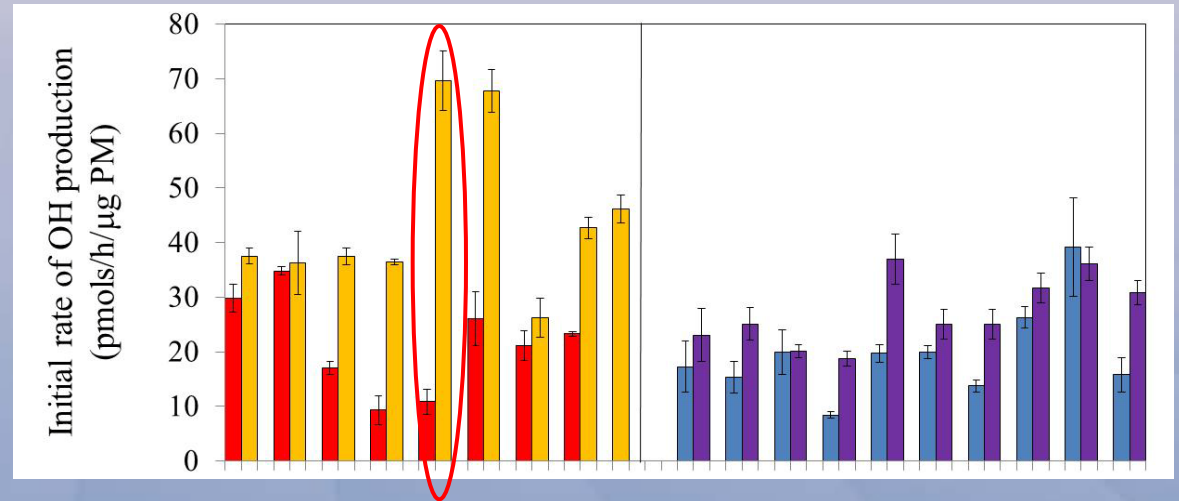


No Effects from the Vehicle mix with more Diesel

Vehicles in Summer

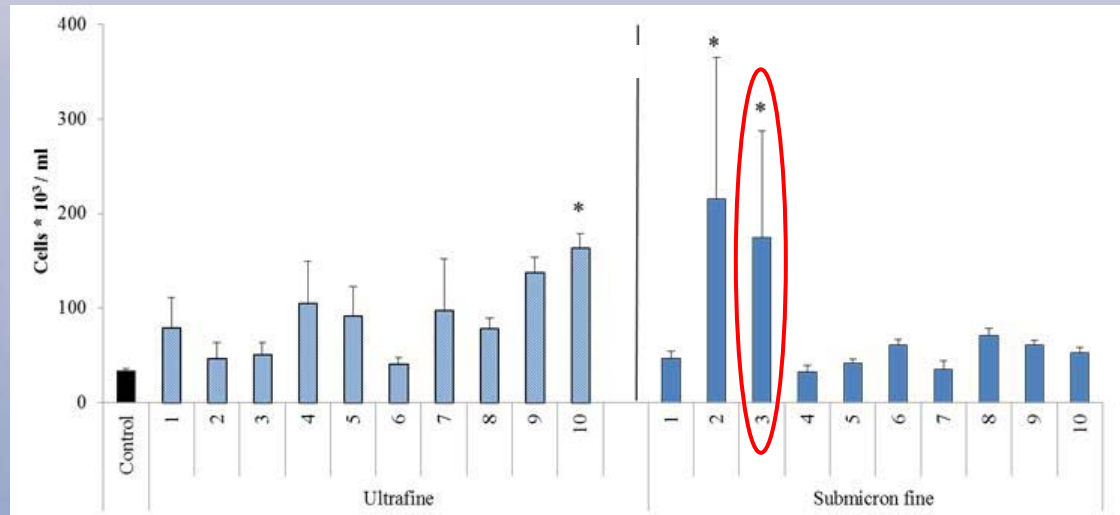
Reactive Oxygen
Species: OH

Submicron Fine

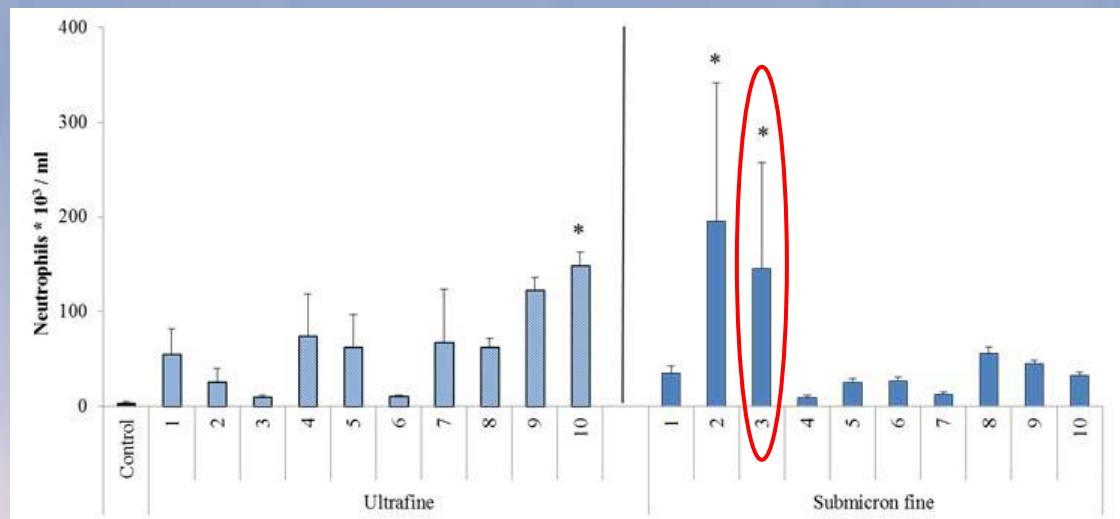


Vehicles in Winter

Lung BAL:
Total Cells



Neutrophils



Systemic Effects in Morning Commute Hours

Conclusions

Source-Oriented Sampling

- Source-oriented sampling is **FEASIBLE**
 - Novel sampling method implemented successfully
 - Different PM samples attributable to different sources
 - Sufficient PM collected for toxicity studies

Conclusions

Source-Oriented Toxicity

- Some particles MORE TOXIC than others
 - Summer PM: metal-containing and vehicular emissions have largest biological response
 - Winter PM: highly processed, vehicular emissions and nighttime mix have largest biological response
 - Ultrafine PM generally elicits greater biological response than submicron fine PM
- Different particles TOXIC in DIFFERENT ways
- Source-oriented regulations are FEASIBLE but further research is necessary
- More Complete CARB presentation:
<http://www.arb.ca.gov/research/seminars/seminars.htm>