Source-Oriented Toxicity to Inform Toxicity-Oriented Emissions Regulations

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Sponsored by
California Air Resources Board and Electric Power Research Institute
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 um
- Sufficient sample in most sources/sizes for tox studies
- Samples represent major sources in Fresno
- Good separation of sources in the samples
Fidelity

Summer 2008

Winter 2009

ChemVol 1
DP = 0.99

ChemVol 1
DP = 0.995

ChemVol 2
DP = 0.97

ChemVol 2
DP = 0.99

ChemVol 3
DP = 0.83

ChemVol 3
DP = 0.995

ChemVol 4
DP = 0.87

ChemVol 4
DP = 0.99

ChemVol 6
DP = 0.95

ChemVol 5
DP = 0.98

ChemVol 7
DP = 0.71

ChemVol 6
DP = 0.99
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 – Temporal Relations

Summer 2008

- CV 1: Residential Cooking
- CV 2: Regional Background
- CV 3: Vehicular – Diesel
- CV 4: Source Mixture
- CV 5: Vehicular – Gas + Diesel
- CV 6: Metals – Unknown Source

Winter 2009

- CV 1: Residential Heating
- CV 2: Regional Background
- CV 3: Vehicular – Gas + Diesel
- CV 4: Processed Biomass
- CV 5: Regional Mixture
- CV 6: Cooking Emissions

Fraction of total ChemVol sampling time

Hour of the day
Source-Oriented Toxicity

Study Design

50 µg 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

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