Health Effects of Organic Aerosols:
Results from the Southeastern Center for Air Pollution & Epidemiology

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Air Pollution Health Effects

- Strong evidence for health effects of ambient air pollution, including PM, PM components, and criteria gases

**Respiratory**
- Coughing, wheezing, reduced lung function
- Exacerbation of asthma, COPD
- Lung cancer
- Respiratory mortality

**Central Nervous**
- Cerebrovascular impairment
  - Stroke (?)

**Cardiovascular**
- Systemic inflammation
  - Autonomic system disorder (HRV reduction, HR increase, dysrhythmias)
  - Atherosclerosis
  - Myocardial infarctions
  - CV mortality

**Reproductive**
- Low birth weight
- Preterm births and intrauterine growth retardation (?)
  - Birth defects (?)
Health Relevance of Organic Aerosols

• Increasing recognition of the health relevance of organic aerosol

• Particulate organic carbon (OC) comprises a substantial portion PM$_{2.5}$, and has been associated with adverse health effects

• Other organic aerosols, including OC species or volatile organic compounds (VOCs), have received less attention

• In general, data limitations have hindered their assessment

• Their assessment presents
  - Classic epidemiologic challenges: study design, model selection, co-pollutant confounding, exposure measurement error
  - Special considerations: different measurement methods; mixtures of gases and particles, many species, from primary and secondary sources
Organic Aerosol Data used in Health Studies

• Measurements at monitoring sites or on subjects, e.g.
  - Particle-phase total OC (e.g., filter samples analyzed via TOR/TOT)
  - Particle-phase non-polar organic compounds (e.g., filter samples analyzed via TD-GCMS)
  - Volatile organic compounds (e.g., air samples analyzed via GC-FID)

• Modeled indices of multi-pollutant mixtures containing organic aerosols, e.g.
  - PM$_{2.5}$ source apportionment $\rightarrow$ high OC content sources
  - PM$_{2.5}$ oxidative potential
Health Study Design?

• Broadly depends on
  - Outcomes of concern (e.g., disease exacerbation vs. onset)
  - Exposure data availability

• Short-term (acute) effects studies
  - Consider short-term temporal variability in pollution (e.g., 1-5 days)
  - Outcomes and exposures compared over time
  - Population-based time-series studies of mortality, hospitalizations
  - Small panel studies of subjects followed repeatedly over short period

• Chronic effects studies
  - Consider long-term spatial/inter-individual variability in pollution (annual, multi-year)
  - Outcomes and exposures compared across communities or individuals
  - Large cohort studies of subjects followed over many years
Time-Series Studies

- Examine associations between daily air pollution concentrations and daily counts of health outcome (morbidity or mortality)

'EXPOSURE':
Daily ambient PM$_{2.5}$ concentrations

OUTCOME:
Daily counts of ED visits for asthma

CONFOUNDERS: time trend, day-of-week, holidays, hospital entry/exit, temperature, dew point
Southeastern Center for Air Pollution and Epidemiology (SCAPE)

- USEPA Clean Air Research Center
- Co-directors: Paige Tolbert (Emory), Ted Russell (Georgia Tech)
- Objective: to improve our understanding of how air pollutant mixtures impact health, using field measurements, modeling and epidemiologic approaches
- Project 4: Multi-City Morbidity Study
  - Extends single-city work in Atlanta, Dallas, and St. Louis (initiated previous to SCAPE with funding from EPRI, USEPA, NIH) to 5 cities
Model Selection: Lag Structure, Concentration-Response Shape?

• Long-term daily monitoring conducted at Atlanta Jefferson St. Site (1998-present)
• Previous analysis of 1998-2004 data
• Significant warm-season OC associations with pediatric asthma ED visits
• Suggestion of non-linearity and possibly longer lags important
• Attenuated with control for $O_3$

Co-Pollutant Confounding?

- Speciated PM$_{2.5}$ measurements collected at St. Louis Supersite at Tudor St., 2001-2003
- Epidemiologic results similar to those observed in Atlanta
- Carbon components more strongly associated with cardiovascular than respiratory outcomes

• Assessed correlations of pollutant data available at multiple monitoring sites in St. Louis to provide an indication of spatiotemporal heterogeneity
  - 4-14 sites, depending on pollutant
• Positive trends between the median inter-site correlations and observed RRs across pollutants for asthma outcome
• Suggests downward bias of observed RRs for pollutants with higher spatiotemporal variability
• Consistent with work in Atlanta
  - Simulation studies (Goldman et al., 2010, 2011, 2012)
  - Application of modeled spatially-resolved AQ data (Sarnat et al., 2013)

Impact of EC/OC Measurement Methods?

• Two common EC/OC measurement methods
  – Thermal optical transmittance (e.g., NIOSH method)
  – Thermal optical reflectance (e.g., IMPROVE method)
  – Differ in how carbon particles are apportioned to EC and OC

• Speciation Trends Network changed from NIOSH-like to IMPROVE method during 2007-2009

• Examined impact of measurement method on observed epidemiologic results in St. Louis

• Associations of ED visits and EC/OC from the two methods generally concordant

• But, differences in warm-season EC associations
  – May reflect differences in composition of PM assigned to EC and OC
  – EC from IMPROVE shown to include more biomass burning-related OC and secondary organic aerosols than EC from NIOSH

Modeled Indices of Mixtures that Contain Organic Aerosols: E.g., PM$_{2.5}$ Oxidative Potential

- Oxidative stress, an imbalance of antioxidants and oxidants in the body, is a mechanism through which PM$_{2.5}$ may adversely impact health
  - Due to oxidants carried to lungs, or
  - Due to potential for inhaled aerosol to generate reactive oxygen species (ROS)
- Weber group has worked on two different antioxidant assays that measure PM$_{2.5}$ OP via antioxidant depletion in vitro
  - Dithiothreitol (DTT), chemical surrogate of cellular reductants
  - Ascorbic acid (AA), a physiological antioxidant found in lung lining fluid
- During SCAPE, collected detailed aerosol measurements on ~200 days at Atlanta Jefferson St. site during 2012-2013, including DTT and AA
- For retrospective epidemiologic studies, develop prediction models for DTT and AA in order to back-estimate PM$_{2.5}$ OP
  - First approach developed such models based on PM$_{2.5}$ source apportionment data
Health Associations with Back-Casted Estimates, Atlanta 1998-2012

- DTT activity associated with asthma and CHF ED visits
- Associations with AA activity weaker or null
- DTT activity strongly correlated with multiple ROS-active pollutants (organic species, water-soluble metals) while AA primarily reflects copper
- DTT a promising integrated indicator for multipollutant ROS activity
- Results support hypothesis that oxidative stress derived from ambient air pollution is a pathway to adverse health outcomes
- Developing other approaches to predict and back-cast PM$_{2.5}$ OP in this study


Fang et al., *Atmospheric Chemistry and Physics*, accepted
Other Study Designs for Targeted Questions

E.g., the Dorm Room Inhalation To Vehicle Emissions (DRIVE) study to develop multipollutant indicators of primary traffic pollution (Sarnat J, Russell; PIs); collect intensive data on CO, NO$_2$, NO, BC, OC, and WS-DTT outdoors and indoors at varying distances from traffic hotspot.
Personal Sampling and Biomonitoring Opportunities

- Continuous personal exposure monitor of PM$_{2.5}$
- Integrated sampling of NO$_2$
- GPS monitor
- Questionnaire on daily activity, dietary pattern and health status
- Biomonitoring of weekly saliva sample and monthly blood sample

Metabolomics Analysis
Summary and Considerations for Future Work

• Health studies increasingly assess acute effects of organic aerosols
  – Classic epidemiologic issues: model selection, co-pollutant confounding, exposure error
  – Special considerations: lack of detailed information on atmospheric chemistry, measurement method impacts, multi-pollutant mixtures

• Few if any long term studies of organic aerosols

• Future measurements for health studies should be designed to take advantage of temporal and/or spatial contrasts
  – For population-based acute effects setting, information on daily levels is critical
  – For panel-based setting, measurement methods that can be used in diverse microenvironments, with low detection limits given lower collected mass on personal samples
  – For long-term cohort studies, models that can accurately predict individual-level long-term concentrations at residences or where subjects spend time
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