The Fresno Asthmatic Children's Environmental Study (FACES) Exposure Assessment

Focus on PAHs
(Polycyclic Aromatic Hydrocarbons)

Particulate Pollution in the San Joaquin Valley

Translating Science into Policy

San Joaquin Valley Air Pollution Control District
Fresno, CA
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University of California, Berkeley
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Why the FACES study?

- Very little data on which asthmatics are susceptible to air pollutants
- Explore in detail air pollutants that have not been studied with respect to exacerbations of asthma
- No data on the relationship between the responses to short-term exposures and the long-term progression of asthma in children
The Fresno Asthmatic Children’s Study: FACES

FACES is focused on the determination of the effects of chronic exposure to air pollution, in combination with bioaerosols, on the progression of childhood asthma.
What were the study methods?

- Recruited 315 children ages 6-11
- Air quality monitoring
- Symptom and lung function monitoring
- Office visits
- Eight years of data collection (2000-2008)
Recruit Children Ages 6-11 With Asthma: Longitudinal Component

- Baseline health evaluation
  - Spirometry with bronchodilator
  - Skin testing
  - Dietary evaluation
  - Buccal cells (family)
- Six month clinic visit with spirometry
- Three-monthly telephone contact
FACES: Acute Component
14 Day Panels

- Three times/year during different seasons
- Health assessment
  - Daily diary
  - 2x daily spirometry
- Exposure assessment
  - Passive 2 week samples: \( \text{O}_3 \), \( \text{NO}_2 \), nicotine
  - Dust: allergens, endotoxin
  - Home survey
FACES

Short Term Exposure to Pollutants

↓

Acute Exacerbation of Asthma

↓

Altered Progression of Asthma
Exposure Assessment Tailored to an Epidemiology Study, FACES

- Focus is *progression* of asthma
- Relationship between *daily* exposures and acute symptoms, medication use, pulmonary function
- Relevant exposure is *daily*, but for 8 years
- 315 subjects--children with asthma
Measurements and Models to Generate Individual-Level Exposure Estimates

Each child
Every Day
8 Years
Effect of Exposure Misclassification on Estimates of Relative Risk

Relative Risk: \[\frac{\frac{10}{1000}}{\frac{2}{1000}} = 5\]
Effect of Exposure Misclassification on Estimates of Relative Risk

Relative Risk: \[\frac{\frac{10}{1000}}{\frac{2}{1000}} = 5\]
Effect of Exposure Misclassification on Estimates of Relative Risk

Relative Risk:

\[
\frac{\frac{10}{1000}}{\frac{2}{1000}} = 5 \\
\frac{\frac{8}{1000}}{\frac{4}{1000}} = 2
\]
Each Child's Exposure on each day + Each Child's Exposure on each day

Relationship between Exposure and Health Outcome
Agents of Interest

- Particles by size $\text{PM}_{2.5}$, $\text{PM}_{10}$, $\text{PM}_{10-2.5}$
  - Mass
  - Organic carbon/Elemental carbon
  - Sulfate, nitrate, & ammonium ions
  - Metals, potassium
Agents of Interest

- Gases
  - NO, NO$_2$, NO$_3$
  - Ozone
  - SO$_2$
Agents of Interest

- **Biological agents**
  - Pollen grains
  - Fungal spores
  - Endotoxin—both airborne & in house dust
  - Allergens in house dust
    - Dust mites
    - Cat dander
    - Dog dander
    - Cockroach eggs
Agents of Interest

- Second Hand Smoke
- Polycyclic Aromatic Hydrocarbons (PAHs)
Overview of Exposure Assessment

- **Temporal** - Daily Samples at EPA Supersite (aka “central site” or First Street)

- **Spatial Relationships** - Measurements and modeling

- **Exposure** - based on microenvironmental concentrations and time-location-activity information from diaries and GPS
Overview of Air Sampling for FACES

**EPA Supersite**
- Hourly and daily collection of target agents

**Panel Studies**
- (all homes, ~ 7-8 times each)
  - Two week integrated sample for NO₂, O₃, nicotine
  - Dust from floors and bed---allergens & endotoxin
  - Home survey

**Homes**

**Home Intensive Study**
- (At 83 homes, 36 twice,)
  - Continuous PM for 2 weeks
  - 24 hr samples
  - Indoors and outdoors at each home on 5 days during 2 week panels

**Schools & Neighborhoods**

**Trailer**

**Trailer**
Location of Schools Studied, CARB
Sampling Sites & the US EPA Supersite
Home Intensive Component

- Conducted during panel study, February 6, 2002 - February 8, 2006
- Subset of panel homes, 4 - 5 per panel
- 24 hour sampling, 8 pm - 8 pm
- 5 days in two week period
- Indoors and outdoors
- 113 sets of home intensive samples collected (83 homes) sampled
This box contains nephelometer, CO monitor, and Temperature sensor.

There are 5 silver air samplers, connected to the pump by long tubes.

This box contains equipment that collects pollen and spores from the air.

The pump in this box runs for five 24-hour periods over two weeks (8 pm to 8 pm). It is controlled automatically by a timer.
Overview of Air Sampling for FACES

**Panel Studies**
(all homes, ~ 7-8 times each)

- Two week integrated sample for NO₂, O₃, nicotine
- Dust from floors and bed--allergens & endotoxin
- Home survey

**Homes**

- Continuous PM for 2 weeks
- 24 hr samples
- Indoors and outdoors at each home on 5 days during 2 week panels

**Home Intensive Study**
(At 83 homes, 30 twice,)

**EPA Supersite**
Hourly and daily collection of target agents

**Trailer**

**Schools & Neighborhoods**

**Trailer**
## Exposure Assessment for FACES

### Outdoor Samples

<table>
<thead>
<tr>
<th>Central Site</th>
<th>Schools</th>
<th>Homes</th>
<th>Homes</th>
<th>Homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>US EPA Supersite</td>
<td>Trailers</td>
<td>Home Intensive</td>
<td>Home Intensive</td>
<td>Panels</td>
</tr>
</tbody>
</table>

- **Hourly and Daily**
  - Hourly and Daily
  - 24 hour
  - 24 hour
  - 2 weeks & grab

- **Daily**
  - Daily
  - 5 days in 2 weeks
  - 5 days in 2 weeks
  - All homes at least 1 / season

**Note:**
- **11/00 - 10/08**
- **14 months**
- **5/02-8/03**
- **80 homes**
Exposure Model

- *Daily* data from the Central Site
- *Spatial* relationships between the Central Site concentrations and those measured at specific homes, in specific neighborhoods, or types of neighborhoods
- *Indoor/outdoor* relationships for types of homes
- *Home specific* data for indoor sources of selected agents
- *Time-location-activity* data for participants
## FACES Continuous Measurements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Central Site</th>
<th>Outdoors</th>
<th>Indoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$<em>{2.5}$ &amp; PM$</em>{10}$ Mass (BAM)</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
<tr>
<td>PM$<em>{2.5}$ &amp; PM$</em>{10}$ Mass (TEOM)</td>
<td>1-hr</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Black Carbon (1-λ,7-λ Aeth)</td>
<td>1-hr</td>
<td>1-hr*</td>
<td>-</td>
</tr>
<tr>
<td>PM$_{2.5}$ EC &amp; OC (R&amp;P)</td>
<td>1-hr</td>
<td>1-hr*</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total particle-bound PAH</strong> (EcoChem)</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
<tr>
<td>PM$_{2.5}$ NO$_3$ &amp; SO$_4$ (R&amp;P)</td>
<td>1-hr</td>
<td>1-hr*</td>
<td>-</td>
</tr>
<tr>
<td>Particle Number (TSI CPC)</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
<tr>
<td>Particle Size (SMPS)</td>
<td>1-hr</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Light Scattering (Radiance Res.)</td>
<td>1-hr</td>
<td>1-hr</td>
<td>1-hr</td>
</tr>
<tr>
<td>Ozone</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
<tr>
<td>NO/NO$_2$</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
<tr>
<td>CO</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>1-hr</td>
<td>1-hr</td>
<td>-</td>
</tr>
</tbody>
</table>

* Two mobile trailers monitor at schools – OC/EC and SO$_4$ not measured on both trailers.
## FACES Integrated Measurements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Outdoors</th>
<th>Indoors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central Site</td>
<td>Schools</td>
</tr>
<tr>
<td>PM$<em>{2.5}$ &amp; PM$</em>{10}$ Mass</td>
<td>24-hr/1 in 6</td>
<td>-</td>
</tr>
<tr>
<td>PM$_{2.5}$ NO$_3$ &amp; SO$_4$</td>
<td>24-hr/1 in 6</td>
<td>-</td>
</tr>
<tr>
<td>PM$_{2.5}$ OC &amp; EC</td>
<td>24-hr/1 in 6</td>
<td>-</td>
</tr>
<tr>
<td>Speciated PAHs (16)</td>
<td>24-hr/2 in 14*</td>
<td>24-hr/2 in 14*</td>
</tr>
<tr>
<td>PM$_{10}$ Metals</td>
<td>24-hr Daily</td>
<td>24-hr Daily</td>
</tr>
<tr>
<td>PM$_{10}$ Endotoxins</td>
<td>24-hr Daily</td>
<td>24-hr Daily</td>
</tr>
<tr>
<td>Pollen Grains</td>
<td>2-hr Daily</td>
<td>2-hr Daily</td>
</tr>
<tr>
<td>Fungal Spores</td>
<td>2-hr Daily</td>
<td>2-hr Daily</td>
</tr>
<tr>
<td>Dust Allergens</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nicotine</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ozone</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

# Integrated samples collected from 8 PM – 8 PM for use with daily symptom data

* 1-year Home Intensive Sampling
PAHs in Fresno

- What are PAHs?
- What are the main sources?
- Why are we interested in PAHs?

Gas, by Edward Hopper 1940
Structure of PAHs

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo[a]anthracene
- Benzo[a]pyrene
- Benzo[b]fluoranthene
- Benzo[ghi]perylen
- Benzo[k]fluoranthene
- Chrysene
- Dibenz[a,h]anthracene
- Dibenz[a,h]pyrene
- Fluoranthene
- Fluorene
- Indeno[1,2,3-cd]pyrene
- Naphthalene
- Phenanthrene
- Pyrene
Characteristics of Airborne PAHs

- Most PAHs are neighborhood-level air pollutants, large number of samples needed.

- PAHs are sampled using active samplers
  - filters only (homes)
  - filters + denuders (Supersite and schools)
  - Continuous sampler (Supersite and schools)
Chemcombs
# Exposure Assessment for FACES

## Central Site

<table>
<thead>
<tr>
<th>Carbohydrate (CARB)</th>
<th>United States Environmental Protection Agency (USEPA)</th>
<th>USEPA/NUATRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>EcoChem PAS2000</td>
<td>Chemcomb (denuders + filters)</td>
<td>Filters</td>
</tr>
</tbody>
</table>

## Outdoor Samples

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<td>Home Intensive</td>
<td>Panels</td>
</tr>
<tr>
<td>11/00 - 10/08</td>
<td>14 mo 6/02-8/03</td>
<td>2/02 – 2/03</td>
<td>2/02 – 2/03</td>
<td></td>
</tr>
</tbody>
</table>

### Hourly and Daily

- **PAHs**: 7/02 – 2/03
- **EcoChem PAS2000**: 7/02 – 2/03

### Indoor Samples

- **Hourly and Daily**
- **24 hour**
- **2 weeks & grab**
- **5 days in 2 weeks**: 80 homes
- **5 days in 2 weeks**: 80 homes
- **All 300 homes at least 1 / season**
Temporal Variability Particle-Phase PAHs

EcoChem PAS 2000
Benzo (a) Pyrene Concentration
July 2002 to February 2003

Sampling Date

BAP Conc. (ng/m³)

Central Site
Trailer #1
Trailer #2
PAHs in Fresno on January 1, 2003

(Copper Hills School)
FACES Participants

Legend
- HI homes
- all FACES homes
- US EPA SuperSite

- Highways
- major roads

Land use
- Urban
- Agriculture
- Semi-agricultural
- Native vegetation
- Waterways
Spatial Data

- Locations sampled on a given day
  - Supersite
  - Two schools
  - Home Intensive—up to 5 homes (matched indoors)

- Timing
  - Continuous, daily data (PAS 2000)
    - Central Site, 2000 – ongoing
    - Schools July 2002 – August 2003
  - Integrated 24 hour samples
    - Supersite July 2002 – August 2003
    - Schools May 2002 – August 2003
    - Homes February 2002 - February 2003
      - 2-5 homes at a time, 5 days/2 weeks [497 samples + QC]
Spatial Variation of PAHs in Fresno
Phenanthrene Concentration Outside Fresno Homes, ng/m³

Concentration of Phenanthrene, ng/m³

0 5 10 15 20 25 30 35

Dates:
- 12/25/2001
- 2/13/2002
- 4/14/2002
- 5/24/2002
- 7/13/2002
- 9/12/2002
- 10/21/2002
- 11/9/2003
- 5/20/2003
Spatial Variables Used for Filter Based PAH Model

- **Traffic related variables**
  - Distance to Highway 99
  - Distance to nearest Minor Collector road
  - Distance to nearest Major Arterial road
  - Length of highway within 100 meter buffer

- **Land use variables**
  - Total agricultural area within 500 meter buffer
  - Total industrial area within 200 meter buffer

- **Other spatial variables**
  - Distance to EPA supersite
  - Direction to EPA supersite
  - Total agricultural burning within 5 miles on day of sampling
Individual Exposure Estimates for Phenanthrene on February 5, 2002

Legend
2/5/2002, n=149
est.PHE ng/m3
- 4.3 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 25.0
- 25.1 - 35.0

FSF
Highways
major roads
land use
Urban
Agriculture
Semi-agricultural
Native vegetation
Waterways

0 1 2 4 Miles
Individual Exposure Estimates for PAH456 on November 22, 2003
Temporal Distribution of Individual Exposure Estimates for PAH456
for all FACES participants on all days
(November 2000 through February 2007)
Conclusions from Modeling

- Longitudinal analysis, especially mixed modeling, is advantageous for modeling daily individual exposure estimates using temporally- and spatially-rich datasets.

- PAH456 & PHE concentrations and ratios fluctuate significantly within a metropolitan region. The use of a single central monitor value would simplify the variability in the daily individual exposure estimates.

- PAH456 & PHE concentrations in greater Fresno, CA are dependant on the PAH concentrations at a central monitor (US EPA Supersite), meteorological conditions, and source proximity.
Summary—Goals

- Exposure assessment for FACES aims to evaluate exposure for each child on each day over 8 years.
- Both temporal and spatial variability important.
- Temporal variability captured with monitoring at USEPA Supersite/ARB.
Conclusions—Spatial Variability

Spatial variability modeled using:

- Air concentrations of total particle-bound PAHs measured continuously for 8 years at Supersite (EcoChem, PAS2000)
- Air concentrations of 16 target PAHs collected on filters & denuders at Supersite, homes, and schools on selected days, 2002-2003
  - up to 8 locations/day
  - Samples collected c. 2 days/week over 1 year
  - ~ 700 samples
- Pine needles collected concurrently at 100 locations
FACES Research Questions

- **Acute effects**: in children who have asthma, in what ways and under what conditions (host factors and exposure conditions) do ambient air pollutants contribute to *acute* worsening of asthma (symptoms and lung function)

- **Chronic effects**: are children whose asthma is made worse by daily increases in air pollution more likely to have severe asthma and/or decreased lung function growth as they get older?
Locations of FACES Participants and the US EPA Supersite.
The Use of Pine Needles to Evaluate Spatial Distribution of PAHs
Vegetation Biomonitoring in Fresno

- Innovative way to understand spatial differences in PAH concentration
- Comparatively inexpensive to sample
- Jeffrey Pine trees distributed throughout the city
- Used for individual-level exposure estimates for PAH
Sampling sites for Pine Needles
February 20, 2008
PAH Distribution Profile in Pine Needles
Fresno, CA
Spatial Distribution of Phenanthrene on Pine Needles

February 20, 2008 in Fresno, CA
Spatial Distribution of Chrysene on Pine Needles

February 20, 2008 in Fresno, CA
Spatial Distribution of Benzo[a]pyrene on Pine Needles

February 20, 2008 in Fresno, CA
### Pine Needle Results
February 20, 2008, ng/gram fresh weight

<table>
<thead>
<tr>
<th>Compound</th>
<th>N</th>
<th>% below LOQ</th>
<th>mean</th>
<th>stddev</th>
<th>CV</th>
<th>median</th>
<th>ratio 90:10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenanthrene</td>
<td>91</td>
<td>0%</td>
<td>41.0</td>
<td>28.47</td>
<td>0.69</td>
<td>36.86</td>
<td>3.3</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>91</td>
<td>0%</td>
<td>10.7</td>
<td>7.12</td>
<td>0.67</td>
<td>9.90</td>
<td>5.0</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>91</td>
<td>8%</td>
<td>1.7</td>
<td>1.38</td>
<td>0.83</td>
<td>1.28</td>
<td>6.6</td>
</tr>
<tr>
<td>Chrysene</td>
<td>91</td>
<td>0%</td>
<td>5.94</td>
<td>4.47</td>
<td>0.75</td>
<td>5.20</td>
<td>5.9</td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>91</td>
<td>13%</td>
<td>1.38</td>
<td>1.38</td>
<td>1.00</td>
<td>0.97</td>
<td>22.1</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>91</td>
<td>53%</td>
<td>0.44</td>
<td>0.53</td>
<td>1.21</td>
<td>0.24</td>
<td>16.1</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>91</td>
<td>35%</td>
<td>1.34</td>
<td>1.62</td>
<td>1.21</td>
<td>0.82</td>
<td>34.9</td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>91</td>
<td>22%</td>
<td>1.18</td>
<td>1.30</td>
<td>1.11</td>
<td>0.80</td>
<td>23.8</td>
</tr>
<tr>
<td>Dibenz[a,h]anthracene</td>
<td>91</td>
<td>36%</td>
<td>0.87</td>
<td>1.40</td>
<td>1.61</td>
<td>0.40</td>
<td>47.3</td>
</tr>
<tr>
<td>Benzo[g,h,i]perylene</td>
<td>91</td>
<td>13%</td>
<td>1.17</td>
<td>1.11</td>
<td>0.95</td>
<td>0.81</td>
<td>20.3</td>
</tr>
</tbody>
</table>
Land Use Regression of Phenanthrene

Spatial variables in model building:

- Traffic
- Land Use
- Industrial sources
- Other sources
- Neighborhood characteristics
Phenanthrene Regression Model

- 4 traffic variables
- Agricultural burning
- 1 other source variable
- 2 land use variables
- 5 neighborhood variables

\[ R^2 = 0.70 \]
Agents of Interest

- **Particles by size**
  - PM$_{2.5}$, PM$_{10}$
    - Mass
    - OC/EC
    - Sulfate, nitrate, & ammonium ions
    - Metals, potassium

- **Gases**
  - NO, NO$_2$
  - Ozone
  - SO$_2$

- **Biological agents**
  - Pollen grains
  - Fungal spores
  - *Airborne endotoxin*
  - Allergens in house dust
    - Dust mites
    - Cat dander
    - Dog dander
    - Cockroach eggs

- **Second hand smoke**

- **PAHs**
Each Child’s Exposure on each day

Relationship between Exposure and Health Outcome
Acknowledgement of Funders

California Air Resources Board, 2000-2005 (Contracts Nos. 99-322 and 99-323), The statements and conclusions in this presentation are those of the author and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

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