The Road to PM Understanding

“Are we there yet?

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Health Effects Institute
The Road to PM Understanding

• The Questions in 1997
• The Road We’re On
• Progress and the Roads Not Yet Traveled
  • Epidemiology
  • Exposure
  • Mechanisms and Susceptibility
  • Toxicity of PM Components and Sources
• Are we there yet?
The Questions in 1997

1. How strong is the short and long term epidemiology?
   • Statistics, other pollutants, harvesting, exposure

2. Exposure
   • Do central monitors represent personal exposure?

3. Mechanisms and Susceptibility
   • Can there be a plausible biological mechanism?
     Who’s affected?

4. Are all particles created equal?
   • The toxicity of PM components and sources
The Straight and Narrow Road
A General Framework for Integrating PM Research from the NAS report on PM research Priorities 2004

Sources → Ambient PM → Personal Exposure → Dose → Health Effects
The Real Route
AAA Never Saw Anything Like It

- Sources
  - Ambient PM
    - Infiltration
    - Gases
      - Toxics
    - Species
    - Personal Exposure
      - Dose
        - Susceptibility
          - Health Effects
            - Heart
            - Lung

- Atmospheric Transformation
- Weather
Measuring Progress

• Good Science is messy and takes time
  • Multiple paths (and dead ends…)
  • Understanding grows with the number of studies

• The NRC Committee identified a 13-year plan in 1998
  • We are only 6 years into that

• We are going to be at the PM NAAQS for 10 - 20 years
  • SIPs, NAAQS reviews, Accountability
1. Epidemiology
The Questions in 1997

• Could the time series studies be right?
  • Statistical methods
  • Other pollutants, PM sizes
  • Exposure
  • “Harvesting”

• Could the few longer term studies withstand close scrutiny?

• NRC Topics 7, 10
Epidemiology:  
*Progress on Short Term Effects*

- Systematic Multi-city studies
  - National Morbidity, Mortality and Air Pollution (NMMAPS) funded by HEI
  - APHEA in Europe funded by EU
- More studies with PM2.5, and the gaseous pollutants
- First efforts on components, sources
NMMAPS
The Original Results (HEI 2000)

• Relatively Consistent Increase in Mortality:
  • 0.4% per 10 μg/m³ of PM$_{10}$
• Smaller results than previous U.S. analyses
• Apparently not sensitive to inclusion of other pollutants
• Enhanced confidence in results
• Some continuing questions
  • Especially different results in different regions
NMMAPS
Concentration - Response for the 20 Largest US Cities
(Daniels et al HEI 2004)
**Epidemiology: Progress on Long-term Effects**

- Reanalysis by HEI of two major long-term studies
  - Harvard 6 Cities and American Cancer Society (ACS)
- Follow-up of the ACS cohort (JAMA 2002)
- A few additional studies reported
  - Southern California Children’s Study
  - Veteran’s Study
  - Netherlands Cohort Pilot Study
Reanalysis Results
Sensitivity Analyses with Additional Variables

• Overall, the reanalysis:
  • Assured the quality of the data
  • Replicated the original results,
  • Tested those results against alternative explanations without substantively altering the original findings of an association between indicators of particles and mortality

• However, also identified:
  • Relationship with education
  • Effects of SO2

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<th>PM2.5</th>
<th>Sulfates</th>
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<td>1.15(1.09,1.21)</td>
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Reanalysis Results
ACS Cardiopulmonary Mortality PM$_{2.5}$
Epidemiology: Continuing Challenges

- Need for continuous improvement in time series models, how to deal with weather
- We need more long-term studies
  - Still only a handful
- The gases have not gone away
  - Do not seem to eliminate PM effect
  - But several also show associations (SO2, NO2)
  - Does this mean independent effects? A surrogate for something else? Co-effects?
The Time Series Models Challenge (GAM)
NMMAPS: Revised Results

Original Results

Revised Results

% Change in Mortality per 10 µg/m² Increase in PM₁₀

%/10µg/m³
Revised Analysis

- Over 30 studies identified by CASAC, EPA for reanalysis
- Mean estimates of effects in revised analyses generally smaller
  - 5% to 35% reduction
- Effect for PM10 still does not appear to be affected by co-pollutants
- Reanalyses renewed questions about the role of other factors (especially weather)

**HEI Review Panel Bottom Line:**
- Studies continue to find associations with PM
  - some benefits estimates will be smaller
- Need for continuous improvement
2. Exposure

- Sources
- Ambient PM
- Personal Exposure
- Toxics
- Infiltration
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- Lung
- Heart
- Susceptibility
- Susceptibility
- Atmospheric Transformation
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Exposure Progress

• Can central monitors reflect actual personal exposure? (NRC Topics 1, 2)
  • Few studies available in 1997
• A number of new studies now completed
  • EPA, HEI, API, EPRI
  • Outdoor, indoor and personal monitors
  • Elderly, children, asthmatics
• Outdoor PM contributes significantly to PM exposure
  • Other sources not correlated day-to-day with PM
Tracers of Outdoor Contribution to Indoor PM (RIOPA)

S used as a tracer to determine the contribution of outdoor PM to indoor PM (Outdoor contribution to indoor PM = $S_{in}/S_{out} \times PM_{out}$).

S tracer for regional PM

In RIOPA, indoor and outdoor EC are highly correlated.

Few homes appear to have indoor sources of EC.

EC tracer of local combustion.

R² = 0.70

$S_{in}/S_{out} = 0.74$ on average

Courtesy of B Turpin (RIOPA study), presented at AAAR 2003 PM Colloquium
Exposure: Continuing challenges

- Need to expand:
  - the number of subjects
  - the types of potentially susceptible individuals
- Better measurement of components and sources of personal exposure
  - NRC Topic 2
- New measurement techniques
  - to enhance ability to detect exposures
  - at lower cost with more precision
3. Mechanisms and Susceptibility

- Sources
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- Heart
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Mechanisms/Susceptibility Progress

• 1997: Few studies suggesting plausible mechanisms
  • NRC Topics 6, 8, and 9
• Today:
  • Many potential pathways
  • Some toxicology or epidemiology for each
• Growing number of potential susceptibles
  • Elderly, children
  • Lung disease
  • Cardiovascular disease
• Other diseases (e.g. diabetes found by Goldberg (2000), confirmed by Zanobetti (2002))
Mechanisms/Susceptibility: Continuing Challenges

• We are in the early stages
  • Latest draft CD notes this in Chapters 7 and 8
  • Need to look at long term mechanisms
  • Need better dose-response info

• First human controlled exposure studies have shown few or modest effects
  • Need more human data (of necessity initial studies have been in healthy or only mildly ill volunteers)

• Draw more experts from other health fields into air pollution (e.g. CVD)
4. Toxicity of PM Components and Sources

• 1997 questions (NRC Topic 5):
  • Is all PM equally toxic?
  • How can we ensure that we control the components and sources with the highest public health effects?

• Progress
  • More epidemiology and toxicology studies on this topic
  • To date:
    • High dose toxicology - most things toxic
    • Many correlated components in epidemiology
    • As yet, few systematic approaches
Toxicity of Components and Sources

Challenges

• Many empty boxes in the “matrix”
• Systematic approaches:
  • Tox: comparable tests of all components; realistic exposures
  • Epi: systematic multi-city approaches
  • Better tools for linking effect, components, gases, and sources
5. Tools for Source Apportionment

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- Weather
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Tools for Source Apportionment
A Challenge Going Forward

• A key challenge for successful implementation of PM SIPs, controls
  • NRC Topics 3 and 4
• Need:
  • Enhanced emissions characterizations and factors for all primary and precursor emissions
  • Improved models for source apportionment and assessment of potential control strategies
Are we there yet?

- Atmospheric Transformation
- Sources
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- Gases
- Personal Exposure
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- Susceptibility
- Lung
- Heart
- Susceptibility

- Infiltration
- Species
- Dose

- Health Effects
Are we there yet?

- We’ve made progress on the road to PM understanding
- We know more about:
  - The epidemiology
  - Exposure
  - A series of possible mechanisms and susceptible populations
Are we there yet?

- To reach our final destination – *cost effective public health strategies for PM over the next 10 years* – we will need:
  - Continuous improvement in epidemiology (models, more long term studies)
  - Improved mechanistic understanding (dose-response, long term)
  - A systematic approach to toxicity of PM components and sources (and the gases!!!)
  - Enhanced tools for source apportionment
Thank You!

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