Integrated Science Assessment for Particulate Matter (1st External Review Draft)

Presentation to the Clean Air Scientific Advisory Committee
NCEA-RTP PM ISA TEAM

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PM ISA Organization

Chapter 1: Introduction
Chapter 2: Integrative Overview
Chapter 3: Source to Exposure
Chapter 4: Dosimetry
Chapter 5: Mode of Action
Chapter 6: Integrated Health Effects of Short-term PM Exposure
Chapter 7: Integrated Health Effects of Long-term PM Exposure
Chapter 8: Public Health Impacts
Chapter 9: Welfare and Ecosystem Effects

Annexes (more detailed summaries of evidence)
A: Atmospheric science and exposure
B: Dosimetry
C: Human clinical
D: Toxicology
E: Epidemiology
Overarching Charge Questions

- The framework for causal determination and judging the overall weight of evidence is presented in Chapter 1. Is this framework appropriately applied for this PM ISA? How might the application of the framework be improved for PM effects?

- Chapter 2 presents the integrative summary and conclusions from the health effects evidence at the beginning of the ISA with the evidence characterized in detail in subsequent chapters. (Environmental and public welfare effects evidence is evaluated and summarized in Chapter 9.) Is this a useful and effective summary presentation? How does the Panel view the inclusion in Chapter 2 of only health categories with causal determinations of (a) likely to be a causal relationship or (b) a causal relationship?

- This first external review draft PM ISA is of substantial length and reflects the copious amount of research recently conducted on PM. EPA has attempted to succinctly present and integrate the policy-relevant scientific evidence for the review of the PM NAAQS. Does the Panel have opinions on how the document can be shortened without eliminating important and necessary content?
Framework for Causal Determination

Weight of Evidence for Causal Determination

• Causal relationship
• Likely to be a causal relationship
• Suggestive of a causal relationship
• Inadequate to infer a causal relationship
• Suggestive of no causal relationship

Page 1-22 of the PM ISA includes a table describing these causal categories and provides examples for health effects and ecological and welfare effects.
Chapter 3 Charge Questions

• To what extent are the atmospheric chemistry and air quality characterizations clearly communicated, appropriately characterized, and relevant to the review of the PM NAAQS?

• Does the information on atmospheric sciences and exposure provide useful context and insights for the evaluation of human health effects of PM in the ISA?
National Scale Variability

2005-07 County-average PM$_{2.5}$
- Highest PM$_{2.5}$ concentrations reported in the San Joaquin Valley, Inland Southern California, Birmingham and Pittsburgh.
- 540 of 3,225 U.S. counties contain qualifying PM$_{2.5}$ data in AQS.

2005-07 County-average PM$_{10-2.5}$
- Based on collocated low-volume FRM monitors.
- Poor geographic coverage where these measurements were available (40 counties).
Regional & Urban Scale Variability

15 metro areas covered in detail

- \( \text{SO}_4^{2-} \) higher in the east
- \( \text{NO}_3^- \) higher in CA and upper Midwest
- OCM higher in the west and southeast
- Crustal important in Phoenix
- EC accounted for 4-11% of PM\(_{2.5}\)

- Generally uniform concentrations & high correlations for PM\(_{2.5}\)
- Spatial variability differs by city and is a function of terrain, source proximity, street canyon effects and meteorology
Exposure Assessment

- Ambient component of personal exposure to PM correlates well with ambient concentrations; non-ambient component does not.

\[
A_{2.5} = 0.76 C_{2.5} - 0.93 \\
R^2 = 0.62
\]

\[
N_{2.5} = 0.004 C_{2.5} + 8.47 \\
R^2 = 0.00
\]


- Exposure error influences health effect estimates and is partially dependent on:
  - Monitor siting and selection
  - Differential infiltration
  - Activity patterns
Chapters 4 and 5 Charge Questions

• Is the review of basic dosimetric principles presented in sufficient detail? Are the new particle translocation data adequately and accurately described? Recognizing an overall goal of producing a clear and concise chapter, are there topics that should be added or receive additional discussion? Similarly, are there topics that should be shortened or removed? To what extent does the Panel find Annex B appropriate, adequate and effective in supporting the ISA?

• Chapter 5 is intended to support the evaluation of health effects evidence for both short-term and long-term exposures to PM. Some potential modes of action may underlie a number of health outcomes and may contribute to health effects of both short- and long-term exposures. Thus, the potential modes of action are described briefly in Chapter 5, and some specific study findings are discussed in more detail in the relevant sections of Chapters 6 or 7. What are the views of the Panel on this approach and on the characterization of potential modes of action for PM-related effects in Chapter 5?
Particle Dosimetry

- Deposition studies generally support prior findings
- Clearance studies provide some new insights
  - Clearance decreases with age post-adolescence
  - Ultrafine particles rapidly (minutes) enter living cells, but do not rapidly enter circulation
  - Rapid movement (hours) of fine and ultrafine particles (various types) from nasal mucosa to olfactory bulb
  - Transport of poorly soluble particles and soluble constituents into the vasculature is increased when the epithelial lining is damaged
Mode of Action: Respiratory Effects

PM Core and Soluble Components

ROS/RNS

Pulmonary Inflammation and Injury

Altered Lung Function

Irritant Receptors

AHR and Airway Remodeling

Allergic Asthma And Other Allergic Disorders

Impaired Host Defense and Infections

Progression of Pre-existing Lung Disease

DNA Damage and Lung Cancer

Death or Hospitalization for Asthma, Pneumonia, COPD and Lung Cancer
Chapters 6 and 7 Charge Questions

- To what extent are the discussion and integration of evidence on the health effects of PM from the animal toxicological, human clinical, and epidemiologic studies, technically sound, appropriately balanced, and clearly communicated? Does the integration of health evidence focus on the most policy-relevant studies or health findings?

- What are the views of the Panel on the conclusions drawn in the draft ISA regarding the strength, consistency, coherence and plausibility of the evidence for health effects of PM?
## Short-Term Exposures to PM and Health Effects

<table>
<thead>
<tr>
<th>Size Fraction</th>
<th>Health Category</th>
<th>Causality Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$</td>
<td>Cardiovascular Morbidity</td>
<td>Causal</td>
</tr>
<tr>
<td></td>
<td>Respiratory Morbidity</td>
<td>Likely to be Causal</td>
</tr>
<tr>
<td></td>
<td>Central Nervous System</td>
<td>Inadequate</td>
</tr>
<tr>
<td></td>
<td>Mortality</td>
<td>Likely to be Causal</td>
</tr>
<tr>
<td>PM$_{10-2.5}$</td>
<td>Cardiovascular Morbidity</td>
<td>Inadequate</td>
</tr>
<tr>
<td></td>
<td>Respiratory Morbidity</td>
<td>Suggestive</td>
</tr>
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</tr>
<tr>
<td>Ultrafine PM</td>
<td>All Outcomes</td>
<td>Inadequate</td>
</tr>
</tbody>
</table>
Short-Term Exposure to PM$_{2.5}$ and Cardiovascular Morbidity

ED Visits and Hospitalizations
• Consistent positive associations of PM$_{2.5}$ with hospital admissions and ED visits for cardiovascular disease, including ischemic heart disease and congestive heart failure.
  ▪ Mean PM$_{2.5}$ concentrations were 13.8-18.8 µg/m$^3$

Other Cardiovascular and Systemic Effects
• Ischemia, HRV changes, altered vasomotor function, and systemic oxidative stress have all been demonstrated in epidemiologic, human clinical, and toxicological studies of PM$_{2.5}$. The evidence demonstrates consistency and coherence across health disciplines, with toxicological studies also providing biological plausibility.

Overall, we conclude that a causal relationship exists between short-term exposure to PM$_{2.5}$ and cardiovascular effects.
Short-Term Exposure to PM\textsubscript{10-2.5} and Respiratory Morbidity

**ED Visits and Hospital Admissions**
- The most consistent evidence is for associations between acute PM\textsubscript{10-2.5} exposure and asthma-related outcomes among children.
- Less consistent evidence among adults.

**Other Respiratory Effects**
- The few epidemiologic panel studies that considered PM\textsubscript{10-2.5} found inconsistent evidence for associations with respiratory symptoms or lung function changes in adults or children.
- Human clinical studies did not find PM\textsubscript{10-2.5} effects on respiratory symptoms or lung function changes, but did report pulmonary inflammation.
- In vivo toxicological studies of PM\textsubscript{10-2.5} reported increases in markers of inflammation and injury with intratracheal instillation exposure.

Overall, we conclude that the relationship between short-term exposure to PM\textsubscript{10-2.5} and respiratory morbidity is suggestive of a causal relationship.
# Long-Term Exposures to PM and Health Effects

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<tr>
<th>Size Fraction</th>
<th>Outcome</th>
<th>Causality Determination</th>
</tr>
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<tr>
<td>PM\textsubscript{2.5}</td>
<td>Cardiovascular Morbidity</td>
<td>Likely to be Causal</td>
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<td></td>
<td>Respiratory Morbidity</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>Reproductive and Developmental</td>
<td>Suggestive</td>
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<td></td>
<td>Cancer</td>
<td>Inadequate</td>
</tr>
<tr>
<td>PM\textsubscript{10-2.5}</td>
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</tbody>
</table>
Long-Term Exposure to PM$_{2.5}$ and Respiratory Morbidity

Epidemiology

• New publications from the Children’s Health Study provide further evidence of PM$_{2.5}$ exposure associated with respiratory symptoms and reduced lung function growth.
  
  ▪ Mean PM$_{2.5}$ concentrations between 12 communities ranged from 5-30 µg/m$^3$.

• Studies conducted in other locations generally support these findings.

Toxicology

• Provides evidence of altered pulmonary function, mild inflammation, oxidative responses, histopathological changes, and airways hyperresponsiveness.

• One study provides coherence for reduced lung function growth that demonstrated impairment of mouse lung development with pre- and post-natal exposure to ambient levels of urban particles.

Overall, we conclude that the relationship between long-term exposure to PM$_{2.5}$ and respiratory morbidity is likely to be causal.
Exposure to PM$_{2.5}$ and Reproductive and Developmental Outcomes

Epidemiology

- Increased risk of low birth weight, preterm birth, and growth restriction related to PM$_{2.5}$ exposure.
  - Strength of the associations greater for PM$_{2.5}$ than for PM$_{10}$.
- Increased risk of infant mortality, especially due to respiratory causes during post-neonatal period.
- Uncertainty exists about the relevant exposure periods for adverse birth outcomes.

Toxicology

- Evidence from toxicological studies shows developmental effects in rodents: immunologic, neurodevelopmental, and behavioral changes.
- Little mechanistic information or biological plausibility for association with PM$_{2.5}$.

Overall, we conclude that the relationship between long-term exposure to PM$_{2.5}$ and reproductive and developmental outcomes is suggestive of a causal relationship.
Chapter 8 Charge Question

• What are the views of the Panel on the definitions of susceptibility and vulnerability in Chapter 8? Are the characteristics included within the broad susceptibility and vulnerability categories appropriate and consistent with the definitions used?
### Public Health Impacts

<table>
<thead>
<tr>
<th>Susceptibility Characteristics&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Vulnerability Characteristics&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age:</strong> children, older adults (65+)</td>
<td>Education level</td>
</tr>
<tr>
<td>Infants: premature, low birth weight</td>
<td>Air conditioning use</td>
</tr>
<tr>
<td><strong>Pregnancy</strong></td>
<td>Proximity to roadways</td>
</tr>
<tr>
<td>Birth defects</td>
<td><strong>Geographic location (West vs. East)</strong></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>Level of exercise</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td>Work environment (e.g., outdoor workers)</td>
</tr>
<tr>
<td><strong>Genetic factors</strong></td>
<td>Socioeconomic status</td>
</tr>
<tr>
<td><strong>Pre-existing disease:</strong> obesity, diabetes, respiratory</td>
<td></td>
</tr>
<tr>
<td>diseases (e.g., asthma), cardiovascular diseases</td>
<td></td>
</tr>
<tr>
<td><strong>Nutritional status</strong></td>
<td></td>
</tr>
</tbody>
</table>

1. Susceptible (i.e., intrinsic) refers to biological characteristics of an individual, which can include life stage, genetics, and pre-existing disease.

2. Vulnerable (i.e., extrinsic) refers to non-biological variables associated with an individual that can result in a health effect.
Chapter 9 Charge Questions

• How useful and complete is the scientific evidence presented and summarized in Chapter 9 regarding the effects of atmospheric PM on the environment, including (a) effects on visibility, (b) effects on individual organisms, (c) direct and indirect effects on ecosystems, (d) effects on materials, and (e) effects on climate?

• To what extent do the discussions and integration of evidence correctly represent and clearly communicate the state of the science?
#### Visibility Impairment

<table>
<thead>
<tr>
<th>Location</th>
<th>Report Date</th>
<th># participants</th>
<th>Source of slides</th>
<th>Visibility range presented</th>
<th>Mean dV found acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denver, CO</td>
<td>1991</td>
<td>214</td>
<td>Actual photos taken between 9am and 3pm</td>
<td>11 to 40 dV</td>
<td>20.3 dV</td>
</tr>
<tr>
<td>Phoenix, AZ</td>
<td>2003</td>
<td>385</td>
<td>WinHaze</td>
<td>15 to 35 dV</td>
<td>23 to 25 dV</td>
</tr>
<tr>
<td>2 British Columbia cities</td>
<td>1996</td>
<td>180</td>
<td>Actual photos taken at 1pm or 4pm</td>
<td>13 to 25 dV (Chilliwack)</td>
<td>~23 dV (Chilliwack), ~19 dV (Abbotsford)</td>
</tr>
<tr>
<td>Washington, DC (pilot)</td>
<td>2001</td>
<td>9</td>
<td>WinHaze</td>
<td>9 to 38 dV</td>
<td>~20 dV (range 20-25)</td>
</tr>
</tbody>
</table>

**Wash, D.C., 5 µg/m³ PM$_{2.5}$**

**Wash, D.C., 35 µg/m³ PM$_{2.5}$ (simulated)**
Effects on Climate

Direct and Indirect Aerosol Effects

- Natural and Anthropogenic Emissions of Particles and Precursor Gases
  - soil, mineral and road dust; sea spray; soot and ashes; POA and VOC, SO₂, etc.

- Atmospheric Aerosols
  - optical properties
  - CCN and IN activity
  - chem. and biol. activity

- Direct Effects
  - Radiation and Temperature
    - absorption and scattering (reflection)
    - solar (UV/VIS) and terrestrial (IR)

- Indirect Effects
  - Clouds and Precipitations
    - water droplets and ice crystals
    - formation, evaporation, deposition

- Atmospheric and Oceanic Circulation, Biogeochemical Cycles
  - mass and heat transport, horizontal and vertical transport, extreme weather events
  - water cycle: surface and ground water, snow and ice, evapotranspiration
  - carbon and sulfur cycle: photosynthesis and decay of biomass, biological metabolisms, biomass burning and fossil fuel combustion, volcanism, etc.
# Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 am</td>
<td>Highlights of Draft ISA and Charge Questions</td>
</tr>
<tr>
<td>9:45 am</td>
<td>Public Comments on <em>Integrated Science Assessment</em></td>
</tr>
<tr>
<td>10:30 am</td>
<td>Break</td>
</tr>
</tbody>
</table>
| 10:45 am | Comments on Charge Question #9 — Environmental effects  
            Comments on Charge Question #1 — Framework  
            Comments on Charge Question #2 — Conclusions and summary |
| 12:15 pm | Lunch                                        |
| 1:00 pm  | Comments on Charge Question #3 — Atmospheric chemistry  
            Comments on Charge Question #4 — Dosimetry  
            Comments on Charge Question #5 — Modes of action  
            Comments on Charge Question #6 — Health effects |
| 3:00 pm  | Break                                        |
|          | Comments on Charge Question #7 — Health effects  
            Comments on Charge Question #8 — Susceptibility and vulnerability  
            Comments on Charge Question #10 — Other general comments |
| 4:45 pm  | Adjourn for Subgroup Writing Sessions         |