Mobile Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects

Northern Transportation and Air Quality Summit
August 14, 2008
Baltimore, MD
HEI Mobile Source Air Toxics Review

• Conducted by Expert Panel
  Expertise in relevant basic and clinical science:
  chemistry
  exposure assessment
  toxicology
  epidemiology
  occupational and environmental health

• Critical review of MSATs
  Identify of highest priority MSATs
  Address key questions
  Reach key conclusions
  Identify research gaps and recommendations

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HEI Air Toxics Review Panel

Thomas Kensler, Chair, Professor, Division of Toxicology, Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health

H. Ross Anderson, Professor of Epidemiology and Public Health, Division of Community Health Sciences, St. George’s Hospital Medical School and Environmental Research Unit, University of London

Michael Brauer, Professor, School of Occupational and Environmental Hygiene, University of British Columbia

Elizabeth Delzell, Professor, Department of Epidemiology, University of Alabama–Birmingham

Mark Frampton, Professor of Medicine and Environmental Medicine, University of Rochester

Helmut A. Greim, Professor, Institute of Toxicology and Environmental Hygiene, Technical University of Munich

Rogene Henderson, Senior Scientist Emeritus, Lovelace Respiratory Research Institute

Brian Leaderer, Susan Dwight Bliss Professor and Vice Chair, Department of Epidemiology and Public Health, Deputy Dean of Yale School of Public Health, and Codirector of the Yale Center for Perinatal, Pediatric and Environmental Epidemiology at the Yale University School of Medicine

William N. Rom, Sol and Judith Bergstein Professor of Medicine and Environmental Medicine and Director of Pulmonary and Critical Care Medicine, New York University Medical Center
Key Questions

Which MSATs are likely to pose the greatest risks at ambient levels of exposure?

- What are the levels of exposure?
  - To what extent are mobile sources a significant source of exposure?
- Does it cause human health effects?
- Does it cause human health effects at ambient levels?
21 Mobile-Source Air Toxics (MSATs)

- acetaldehyde
- acrolein
- arsenic cmpds
- benzene
- 1,3-butadiene
- chromium cmpds
- diesel PM and diesel exhaust organic cmpds*
- dioxin/furans
- ethylbenzene
- formaldehyde
- n-hexane
- lead cmpds
- manganese cmpds
- mercury cmpds
- MTBE
- naphthalene
- nickel cmpds
- POM
- styrene
- toluene
- xylene
21 Mobile-Source Air Toxics (MSATs)

Priority MSATs selected based on ambient exposures (and role of mobile sources), and toxicity information (particularly in humans)

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*Because of (a) all of the review activity of HEI and others on diesel and (b) the expected reductions in emissions with the 2007 and 2010 engine technologies, the Panel elected not to place it on the list of targeted air toxics – however, an expanded overview and summary is being developed.
Mobile Source Air Toxics
(primary reasons for de-selection)

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- Low levels of exposure, both absolute and in terms of proportion from mobile sources
- Low ambient air concentrations relative to indices of toxicity
- Trends indicating substantial declines in exposure
Example of Critical Review: Benzene
What are the Levels of Exposure? To What Extent are Mobile Sources a Significant Source?

- Most air monitoring data
- Urban roadside and urban in-vehicle higher than typical highest ambient levels measured: mobile sources likely to be important component of overall exposure
- Personal exposures to benzene appear to be in the same range as outdoor settings

Figure 8. Concentrations of benzene (μg/m³) at various locations. Data for figure are from Table 4.
Benzene: Exposure Trends

Temporal trends


Figure 9. Annual mean concentrations of benzene measured in Canadian urban and rural locations from 1991 to 2004. (Courtesy of T. Dann, Head, Air Toxics Analysis and Air Quality, Environment Canada, 2007. Data are available from the National Air Pollution Surveillance (NAPS) Network at www.etc-cte.ec.gc.ca/naps/index_e.html.)
Does Benzene Cause Human Health Effects?

- **Occupational Studies: Cancer**
  - Follow-up of Pliofilm cohort (leukemia)
  - New Cohorts (e.g., Aussie petroleum workers, gas & electric utility workers) leukemia at low exposures

- **Supporting evidence**
  - **Biomarker**
    - urinary benzene in Thai study
    - urinary benzene biomarker & cytogenetic abnormalities in community settings
    - street-side vendors, petrol service attendants, school children near major roads
  - **Genetics**
    - genetic variations in enzymes that metabolize benzene related to effects on blood cell counts (Chinese worker study)
    - deletion of enzyme in knockout mice leads to myeloid hyperplasia following benzene exposure

Clear and widely accepted evidence from a variety of occupational studies that risks of acute myeloid leukemia are increased but there is less certainty concerning other lymphohematopoietic cancers.
Does Benzene Cause Human Health Effects at Ambient Exposure Concentrations?

Community Studies – Cancer

*as with other compounds, identifying effects in community studies is challenging*

- Risk for childhood leukemia associated with proximity to petrochemical works and petrol stations in some studies
  - Not possible to single out benzene
  - Mixed results regarding association between traffic and childhood leukemia

Hematological outcomes

*Recent studies reveal effects on hematological indices @ lower levels*

- China: incr. exposures & reductions in RBSs, WBCs & neutrophils
  - Effects observed in lowest exposed group (≤ 0.25 ppm [≤ 815 µg/m³]) compared w/ controls
- US: no assoc. between any hematologic indicator & mean benzene exposure between 0.14 and 0.60 ppm [46 and 1,960 µg/m³]

*Thus, considerable uncertainty as to the lowest concentration that might be associated with hematological effects*
Benzene: References


Looking Across MSATs: Aldehydes
To What Extent Are Mobile Sources a Significant Source of...

**Acetaldehyde?**
- Mobile sources are significant, but not dominant source

**Acrolein?**
- On-road mobile sources account for approximately a quarter of emissions into ambient air in urban areas
- Limited urban roadside & in-vehicle data do not suggest elevated exposures
- Shortcomings in several sampling methods limit confidence in all measurements

**Formaldehyde?**
- Mobile sources important contributors to ambient levels, but exposures dominated by indoor sources
- Summer photochemistry more important than direct vehicle emissions → seasonal effect.

[Chemical structures for formaldehyde, acetaldehyde, and acrolein]
## Acetaldehyde, Acrolein, and Formaldehyde: Exposures

<table>
<thead>
<tr>
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<th>Indoor</th>
<th>In-vehicle or near-roadway</th>
<th>Personal</th>
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<td>36.1 – 55 μg/m³</td>
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Do Acetaldehyde, Acrolein, or Formaldehyde Cause Human Health Effects at Ambient Levels?

- **Acetaldehyde**: Irritating (eye, skin, respiratory tract). Data on carcinogenicity inadequate. Environmental concentrations are far below levels causing irritation.

- **Acrolein**: Very irritating to respiratory tract. Chronic inhalation studies: inflammation. Environmental concentrations & personal exposures (2X higher) are lower (but not that much lower) to conc. causing irritation.

- **Formaldehyde**: Irritating (eye, skin, respiratory tract). Recently classified as human carcinogen (IARC): nasopharyngeal cancer at levels historically encountered in industry. Mechanism not fully understood. Limited & inconclusive evidence that indoor exposure increases occurrence of asthma symptoms in children.
Polycyclic Organic Matter (POM)

Mixture of hundreds of chemicals including polycyclic aromatic hydrocarbons (PAHs), their oxygenated products and nitrogen analogs.

Some POM in gas phase, some in particle phase, some in both

Different analytical studies look at different combinations of POM: many definitions
Do POM Cause Human Health Effects?

Asphalt workers: ischemic heart disease mortality

• High workplace exposures (coke oven): sufficient evidence for increased risk of lung tumors

• Highly polluted industrial sites: indication of reduced birth weights

• At Ambient Levels? ingestion from food dominates exposure
General Observations
Urban vs Rural Exposures to Individual Priority MSATs

Mean concentration (mg/m³): measured mean concentrations (open circles); maximum measured concentrations (closed circles); estimated mean concentration determined by modeling (triangles, NATA – EPA 2006)
Contribution of Mobile Sources to Overall Exposure

- 1,3-Butadiene > Benzene > Formaldehyde, Acetaldehyde > Acrolein
- POM
  - Depends on specific species
  - PAH: clear mobile source impact
- Naphthalene
  - Insufficient data, but likely low mobile source contribution
Major Future Research Needs for MSATs

• Continue to update exposure models and monitoring
  − Compare models to actual measurements, to improve their usefulness in predicting the effects of alternative fuels and engines.
  − Monitoring network capable of tracking long-term aldehyde concentrations.

• Greater focus on non-cancer endpoints (especially aldehydes)

• Susceptible subpopulations?

• Metabolism of MSATs in humans; how to relate to animal models?

• Risks of ambient exposures
  − traditional epi approaches excellent looking at health effects of overall emissions (e.g., proximity to roadways) but likely not for individual MSATs
  − biomarkers might help understand mixtures & facilitate high-to-low exposure extrapolations. Need new tools (or more sensitive ones) for use in ambient settings
  − emerging hotspots may provide better understanding of intensity/ variations in personal and ambient exposures to air toxics derived from mobile and other sources as well as impacts on health
Thank you!

Debra A. Kaden
dkaden@healtheffects.org
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