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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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)

- 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

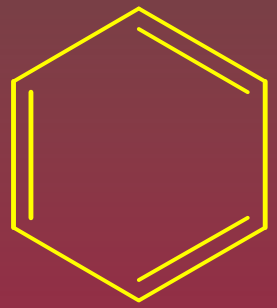
*Because of (a) all of the review activity of HEI and others on diesel and (b) the expected reductions in emissions with the 2007 and 2010 engine technologies, the Panel elected not to place it on the list of targeted air toxics – however, an expanded overview and summary is being developed

Mobile Source Air Toxics
(*primary* reasons for de-selection)

- 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

- 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?

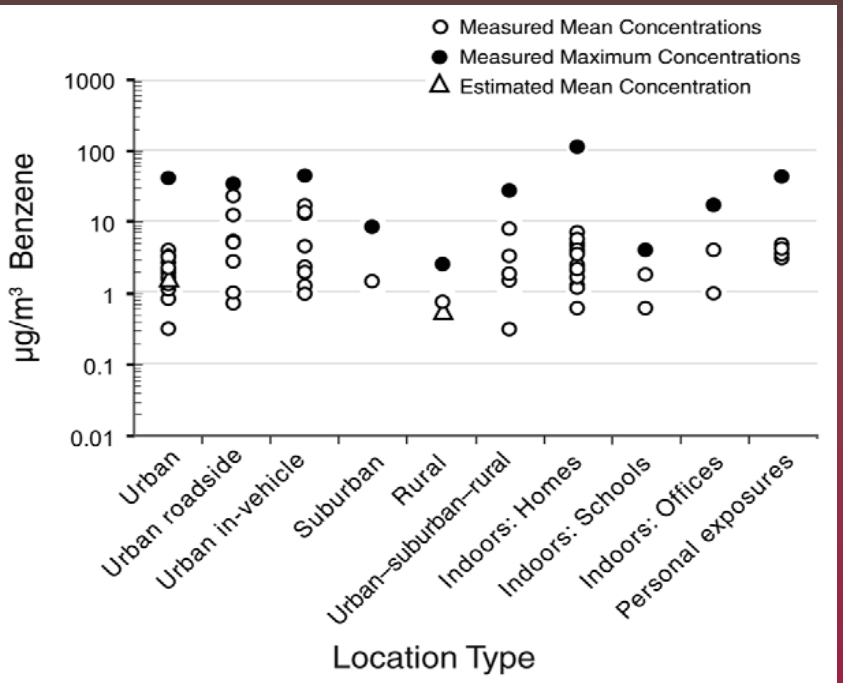


Figure 8. Concentrations of benzene (µg/m3) at various locations. Data for figure are from Table 4.

- 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

Benzene: Exposure Trends

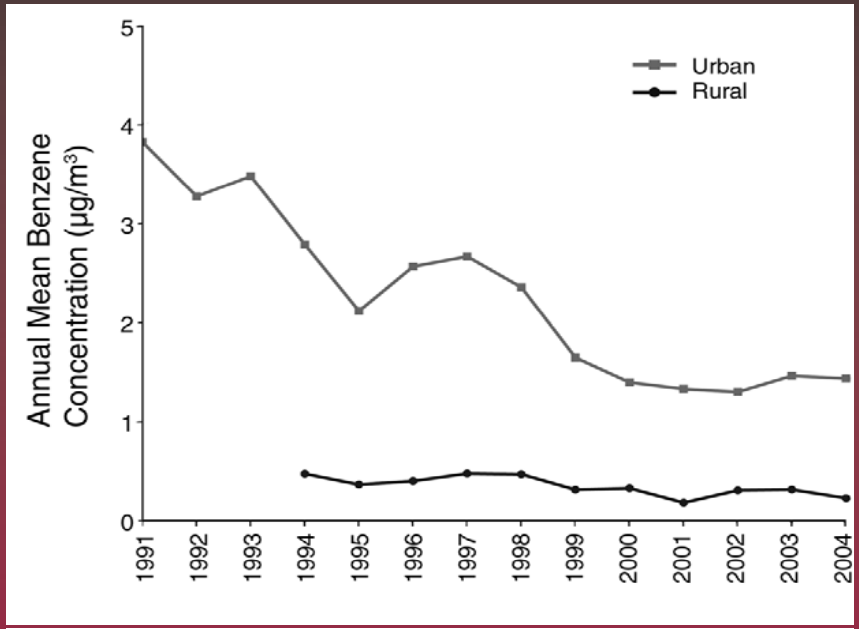


Figure 9. Annual mean concentrations of benzene measured in Canadian urban and rural locations from 1991 to 2004. (Courtesy of T. Dann, Head, Air Toxics Analysis and Air Quality, Environment Canada, 2007. Data are available from the National Air Pollution Surveillance (NAPS) Network at *www.etc-cte.ec.gc.ca/naps/index_e.html*.)

Temporal trends

Urban benzene concentrations decreased by 65% between 1990 and 2000 with essentially no further change between 2000 and 2004. Rural benzene concentrations decreased by 50% between 1994 and 2004.

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/m^3]) 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/m^3]

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

Benzene: References

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(continued)

Looking Across MSATs: Aldehydes

To What Extent Are Mobile Sources a Significant Source of…

Acetaldehyde?

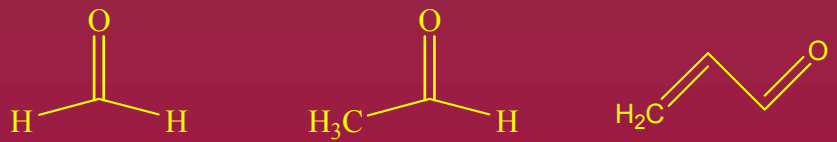
- Mobile sources are significant, but not dominant source

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.



formaldehyde acetaldehyde acrolein

Acetaldehyde, Acrolein, and Formaldehyde: Exposures

	Ambient	Indoor	In-vehicle or near-roadway	Personal
Acetaldehyde	1 – 7 $\mu g/m^3$	5 – 23 $\mu g/m^3$	0.7 – 7 $\mu g/m^3$	5 – 23 $\mu g/m^3$
Acrolein	0.03 – 6 $\mu g/m^3$	<0.1 – 2 $\mu g/m^3$	0.1– 6 $\mu g/m^3$	11 – 13 $\mu g/m^3$
Formaldehyde	1– 6 $\mu g/m^3$	12– 68 $\mu g/m^3$	5– 20 $\mu g/m^3$	12– 28 $\mu g/m^3$

Acetaldehyde, Acrolein, and Formaldehyde: Exposures

	Ambient	Indoor	In-vehicle or near-roadway	Personal
Acetaldehyde (US)	1 – 7 $\mu g/m^3$	5 – 23 $\mu g/m^3$	0.7 – 7 $\mu g/m^3$	5 – 23 $\mu g/m^3$
Acetaldehyde (Brazil)	36.1 – 55 $\mu g/m^3$		4.3 – 438 $\mu g/m^3$	
Acrolein	0.03 – 6 $\mu g/m^3$	<0.1 – 2 $\mu g/m^3$	0.1– 6 $\mu g/m^3$	11 – 13 $\mu g/m^3$
Formaldehyde (US)	1– 6 $\mu g/m^3$	12– 68 $\mu g/m^3$	5– 20 $\mu g/m^3$	12– 28 $\mu g/m^3$
Formaldehyde (Brazil)	1– 54 $\mu g/m^3$		17 – 80 $\mu g/m^3$	

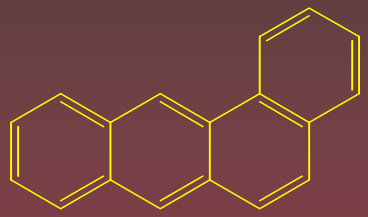
Do Acetaldehyde, Acrolein, or Formaldehyde Cause Human Health Effects at Ambient Levels?

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

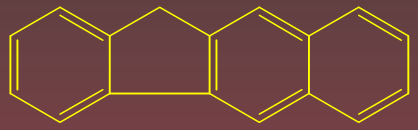
- **Acrolein:** Very irritating to respiratory tract. Chronic inhalation studies: inflammation. Environmental concentrations & personal exposures (2X higher) are lower (but not that much lower) to conc. causing irritation.

- **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.

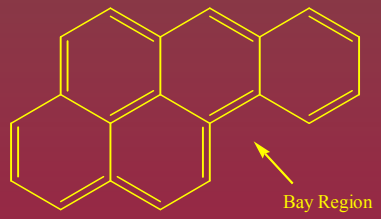
Polycyclic Organic Matter (POM)



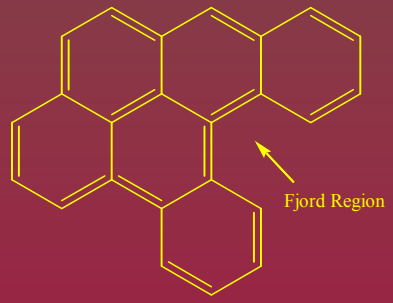
Benzo(a)anthracene



Benzo(b)fluoranthene



Benzo(a)pyrene



Dibenzo(a,l)pyrene

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?

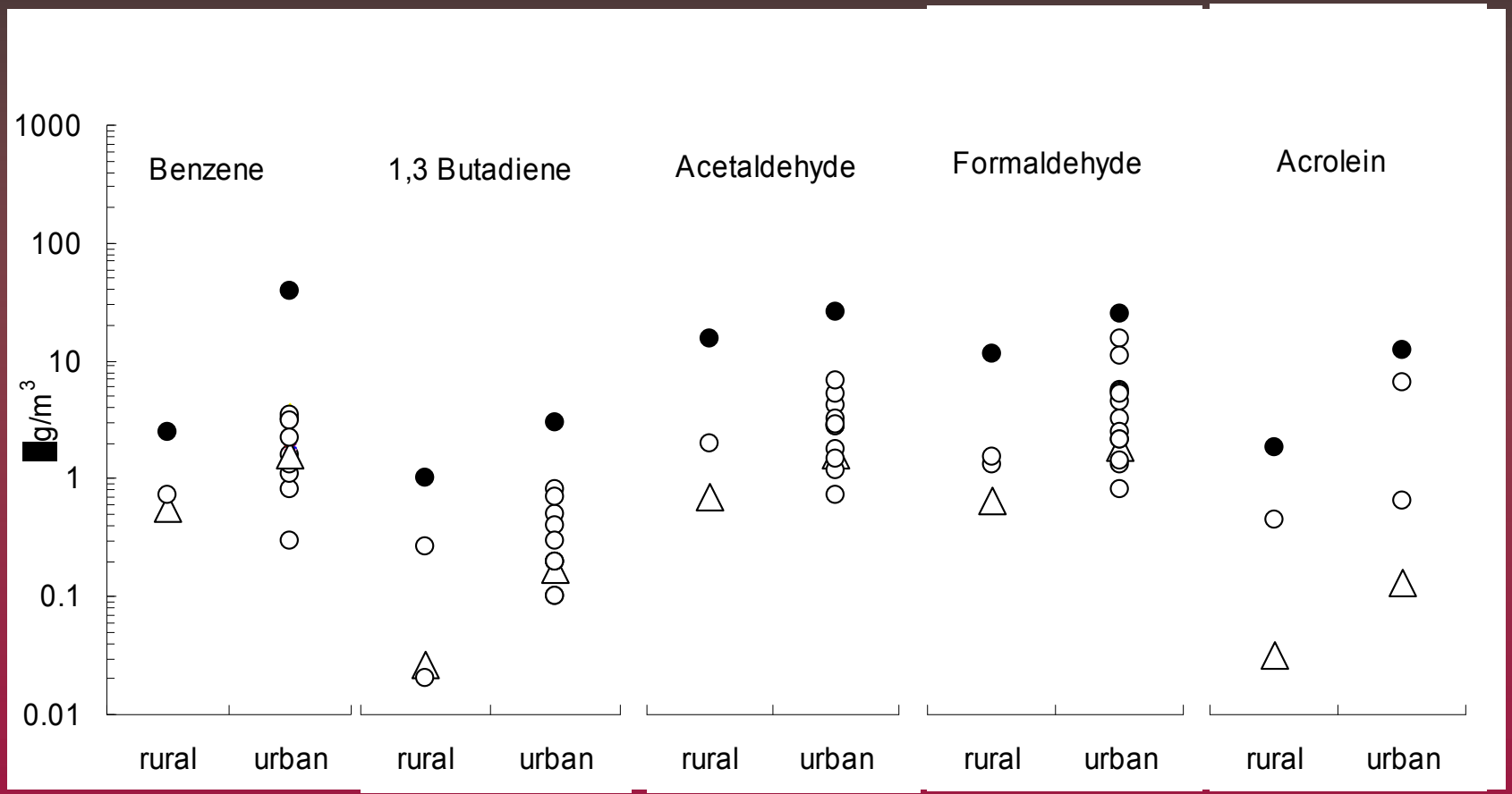
Asphalt workers: ischemic heart disease mortality

- 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!

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