Vehicle Emissions and Health:
A Global Perspective on Effects, Placed in an Indian Context

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Delhi, India
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Vehicle Emissions and Health

• What do vehicles contribute to exposure?
• What do we know about health effects?
  • Particulate Matter
  • Ozone and NO2
  • Traffic
• Concluding Thoughts
The Health Effects Institute

- Non-profit institute providing *trusted science on the health effects of air pollution* for over 30 years
- Joint core support from
  - Government (US EPA) and Industry (Worldwide Motor Vehicle)
  - Partnerships with WHO, ADB, CAI-Asia, EU, US DOE, other industries, Hewlett foundation
- Independent Board and Expert Science Committees
  - Including international experts (e.g. India (AIIMS), China, Thailand)
- Over 270 studies, scientific reviews, reanalysis conducted around the world, including:
  - *Public Health and Air Pollution in Asia (PAPA)* program
- HEI delivers science; no policy positions taken

*Understanding local impacts in a global context*
Major Report from:
HEI’s Public Health and Air Pollution in Asia (PAPA)
Nov. 2010

Summary of Current Global Epidemiologic Evidence on Health Effects of Air Pollution: Implications For Asia

PAPA SAN: Overview of all Asian health effects studies identified through 2007

Quantitative review (meta-analysis) of more than 80 time-series studies of daily mortality and hospital admissions
- Including 7 NEW PAPA Studies

First-ever review of over 100 studies of the chronic effects of exposure to air pollution (to be published separately)
• Web compendium of studies on health effects of air pollution in Asia
• Currently > 420 studies in 11 countries
  • 44 Studies in India

*available at [http://www.healtheffects.org/Asia/papasan-home.htm](http://www.healtheffects.org/Asia/papasan-home.htm)
What do vehicles contribute to exposure?
Air Pollution: A Problem Worldwide
Ambient Levels of Particulate Matter (PM) Exceed Current WHO Air Quality Guidelines
Especially in Some Asian Countries

Annual average PM$_{10}$ concentrations ($\mu$g/m$^3$)

World Health Organization 2006
Asia PM 2.5 Source Apportionment: Vehicles ~20% - 35%

Source: Chowdhury, HEI 2010
Seasonality of Sources in India

Vehicles ~20% - 30% of total PM2.5 (depending on city and season)

- Fossil fuel and biomass combustion dominates:
  - Fossil Fuel
    - Del: 25-33%
    - Kol: 37-53%
    - Mum: 21-35%
  - Biomass
    - Del: 7-19%
    - Kol: 13-18%
    - Mum: 7-20%

- Dust dominates during Spring and Summer:
  - Long range transport and dust from local construction

- Biomass and coal are high in winter:
  - Heating
  - Poor mixing and atmospheric inversion

Road Dust an additional 10% - 30%

Source: Adapted from Chowdhury et al. (2007).

Environmental Health, Graduate School of Public Health

Next Session to Discuss Source Apportionment in Detail
What Do We Know About Health Effects?

- PM and Gases (Ozone and NO2)
- Traffic as a “Source” Exposure
Major Vehicle/Fuel Emissions
Many substances, not all of equal concern

- Carbon Monoxide
- Carbon Dioxide (Climate Change)
- Diesel Exhaust
- Particulate Matter (PM)
- Lead
- Ozone precursors
  - Nitrogen Oxides (NOx) and Hydrocarbons (HC)
- Nitrogen Dioxide
- Air Toxics
  - Aldehydes
    - formaldehyde
    - acetaldehyde
    - others
  - Benzene
  - 1,3-butadiene
  - Metals
  - Polycyclic organic matter (e.g. PAHs)
PM

- Sources:
  - wide range of combustion sources;
  - vehicles are significant, though not only, contributor
- High levels of PM (> 500 µg/m³) known to cause premature death
  - e.g. London 1952
- Studies in US, Europe, elsewhere have found association of PM with mortality at much lower levels (<50 µg/m³)
  - no evidence of a “threshold” (safe level)

London at Noon, December 1952
PM10 in Delhi: Substantially Above Indian NAAQS of 60 µg/m³

PM10: Annual average levels

Source: CSE analysis based on CPCB air quality data
## Effects of long-term PM$_{2.5}$ Exposure
Extended Follow-Up of the American Cancer Society Study of PM and Mortality; HEI Report #140, 2009

Tracking detailed effects in 600,000 people over 18 years

**Large effects, especially for heart disease**
*(18% - 24% increase in risk per 10 µg/m$^3$ PM$_{2.5}$)*

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Standard Cox Model</th>
<th>Random Effects Cox Model$^b$</th>
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<tbody>
<tr>
<td>HR per 10-µg/m$^3$ Change in PM$_{2.5}$ Exposure Level (Average for 1979–1983)</td>
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<td></td>
</tr>
<tr>
<td>All causes</td>
<td>1.03 (1.01–1.04)</td>
<td>1.04 (1.03–1.06)</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>1.12 (1.09–1.16)</td>
<td>1.18 (1.15–1.22)$^b$</td>
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<tr>
<td>Cardiopulmonary disease</td>
<td>1.06 (1.04–1.08)</td>
<td>1.09 (1.06–1.11)</td>
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<tr>
<td>Lung cancer</td>
<td>1.08 (1.03–1.14)</td>
<td>1.09 (1.03–1.15)</td>
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*Commentary Table 3. Associations Between Various Causes of Death and Long-Term Exposure to PM$_{2.5}$ in Two Time Periods from the Nationwide Analysis$^a$*
**Short Term (Daily) PM Effects**

National Morbidity, Mortality and Air Pollution Study (NMMAPS)

Approximately 0.2% increase in mortality per 10 µg/m³ PM10

20 largest US cities
(Daniels et al HEI 2004)
New HEI PAPA Studies in India

- Three studies chosen competitively and overseen by international experts
- Major new HEI Report, March 2011:
  - Chennai – Dr. Kalpana Balakrishnan and colleagues, Sri Ramachandra University
  - Delhi – Dr. Uma Rajarathnan, and colleagues, TERI
- Also,
  - Ludhiana – Dr. Rajesh Kumar, PGI Chandigarh
    - Published in the Indian Journal of Public Health
New Data from India: HEI Study in Chennai

• Careful analysis of daily trends in air pollution and all cause mortality
• Dr. Kalpana Balakrishnan and colleagues
• Overseen by HEI International Science Oversight Committee
• Independently and Intensively Peer Reviewed
Chennai Results:
Approximately 0.3% -0.6% increase in mortality per $10 \mu g/m^3$ PM10

Fig. 23: A comparison of the estimated RR’s for PM10 obtained from the core zonal model, alternative models and sensitivity analysis.
**New Data from India:**
HEI Study in Delhi

Approximately 0.15% to 0.17% increase in mortality per 10 µg/m³ PM10 (~0.3%/ 20 µg/m³)

- Careful Analysis of Daily trends in air pollution and all cause mortality
- Dr. Uma Rajarathnam and colleagues at TERI
- Overseen by HEI International Science Oversight Committee
- Independently and Intensively Peer Reviewed

![Graph showing relative risk of mortality vs PM10 concentration]
What might “X% increase in risk per 20µg/m³” mean for public health?

- Very high levels of RSPM (PM$_{10}$):
  - Chennai (red in upper graph);
  - Delhi (black in lower graph)

- Many days above Indian 24-hour RSPM AQ Standard (100µg/m³) (black line)

- Can regularly be as high as 250 – 300µg/m³ with peaks as high as 800µg/m³ in Delhi
What might X% increase in risk per 20µg/m³ mean for public health?

• For example: if annual Delhi RSPM levels are 250µg/m³, levels are 150µg/m³ higher than the Indian National Ambient Air Quality Standard

• Using HEI’s India results (0.3 - 0.6% increase per 20 µg/m³), risk of premature mortality would be ~ 2% - 4.5% higher due to air pollution (i.e. 150/20 = 7.5; 7.5 X 0.3 – 0.6% = 2.25% – 4.5% increase in risk)

• This is a relatively small increase in risk, although if applied to overall deaths in Delhi (~100,000 per year), the public health implications could be much larger
  • e.g.~2,250 – 4,500 premature deaths per annum

• This is based on short term studies of daily effects;
  • the longer term effects are likely to be significantly larger
The Broader Asian Evidence (HEI Review 2010): PM$_{10}$ and daily mortality: consistent small increase in premature mortality risk

- Short-term exposure associated with increased daily mortality from all non-accidental causes (0.27%).
  - About halfway between the Chennai and Delhi results

- Larger estimates for respiratory (0.84%) and cardiovascular (0.36%) mortality

- Somewhat larger estimated effects among those >65 yr.
Figure 1

Estimates from Meta-analyses

- 29 cities (PM$_{10}$) (Levy et al. 2000)
- 6 U.S. cities (PM$_{10}$) (Kemmn and Mason 2003)
- 15 Asian cities (PM$_{10}$) (ALR Quantitative Analysis; 15 Asian cities (PM$_{10}$), (HEI International Scientific Oversight Committee 2010))
- 9 Californian cities (PM$_{2.3}$) (Eto et al. 2006)
- 12 Canadian cities (PM$_{10}$) (APHENA, 12 Canadian cities (PM$_{10}$)
- 22 European cities (PM$_{10}$) (Katsouyanni et al. 2009)
- 8 European cities (PM$_{10}$) (Katsouyanni et al. 2010)
- 9 Latin American cities (PM$_{10}$)

Estimates from Multicity Studies

- 13 Latin Am. studies (PM$_{10}$) (Anderson et al. 2005)
- 8 Latin Am. studies (PM$_{10}$) (PAHO 2005)
- 10 U.S. cities, case-crossover (PM$_{10}$) (Schwartz 2004)
- 9 U.S. cities (PM$_{10}$) (Schwartz 2000; Schwartz and Coull 2003)
- 14 U.S. cities (PM$_{10}$) (Schwartz 2000)

Per 10 -µg/m$^3$ Increase in PM

Asia in a Global Context

(Risk of Premature Mortality with Increased Exposure to PM10)

Effects of pollution in India and Asia are similar to results around the world
Ozone

• Sources: VOCs, NOx from mobile and other sources

• Known to:
  • Cause inflammation in respiratory tract
  • Reduce ability to breathe (lung function) for some
  • Increase hospitalization for asthma, other lung diseases

• Recent multi-city evidence of effects on premature mortality
  • Long term effects are less certain
**Ozone Evidence from Asia: Increased Hospitalization**  
(HEI Review, 2010)

### Ozone and Respiratory Admissions – Specific Ages and Diseases

- **Consistent small increases in risk**

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Time Period</th>
<th>Age Group</th>
<th>Disease</th>
<th>Risk Increase</th>
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<td>Chang 2002 Taipei 1 hour all respiratory</td>
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Nitrogen Dioxide (NO2)

• Sources: vehicles a significant source; also thermal power plants
• Known, like many “oxidants” to cause inflammation
• May cause serious problems at lower levels and short, high doses
• Also may be a “marker” for other pollutants (e.g. fine PM)
NOx Levels Rising in Delhi

Nitrogen oxide levels are rising in almost all locations in Delhi.

NOx also contributes to the problem of ozone pollution.

Source: CSE analysis based on CPCB air quality data
Childhood lung function development reduced in those exposed to higher NO2

Community-specific average growth in FEV1 among Girls and Boys for the period 1993 to 2001 plotted against average nitrogen dioxide (NO2) levels from 1994 to 2000 (Gauderman 2004)
New NOx Results from India: HEI Study in Delhi

- Delhi study also tested Nitrogen Oxide associations
  - Independently and with PM10
- Found higher estimates of risk for NOx (0.65%/10 µg/m³) than for PM10
Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects

HEI Expert Panel
Dr. Ira Tager, UC Berkeley, Chair
January 2010
There are many studies (over 700) that have attempted to look at traffic exposure and effects. However, they are not all of equal quality.
Who is Likely to be Exposed?
Highest levels within 300 – 500 meters of a major road

Toronto, Beckerman et al. (2008)
The HEI Traffic Review:

In Los Angeles, 44% of population live in the maximum zone of impact of major roads (within 500 meters of an expressway; 100 meters of a major road)
The Traffic Impact Area in Delhi:
New HEI Analysis: 55% of the Population within 500 meters of a Freeway; 50 meters of a Major Road
Overall Traffic Conclusions

• The data are incomplete on emissions, their transformations, and exposure assessment

• There were enough studies to find:
  
  • *Sufficient* evidence that exposure to traffic can cause exacerbation of asthma, especially in children
  
  • *Suggestive* evidence for other health effects (premature mortality, lung function, respiratory symptoms, and others)
  
  • But only *limited evidence* of effects for: Adult onset asthma; Health care utilization; COPD; Non-asthmatic allergy; Birth outcomes; Cancers
**Overall Traffic Conclusions II**

- Epidemiology studies are based on past estimates of exposure
  - they may not provide an accurate guide to estimating health associations in the future
- However, given the large number of people living within 300-500 meters of a major road, the Panel concluded that exposures to primary traffic generated pollutants are likely to be of public health concern and deserve attention.
Concluding Thoughts

• Traffic is a significant but *not the only* contributor to major air pollutant exposure
  • Key pollutants: PM, Ozone, NO2
  • Traffic as a “source” exposure

• Strong body of evidence of effects for most of these pollutants
  • Growing Asian and Indian evidence suggesting similar effects

• Significant fuel and technology enhancements underway:
  • HEI Vice President Bob O’Keefe will describe these tomorrow
Thank You

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