Premature Mortality and Particulate Matter: A Critical Challenge in Urban Management

A Global Perspective on Effects, Placed in an Asian Context

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Sustainable Mobility and the Challenge of Particulate Matter

The evidence from Asia, in a global context

- The problem of Particulate Matter (PM)
  - PM levels in Asia
- What do we know about health effects?
  - PM, Nitrogen Oxides (NOx)
  - Effects of Traffic Exposure
  - Are effects similar in the developed and developing world?
- Who is most susceptible?
  - And how can transport policy exacerbate that?
-Hope for the future: the benefits of clean air
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$^3$)

ASIA

World Health Organization 2006
India: Many Cities Substantially Exceed WHO and Indian Air Quality Guidelines

![2008 Annual Mean PM$_{10}$ Levels In Indian Cities*](image)

- WHO Guideline: 20 µg/m$^3$
- India Standard: 60µg/m$^3$

*Source: WHO 2011*
Most Chinese Cities Exceed WHO Air Quality Guidelines for PM$_{10}$

2009 Annual Mean PM$_{10}$ Levels in Chinese Cities

WHO Guideline: 20 µg/m$^3$ (Interim Targets 30 – 50 – 70)

China Class II: 100 µg/m$^3$

Source: WHO 2011
An Increasingly Urban Population
(data from UN/UN Centre for Human Settlements 1995-2002)
Sustainable Mobility and PM:

What Do We Know About Health Effects?

- PM
- Nitrogen Oxides (NOx)
- Traffic Health Effects
HEI Major Critical Review (November 2010):

“Outdoor Air Pollution and Health in the Developing Countries of Asia”

- Asian Science in A Global Context

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

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
Public Health and Air Pollution in Asia – Science Access on the Net (PAPA-SAN)*

Studies of Air Pollution and Health in Asia, 1980–2007

- Web-based compendium of studies on health effects of air pollution in Asia
- Currently > 420 studies in 11 countries

*available at http://www.healtheffects.org/Asia/papasan-home.htm
PM

• High levels of PM (> 500 µ/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 µ/m³)
  • No evidence of a “threshold” (safe level)
PM10 in Delhi:
Substantially Above Indian NAAQS of 60 µg/m³

PM10: Annual average levels

Source: CSE analysis based on CPCB air quality data

New Delhi, November 08, 2011
“Toxic Capital Air Killing Like Never Before”
New Delhi India Gate November 21, 2011, 7:20 am
AQI 320, “Hazardous”
Source: Ministry of Earth Sciences, Govt. of India
### 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$_{2.5}$)*

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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$^a$

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Standard Cox Model</th>
<th>Random Effects Cox Model$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR per 10-µg/m$^3$ Change in PM$_{2.5}$ Exposure Level (Average for 1979–1983)</strong></td>
<td></td>
<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)</td>
</tr>
<tr>
<td>Cardiopulmonary disease</td>
<td>1.06 (1.04–1.08)</td>
<td>1.09 (1.06–1.11)</td>
</tr>
<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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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 Indian Results: PM10 Evidence from Chennai PAPA study
Approximately 0.3% -0.6% increase in mortality per 10 µg/m³ PM10

Fig. 23: A comparison of the estimated RR’s for PM10 obtained from the core zonal model, alternative models and sensitivity analysis.

Dr. Kalpana Balakrishnan and colleagues HEI 2011
Chinese and Thailand Results
PM10 Evidence from the PAPA Multi-City, Coordinated Studies

Consistent small increase in premature mortality risk with daily increase in PM10

Excess risk (%) of mortality for a 10mg/m3 increase in average concentration of pollutants (lag 0-1 days)

HEI Research Report 154, November 2010
Asia in a Global Context
(Risk of Premature Mortality with Increased Exposure to PM10)
Effects of pollution on people around globe are more similar than different

Figure 1

Estimates from Meta-analyses
- AIR Quantitative Analysis, 15 Asian cities (PM10) (HEI International Scientific Oversight Committee 2010)
- PM10 (Stieb et al., 2002; Mosley et al., 2003)
- Non-GM based studies (PM10) (Stieb et al., 2002; Mosley et al., 2003)
- Unadjusted for publication bias (PM10) (Stieb et al., 2002; Mosley et al., 2003)
- Publication bias adjusted (PM10) (Anderson et al., 2008)
- PAHO (PM10) (Anderson et al., 2008)
- 18 Latin Am. studies (PM10)

Estimates from Multicity Studies
- 6 U.S. cities (PM2.5) (Henni and Mason, 2003)
- 9 Californian cities (PM2.5) (Osio et al., 2003)
- 10 U.S. cities, case crossover (PM2.5) (Schwartz and Coull, 2003)
- 9 U.S. cities, case crossover (PM2.5) (Schwartz, 2004)
- 14 U.S. cities, case crossover (PM2.5) (Schwartz et al., 2009)
- APHEA 12, Canadian cities (PM10) (Katsouyanni et al., 2009)
- APHEA 22, European cities (PM10) (Katsouyanni et al., 2009)
- PAPA Combined Analysis, 4 Asian cities (PM10) (Wong et al., 2006)
- ESCALA (Primary Results), 9 Latin American cities (PM10) (Romeu et al., 2010)

Estimates impact of urban outdoor air pollution worldwide:
~795,000 premature deaths per year attributable to PM air pollution in Asian cities
Nitrogen Dioxide (NO2)

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

NOx also contributes to the problem of ozone pollution.
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 Delhi (March 2011)

- Delhi study also tested Nitrogen Oxide and daily mortality associations
  - Independently and with PM10
- Found higher estimates of risk for NOx (0.65%/10 µg/m³) than for PM10
The Role of Traffic Related Air Pollution
Traffic Related Air Pollution & Health: A Major Expert HEI Review 2010

Summarized & synthesized over 700 studies on health effects of traffic

- Across a diverse and complex literature

Found:

- Highest exposures 300-500 meters from major roads
- Growing evidence of effects, especially asthma exacerbation in children
- Some questions still to be answered
Asia PM 2.5 Source Apportionment: Vehicles ~20% - 35%

Source: Chowdhury, HEI 2010
Who is Likely to be Exposed?
Highest levels within 300 – 500 meters of a major road

VOC (TraceAir) Distance Decay Around Highway 401, Toronto

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 highway; 50 meters of a major road
The Traffic Impact Area in Beijing:
New HEI Analysis: 76% of the Population within
500 meters of a highway; 50 meters of a major road
Overall Traffic Conclusions

• While the data are often incomplete, the Panel found:
  • *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

• “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”

Estimates impact of urban outdoor air pollution worldwide:
~795,000 premature deaths per year attributable to PM air pollution in Asian cities
Who is most at risk from premature mortality from PM Exposure?

- Highest effects generally seen among:
  - Older, frail members of society
  - Those with preexisting heart or lung disease

*Highest PM effects for Heart disease*  
(18% - 24% increase in risk per 10 µg/m³PM2.5)

Diseases that increase as populations age
Diseases that increase with obesity, sedentary lifestyle
Number of people at high CV risk globally in 2000
(A Rogers 2005)

Legend
- AfrD
- AfrE
- AmrA
- AmrB
- AmrD
- EmeA
- EmeB
- WprA
- WprB

A: very low child and adult mortality
B: low child and adult mortality
C: low child, high adult
D: high child, high adult
E: high child, very high adult

>175 million people at 25% + risk of a major CV event in the next decade, by WHO sub-region
The demographic transition:
As Asia ages – and economies grow - susceptibility to heart disease increases

India 2000

> 65 yrs

2025

2050

China 2000

> 65 yrs

2025

2050
And how can transport policy exacerbate these trends?

As Asia ages, and economies grow, barriers to cardiovascular fitness are also increasing
Non-walkable environment

Sedentary lifestyle

Overweight

Increase in Cardiovascular disease

Increasing susceptibility to air pollution
Can We Look To the U. S. for Solutions to a motorized society?
The “No Sidewalk” Approach
The obstructed sidewalk
The Mixed Message
Perhaps, but only sometimes…
Increasing Motorization Across Asia

Vehicles

Diesel Vehicles

Source: 2009. ADB, CAI-Asia, Segment Y Ltd., and IEA
And what can come with car-based economies?
No need to walk to the mail box!
Drive-Thru Wedding Chapel
Las Vegas, NV
So much for the “walk down the aisle”
You can avoid exercise and eat pastry at the same time.
An especially good idea, purchase alcohol while driving
Drive-Thru Funerals

Gardner Memorial Chapel
Junior Funeral Home
Adams Funeral Parlor
Global Concern for Road Safety

*Increasing Vehicles vs. Rates of Mortality (Bhalla 2009)*

**WHO 2002:**

- 1.2 million fatalities worldwide
- 50 million injuries
- Estimated as 11th leading cause of death in the world

Panel Data: 1963-1999, 88 countries
Toward a Sustainable Future:

Many ways forward
Toward a sustainable future

Many ways forward

- Cleaner fuels and vehicles
- Green Freight
- Improved Urban Planning
- Public transit
- Improved walkability
- Bicycle paths

- Many, many others……
Evaluated changes in Life Expectancy with changes in PM2.5 for the 2-decade period of approximately 1980-2000

Matching PM$_{2.5}$ data for 1979-1983 and 1999-2000 in 51 Metro Areas

Life Expectancy data for 1978-1982 and 1997-2001 in 211 counties in 51 Metro areas
A 10 µg/ m³ decrease in PM$_{2.5}$ was associated with a **7.3 month** increase in life expectancy.

This increase in life expectancy persisted even after controlling for socio-economic, demographic, or smoking variables (± 2.4) months.
The Bottom Line:

Whether in the developed or the developing world, the evidence is clear:

*Reducing Air Pollution Extends Lives*

…and sound transport policy can help reduce susceptibility as well…
Special Thanks

• Howard Frumkin M.D., Dean University of Washington School of Public Health

• Clean Air Initiative For Asian Cities (CAI-Asia)
Thank You

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