Air Pollution in Ulaanbaatar: Public Health Impacts and Research Opportunities

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American Center for Mongolian Studies
Speaker Series
January 22, 2013
Presentation Overview

- What do we know about air pollution’s effects on human health?
  - What have we learned recently?

- Air pollution in a global context
  - A major problem in much of Asia
  - 2010 Global Burden of Disease study

- The situation in Ulaanbaatar

- What happens when we remove the pollution?

- UGAAR Study
Particulate Matter (PM) Air Pollution

- Typically expressed as mass per unit volume ($\mu g/m^3$)
  - Particles with diameter less than 10 micrometers ($PM_{10}$)
  - Particles with diameter less than 2.5 micrometers ($PM_{2.5}$)
    - i.e., “fine PM”

[1 $\mu m = 1/1,000,000 m = 1/1,000 mm$]
Air Pollution and Health
The Harvard Six Cities Study

Cleanest Air Cities

Dirtiest Air Cities

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Most vs. Least Polluted City</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1.26 (1.08-1.47)</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>1.37 (0.81-2.31)</td>
</tr>
<tr>
<td>Cardiopulmonary</td>
<td>1.37 (1.11-1.68)</td>
</tr>
<tr>
<td>All Other</td>
<td>1.01 (0.79-1.30)</td>
</tr>
</tbody>
</table>

Adjusted for smoking, age, gender, BMI, education, occupational exposure

Dockery et al., NEJM, 1996
Air Pollution and Health
Recent Advances

- Cardiovascular impacts
- A growing list of health effects associated with air pollution
  - Pregnancy effects
  - Others: impaired lung growth, asthma, allergies, infections, cognitive decline...
- Importance of exposure differences within cities (location, location, location)
- The search for a "safe" concentration (threshold)
"It is the opinion of the writing group that the overall evidence is consistent with a causal relationship between PM$_{2.5}$ exposure and cardiovascular morbidity and mortality."
# Air Pollution and Health

## Recent Advances: Cardiovascular Impacts

<table>
<thead>
<tr>
<th>World</th>
<th>Deaths in millions</th>
<th>% of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischaemic heart disease</td>
<td>7.25</td>
<td>12.8%</td>
</tr>
<tr>
<td>Stroke and other cerebrovascular disease</td>
<td>6.15</td>
<td>10.8%</td>
</tr>
<tr>
<td>Lower respiratory infections</td>
<td>3.46</td>
<td>6.1%</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>3.28</td>
<td>5.8%</td>
</tr>
<tr>
<td>Diarrhoeal diseases</td>
<td>2.46</td>
<td>4.3%</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>1.78</td>
<td>3.1%</td>
</tr>
<tr>
<td>Trachea, bronchus, lung cancers</td>
<td>1.39</td>
<td>2.4%</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>1.34</td>
<td>2.4%</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1.26</td>
<td>2.2%</td>
</tr>
<tr>
<td>Road traffic accidents</td>
<td>1.21</td>
<td>2.1%</td>
</tr>
</tbody>
</table>
Air Pollution and Health
Recent Advances: Pregnancy Effects

- An active area of research
- Some evidence of associations with low birth weight, pre-term birth, and impaired fetal growth
  - Inconsistent results
- Methodological challenges/limitations
  - Exposure assessment, confounding
Air Pollution and Health
Recent Advances: Location, Location,…

Kunzli et al., 2005

- Quality and quantity of measurements have increased, and exposure assessment techniques have improved
- Health risks from air pollution depend on where you live (and work and play)
- In some cases, exposures (and therefore health risks) vary over short distances, so...
  - ...health risk depends on **exactly** where you spend time
Air Pollution and Health
Recent Advances: A safe exposure level?

As argued elsewhere, from at least one perspective, these results are good news, because they suggest that even at common levels of air pollution, further improvements in air quality are likely to result in corresponding improvements in public health.

“...across the range of particulate pollution observed in most recent studies, the concentration-response relationship can reasonably be modeled as linear.

From a public policy perspective...a linear concentration-response function without a well-defined safe threshold level might be inconvenient.

As argued elsewhere, from at least one perspective, these results are good news, because they suggest that even at common levels of air pollution, further improvements in air quality are likely to result in corresponding improvements in public health.”

Pope and Dockery, Air & Waste Management Association, 2006
In 2005, 89% of world’s population lived in areas exceeding the WHO Air Quality Guideline. (99% in South and East Asia)

Brauer et al., Environmental Science & Technology, 2012
Air Pollution Around the World

Don’t Adapt to Air Pollution

The more dirty air you breathe, the more nose hair you need. Today, 70% of developing Asian cities have harmful levels of fine particulate pollution. These are impurities that enter your nose and penetrate your lungs. It causes over 800,000 premature deaths in Asia every year.

See how much nose hair you need to survive without clean air in your city.

http://cleanairasia.org/hairynose
Air Pollution Around the World

http://cleanairasia.org/hairynose/map
Air Pollution Around the World

- 2011 WHO Database
- Smaller Asian cities
- Similarities across cities

“...largest contributors to urban outdoor air pollution include motor transport, small-scale manufacturers and other industries, burning of biomass and coal for cooking and heating, as well as coal-fired power plants.”

The 10 Most Air-Polluted Cities in the World

1. Ahwaz, Iran
2. Ulan Bator, Mongolia
3. Sanadaj, Iran
4. Ludhiana, India
5. Quetta, Pakistan
6. Kermanshah, Iran
7. Peshawar, Pakistan
8. Gaborone, Botswana
9. Yasouj, Iran
10. Kanpor, India

Lancet 2012; 380: 2224–60
Vol 380  December 15/22/29, 2012
An assessment of air pollution and its attributable mortality in Ulaanbaatar, Mongolia

Ryan W. Allen • Enkhjargal Gombojav • Baldorj Barkhasragschaa • Tsogtbaatar Byamba • Oyuntogos Lkhasuren • Ofer Amram • Tim K. Takaro • Craig R. Janes

- Limited published, peer-reviewed information on UB air quality at the time
- 3 main goals
  - Publish concentrations
  - Characterize temporal and spatial patterns
  - Quantify public health (mortality) impacts
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DOI 10.1007/s11869-011-0154-3
$R^2 = 0.66$

Greenness 1000m Buffer $\times -0.4$

1 / Distance to Centre$^2$ $\times 0.8$

Major Roads 100 m Buffer $\times 18.0$

Peace Ave 75 m Buffer $\times 33.8$

Ger Area 750m Buffer $\times 0.02$

$\text{NO}_2$
\[ \text{Greenness 1000m Buffer} \times -0.56 + \text{Ger Area 2000m Buffer} \times 0.03 = R^2 = 0.75 \]
Conservatively estimated that 9.7% of mortality in Ulaanbaatar can be attributed to outdoor air pollution.

Estimates under other realistic scenarios ranged as high as 19%

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Table 4: Estimates of mortality attributable to long-term PM$_{2.5}$ air pollution exposure in Ulaanbaatar under different model scenarios

<table>
<thead>
<tr>
<th>Shape of concentration-mortality relationship</th>
<th>Counterfactual PM$_{2.5}$ concentration (µg/m$^3$)</th>
<th>Maximum truncation concentration (µg/m$^3$)</th>
<th>Attributable fraction of lung cancer deaths (95% CI)</th>
<th>Attributable lung cancer deaths (95% CI)</th>
<th>Attributable fraction of cardiopulmonary deaths (95% CI)</th>
<th>Attributable cardiopulmonary deaths (95% CI)</th>
<th>Percentage of Ulaanbaatar deaths attributable to outdoor air pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log-linear</td>
<td>3.0</td>
<td>96a</td>
<td>52.3% (23.9–70.1%)</td>
<td>60 (27–80)</td>
<td>39.0% (16.4–55.5%)</td>
<td>783 (329–1,114)</td>
<td>13.1%</td>
</tr>
<tr>
<td></td>
<td>75f</td>
<td>56 (25–77)</td>
<td>36.7% (15.3–52.7%)</td>
<td>736 (306–1,057)</td>
<td>12.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>75f</td>
<td>45 (19–64)</td>
<td>28.8% (11.6–42.7%)</td>
<td>578 (232–857)</td>
<td>10.6%</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>75f</td>
<td>49 (21–69)</td>
<td>31.5% (12.8–46.1%)</td>
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<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3.0</td>
<td>96f</td>
<td>69.2% (33.1–85.8%)</td>
<td>79 (38–98)</td>
<td>56.4% (25.9–74.4%)</td>
<td>1,132 (519–1,493)</td>
<td>18.8%</td>
</tr>
<tr>
<td></td>
<td>75f</td>
<td>68 (30–89)</td>
<td>47.4% (20.7–65.1%)</td>
<td>952 (415–1,308)</td>
<td>15.9%</td>
<td></td>
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<td>75f</td>
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<td></td>
<td>7f</td>
<td>77 (36–96)</td>
<td>54.6% (24.8–72.6%)</td>
<td>1,096 (498–1,458)</td>
<td>18.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>66 (29–86)</td>
<td>45.3% (19.5–62.8%)</td>
<td>908 (392–1,260)</td>
<td>15.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>47 (19–67)</td>
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**An assessment of air pollution and its attributable mortality in Ulaanbaatar, Mongolia**

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Air Qual Atmos Health
DOI 10.1007/s11869-011-0154-3
Health and Economic Impacts

- 27% of mortality in Ulaanbaatar attributable to air pollution
- $463 million in attributable health costs (mortality, bronchitis, and hospitalizations)
  - 19% of city’s GDP
- Proposed a range of abatement options
  - Reduce start-up emissions
  - Replace stoves
  - Replace stoves and improve fuel
  - Install electric heaters in gers
  - Relocate to apartments
We’ve Been Here Before…

London, mid-1900s

Ulaanbaatar, 2010

- Some similarities between current air quality challenges in Asia and past challenges in North America & Europe
  - Population growth, increased urbanization
  - Heavy use of coal for home heating and power generation

http://legacy.london.gov.uk/mayor/environment/air_quality/docs/50_years_on.pdf
Typical Pattern of Air Pollution vs. Development

Fig. 3. Schematic presentation of a typical development of urban air pollution levels. Depending upon the time of initiation of emission control the stabilisation and subsequent improvement of the air quality may occur sooner or later in the development. (Based on WHO/UNEP, 1992; Mage et al., 1996).
We’ve Been Here Before…

- Air pollution recognized as a “nuisance” and suspected to impact health as early as 1200s
  - “Fumifugium; or the Inconvenience of the Aer and Smoak of London Dissipated” (1661)
- Hundreds of years of sporadic and local attempts to control air pollution
- Clean Air Act of 1956 (& amendments of 1968)
  - Partly in response to 1952 pollution event that killed thousands
What Happens When We Remove the Pollution?

Coal sales banned in Dublin

- 5.7% decrease in total non-trauma deaths
- 15.5% decrease in respiratory deaths
- 10.3% decrease in cardiovascular deaths

controlling for temperature, humidity, day of week, respiratory epidemics, death rates in the rest of Ireland

What Happens When We Remove the Pollution?

- Geneva steel mill in Utah, USA
- Responsible for 50 – 80% of particle emissions in the area
- Closed from August 1986 to September 1987 due to a labor dispute
- Winter particle concentrations 2 times higher with mill open

Pope, American Journal of Public Health, 1989
What Happens When We Remove the Pollution?

- Children’s respiratory hospital admissions 2-3 times higher when mill was open

![Graph showing hospital admissions](image)

**FIGURE 3—Actual and Estimated Hospital Admissions, April 1985 through January 1988, Utah Valley**

Pope, American Journal of Public Health, 1989
What Happens When We Remove the Pollution?

- 10 ug/m$^3$ reduction in PM$_{2.5}$ associated with average 0.6 yr increase in life expectancy

  - Assuming linearity:
    100 ug/m$^3$ $\rightarrow$ 10 ug/m$^3$ would equate to > 5 year increase in life expectancy

- Air pollution reductions accounted for up to 15% of total life expectancy increases in study areas.
69 pregnant women randomized to receive a chimney stove vs. 105 controls using open fires

Children of women using stoves had birth weight 89 g (95% CI: -27 – 204) greater than children of women using open fires
Ulaanbaatar Gestation and Air Pollution Research (UGAAR) Study

- www.sfu.ca/ugaar
- Randomized intervention study of fetal growth
  - Intervention is a portable indoor air filter
- Motivation
  - Need for near-term interventions that can be targeted to susceptible populations
  - Randomized trials are the ‘gold standard’ study design, but opportunities are rare in environmental research
- Funded by Canadian Institutes of Health Research
- Will begin recruiting participants in June, 2013
Co-Investigators

- Simon Fraser University
  - Tsogtbaatar Byambaa, MS
  - Craig Janes, PhD
  - Bruce Lanphear, MD, MPH
  - Tim Takaro, MD, MPH
  - Scott Venners, PhD

- Tsetsegmaa Agvaandondov, MD
  - Sukhbaatar Health Department

- Enkhjargal Gombojav, PhD
  - Health Sciences University of Mongolia

- Oyuntogos Lkhasuren, PhD
  - WHO Mongolia Office
Why Ulaanbaatar?

1) There is a need for near-term intervention strategies that can target susceptible populations.

2) High pollution levels provide adequate statistical power among moderate sample population

<table>
<thead>
<tr>
<th></th>
<th>Ulaanbaatar</th>
<th>Vancouver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Avg. PM$_{2.5}$ (ug/m$^3$)</td>
<td>~75</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Winter Avg. PM$_{2.5}$ (ug/m$^3$)</td>
<td>~150</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Estimated exposure reduction from indoor air filtration* (ug/m$^3$)</td>
<td>15</td>
<td>1.5</td>
</tr>
<tr>
<td>Estimated Δ mean birth weight from intervention (grams)**</td>
<td>120</td>
<td>12</td>
</tr>
<tr>
<td>N to achieve 80% power</td>
<td>500</td>
<td>&gt;20,000</td>
</tr>
<tr>
<td>Approximate Cost</td>
<td>$280,000</td>
<td>$Millions</td>
</tr>
</tbody>
</table>

*Conservative, assuming 45% reduction in home indoor concentrations and 32% of time spent outside of home

**Assuming effect of PM$_{2.5}$ is linear across the exposure range.
Summary

- Air pollution now a widely accepted *cause* of illness and death
  - Increasing evidence of effects on a wide range of illnesses

- A particularly important problem in Asian cities due to high pollution levels and large exposed populations

- Evidence of a major public health burden (and economic impact) from air pollution in Ulaanbaatar

- Clear evidence from many settings that if you reduce the air pollution, populations get healthier (and you save money!)

- UGAAR Study will evaluate a potentially useful exposure reduction tool *and* address limitations of previous studies – only possible due to high pollution levels in UB