Health effects of household and ambient air pollution: How was it determined for Ulaanbaatar under alternative policy pathways?

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Workshop on Accelerating Clean Heating and Cooking Access
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Report of the Project:

Impact of Urban Air Pollution on Public Health

For the Ministry of Environment and Green Development, Ulaanbaatar
Health assessment of future PM$_{2.5}$ exposures from indoor, outdoor, and secondhand tobacco smoke concentrations under alternative policy pathways in Ulaanbaatar, Mongolia

Abstract

Introduction

Winter air pollution in Ulaanbaatar, Mongolia is among the worst in the world. The health impacts of policy decisions affecting air pollution exposures in Ulaanbaatar were modeled and evaluated under business as usual and two more-stringent alternative emissions pathways through 2024. Previous studies have relied on either outdoor or indoor concentrations to assess the health risks of air pollution, but the burden is really a function of total exposure. This study combined projections of indoor and outdoor concentrations of PM$_{2.5}$ with population time-activity estimates to develop trajectories of total age-specific PM$_{2.5}$ exposure for the Ulaanbaatar population. Indoor PM$_{2.5}$ contributions from secondhand tobacco smoke (SHS) were estimated in order to fill out total exposures, and changes in population and background disease were modeled. The health impacts were derived using integrated exposure-response curves from the Global Burden of Disease Study.

Hill et al Oct 2017, PLOSOne
Study objectives

• Develop 3 emissions policy pathways for Ulaanbaatar (UB), 2014-2024
  1. Business as usual, or BAU: no major changes from 2013 emissions trends
  2. Pathway 1: moderate emissions reductions
  3. Pathway 2: major but feasible emissions reductions

• Estimate demographics and background disease values, 2014-2024
  • Diseases considered: stroke, lung cancer, ischemic heart disease, chronic obstructive pulmonary disease, and acute lower respiratory illness in children

• Estimate UB-wide PM$_{2.5}$ exposures under each pathway

• Convert exposures into estimates of health effects
### Summary of key baseline and pathway features

<table>
<thead>
<tr>
<th>2014</th>
<th>Business as Usual (BAU)</th>
<th>Pathway 1</th>
<th>Pathway 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td><strong>Not much change from home heating schema of 2014</strong></td>
<td><strong>”Clean indoor” heat in many houses, all apartments</strong></td>
<td><strong>”Clean indoor” heat in all homes</strong></td>
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</table>
| - “Clean indoor” heat in apartments  
  - assumes no indoor emissions  
  - Some heat-only boilers (HOB)  
  - Houses & ger heat with ”improved” MCA stove or similar (e.g. low pressure boiler, [LPB])  
  - 4 combined heat & power plants (CHP)  
  - Nearly 100% growth in traffic from 2010 values | - Add 1 CHP, meets US standards (NSPS)  
  - 2.5% traffic growth per year from 2014, Euro III emissions standards | - 50% HOB retired, others retrofitted  
  - 3 original CHP retrofitted  
  - Add 1 CHP at US NSPS  
  - 1 CHP replaced by renewables and/or imports  
  - 50% reduction in traffic emissions from Pathway 1 | - All HOB retired  
  - 3 original CHP retrofitted  
  - Add 1 CHP at US NSPS  
  - 1 CHP replaced by renewables and/or imports  
  - 50% reduction in traffic emissions from Pathway 1 |

Adapted from Table 1, Hill et al 2017. Summary of the assumptions made for emissions sources, by category.
Estimates of demographic and disease trends

Findings from Hill et al 2017
Anticipate major growth in total population and household number

Expect increase in % population living in Apartments

see manuscript for methods, data sources, assumptions
Projected annual background mortality for 5 diseases

see manuscript for methods, data sources, assumptions
Key aspects of the exposure assessment

Findings from Hill et al. 2017
Total exposure approach

Combined:
• Modeled outdoor concentrations
• Indoor concentrations estimated by:
  • Home type
  • Home heating type
  • Presence of tobacco smoke (SHS)
• Estimated time activity values

Produced estimates of seasonal and annual average PM$_{2.5}$ exposures in UB

Findings from Hill et al 2017
Annual average PM$_{2.5}$ exposures in UB

2014: 59 µg/m$^3$

2024:
- BAU: 60 µg/m$^3$
- Pathway 1: 32 µg/m$^3$
- Pathway 2: 12 µg/m$^3$
Summary of PM$_{2.5}$- attributable health impact estimates
Metrics

• Premature deaths due to air pollution caused diseases

• Disability Adjusted Life Years lost – DALYs
  • This metric is adjusted to account for the age of death and the severity of the illness even if not fatal
  • Important when adding together child and adult outcomes
PM$_{2.5}$ attributable deaths and DALYs estimated from:

- Annual avg. UB exposure estimates
- PM$_{2.5}$ exposure-response curves used in the 2010 Global Burden of Disease study (Burnett et al 2014, Lim et al 2012)
  - Counterfactual (i.e. relative risk = 1) of 12.0 µg/m$^3$
- Projected demographics and background total mortality for 5 diseases
- Disease-specific Death/DALY ratios for Mongolia in 2010 (Lim et al 2012)

Findings from Hill et al 2017

the Lancet, Sep 16, 2017
Burnett et al., EHP. 2014, Integrated Exposure-Response Functions
Table 2. Adjusted relative risk estimates for various increments of exposure from cigarette smoking (versus never smokers), second hand cigarette smoke, and ambient air pollution from the present analysis and selected comparison studies.

<table>
<thead>
<tr>
<th>Source of risk estimate</th>
<th>Increments of Exposure</th>
<th>Lung Cancer</th>
<th>Adjusted RR (95% CI)</th>
<th>CVD</th>
<th>CPD</th>
<th>Estimated Daily Dose PM$_{2.5}$ (mg$^\text{a}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-present analysis</td>
<td>2-3 (1.5) cig/day</td>
<td>10.44 (7.30-14.94)</td>
<td>1.61 (1.27-2.03)</td>
<td>1.58 (1.32-1.89)</td>
<td>1.72 (1.46-2.03)</td>
<td>18</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>4-7 (5.5) cig/day</td>
<td>8.03 (5.89-10.96)</td>
<td>1.64 (1.37-1.96)</td>
<td>1.73 (1.51-1.97)</td>
<td>1.84 (1.65-2.08)</td>
<td>96</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>8-12 (10) cig/day</td>
<td>11.63 (9.51-14.24)</td>
<td>2.07 (1.84-2.31)</td>
<td>2.01 (1.84-2.19)</td>
<td>2.10 (1.94-2.28)</td>
<td>120</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>13-17 (15) cig/day</td>
<td>13.93 (11.04-17.58)</td>
<td>2.18 (1.89-2.52)</td>
<td>1.99 (1.77-2.23)</td>
<td>2.08 (1.87-2.32)</td>
<td>180</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>18-22 (20) cig/day</td>
<td>19.88 (17.14-23.06)</td>
<td>2.36 (2.19-2.55)</td>
<td>2.42 (2.28-2.56)</td>
<td>2.52 (2.39-2.66)</td>
<td>240</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>23-27 (25) cig/day</td>
<td>23.82 (18.80-30.18)</td>
<td>2.29 (1.91-2.75)</td>
<td>2.33 (2.02-2.69)</td>
<td>2.33 (2.03-2.67)</td>
<td>300</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>28-32 (30) cig/day</td>
<td>26.82 (22.54-31.91)</td>
<td>2.22 (1.97-2.49)</td>
<td>2.17 (1.98-2.38)</td>
<td>2.39 (2.15-2.60)</td>
<td>360</td>
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<td>ACS-present analysis</td>
<td>33-37 (35) cig/day</td>
<td>26.72 (18.93-38.44)</td>
<td>2.18 (1.91-3.47)</td>
<td>2.32 (1.98-3.19)</td>
<td>2.83 (2.28-3.52)</td>
<td>420</td>
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<td>ACS-present analysis</td>
<td>38-42 (40) cig/day</td>
<td>30.63 (25.79-36.38)</td>
<td>2.30 (2.05-2.59)</td>
<td>2.37 (2.16-2.59)</td>
<td>2.61 (2.40-2.84)</td>
<td>480</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>43+ (45) cig/day</td>
<td>39.16 (31.13-49.26)</td>
<td>2.00 (1.62-2.48)</td>
<td>2.17 (1.84-2.56)</td>
<td>2.37 (2.04-2.76)</td>
<td>540</td>
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<td>ACS-air pol. original</td>
<td>24.3 μg/m$^3$ ambient PM$_{2.5}$</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.31 (1.17-1.46)</td>
<td>0.44</td>
</tr>
<tr>
<td>ACS-air pol. extend.</td>
<td>10 μg/m$^3$ ambient PM$_{2.5}$</td>
<td>1.14 (1.04-1.23)</td>
<td>1.18 (1.04-1.23)</td>
<td>1.16 (1.08-1.15)</td>
<td>1.09 (1.03-1.16)</td>
<td>0.18</td>
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<tr>
<td>HSC-air pol. original</td>
<td>18.6 μg/m$^3$ ambient PM$_{2.5}$</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.24 (1.10-1.44)</td>
<td>0.33</td>
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<tr>
<td>HSC-air pol. extended</td>
<td>10 μg/m$^3$ ambient PM$_{2.5}$</td>
<td>1.21 (0.92-1.69)</td>
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<td>WHI-air pol.</td>
<td>10 μg/m$^3$ ambient PM$_{2.5}$</td>
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<td>1.24 (1.09-1.41)</td>
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<td>Low-moderate SHS exp.</td>
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<td>SGR-SHS</td>
<td>Moderate-high SHS exp.</td>
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<td>1.26 (1.12-1.42)</td>
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<td>SGR-SHS</td>
<td>Live with smoking spouse</td>
<td>1.21 (1.13-1.30)</td>
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<td>SGR-SHS</td>
<td>Work with SHS exposure</td>
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<td>0.72</td>
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<td>INTERHEART</td>
<td>1-7 hrs/wk SHS exp.</td>
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Pope et al.
Environmental Health Perspectives
2011,
Lung Cancer

Heart Disease

Pope et al. Environmental Health Perspectives 2011,
IHD risks from combustion particles
Annual average PM2.5 in ug/m3

IHD risks from combustion particles
Annual average PM2.5 in ug/m3
At baseline, 2014
- 1,400 deaths
- 40,000 DALYs

Deaths accrued, 2014 - 24
- BAU: 18,000
- Pathway 1: 14,000
- Pathway 2: 9,800

DALYs accrued, 2014 - 24
- BAU: 530,000
- Pathway 1: 420,000
- Pathway 2: 290,000
Pathways 1 & 2 avert thousands of deaths and many more DALYS otherwise accrued under BAU

Child disease (ALRI) accounts for many of the averted DALYS

**Substantially more burden averted by Pathway 2 than Pathway 1**
Total DALYs from PM$_{2.5}$ increase by 2024
• Due in part to population growth

Large reductions in total annual DALYs from PM$_{2.5}$ are achieved under the major emissions reduction policy pathway
Caveats

• Does not include every source of pollution; only the major ones
• Tobacco smoke, which begins to be important late in the period, may come down as anti-tobacco policies are implemented
• Not all air pollution health effects included, only the five in the Global Burden of Disease studies
• There is growing evidence of other effects, however, including
  • Other cancers
  • Adverse pregnancy outcomes
  • TB, adult pneumonia, and flu
  • Diabetes
  • Etc.
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<td>boiler, [LPB])</td>
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<td>from 2010 values</td>
<td>• Same traffic growth as BAU, Euro V</td>
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<td></td>
<td></td>
<td>standards</td>
<td>imports</td>
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What might be done?

• Better coal stoves: Not clean enough, not reliable enough
• LPG: Requires imports
• Natural Gas: Requires imports plus pipelines
• Synthetic NG or LPG from coal? Requires synfuel industry and pipelines
• Electric heating: Most households electrified, but conventional heaters too inefficient
Estimated Burden of Disease for China - 2016
Satellite-based ambient PM$_{2.5}$

20-38% from households in China
More than half from heating
Higher in the north, less in south

van Donkelaar et al, EHP 2010
Household contribution to ambient air pollution
Welcome to HAPIT!

HAPIT estimates and compares health benefits attributable to stove and/or fuel programs that reduce exposure to household air pollution (HAP) in developing countries. HAPIT allows users to customize two scenarios based on locally gathered information relevant to their intervention, which is then worked at the dissemination site to demonstrate pollution exposures before and after the intervention in a representative sample of households. Conservative default values for four broad classes of household energy interventions based on the available literature -- liquid fuels, chimney, stove, and fuel type -- are used. However, country’s health and HAP situation is different, HAPIT currently contains the background data necessary to conduct the analysis in 55 countries with cooking and China, which has a lower percentage of households using solid fuels for cooking, but a high number in absolute terms. See the documentation for details.

HAPIT also estimates program cost effectiveness in US dollars per averted DALY (disability adjusted life year) based on the World Health Organization (WHO) database.
Thank you

Publications and presentations on website: Just Google“Kirk R. Smith