The Global Burden of Disease
Due to Urban Air Pollution

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CRA project and WHR 2002
The Global Burden of Disease Due to Urban Air Pollution

- Estimating the Global Burden of Disease
- Magnitude and distribution of the attributable burden
- Major sources of uncertainty
- Estimating the avoidable burden
## Risk factors in CRA

### Child & maternal under-nutrition
- Childhood and maternal underweight
- Iron deficiency
- Vitamin A deficiency
- Zinc deficiency

### Other nutrition-related risks & inactivity
- High blood pressure
- High cholesterol
- Overweight and obesity
- Inadequate fruit and vegetable intake
- Physical inactivity

### Addictive substances
- Smoking and oral tobacco
- Alcohol
- Illicit drugs

### Sexual and reproductive health risks
- Unsafe sex
- Non-use and ineffective use of contraception

### Environmental risks
- Unsafe water, sanitation, and hygiene
- Urban air pollution
- Indoor smoke from solid fuels
- Lead exposure
- Climate change

### Occupational risks
- Risk factors for injury
- Carcinogens
- Airborne particulates
- Ergonomic stressors
- Noise

### Other selected risks to health
- Contaminated health care injections
- Child sexual abuse

### Distributions of risks by poverty

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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
Basic CRA framework and goals

Risk factor levels
- current distribution
- counterfactual distribution(s)

Risk factor-disease relationships
- risk accumulation
- risk reversal

Disease burden

Attributable burden in 2000
Avoidable burden in 2010 & 2020
Mortality and Burden of Disease

- Mortality = Numbers of Deaths
- Burden = Disability Adjusted Life Year \textit{or} DALY
- DALY = YLL + YLD
  - \textit{years of life lost because of premature death (YLLs)}
  - \textit{years of life lived with disability (YLDs)}
  - one DALY = one lost year of healthy life
Applying the CRA Methods to Urban Air Pollution

• Specification of risk factor levels and counterfactuals

• Choice of risk factor-disease relationships

• Calculation of disease burden
Availability of Exposure Data at Fixed Monitoring Sites in Residential Areas

Data availability
- PM10 current
- PM10 hist only
- TSP 1999 only
- TSP hist only
Determinants of Ambient Concentration of PM

- Anthropogenic factors
  - Emissions / economic activity
  - Pollution abatement policies
  - Technology / knowledge

- Natural / geo-climatic factors
  - Direct sources
  - Dissipative / dispersive factors
Estimated PM$_{10}$ Concentration in World Cities (pop $\geq$100,000)
Population Distribution of Estimated PM$_{10}$ Levels for 3200 Cities

Figure 17.3 Distribution of the urban population according to estimated concentrations of PM$_{10}$ in cities with populations of >100 and in national capitals, by subregion

Cohen et al 2004
American Cancer Society II Cohort
500,000 adults followed 1982 – 1998
(Pope et al JAMA 2002)

<table>
<thead>
<tr>
<th>Condition</th>
<th>RR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiopulmonary</td>
<td>1.06</td>
<td>1.02-1.10</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>1.08</td>
<td>1.01-1.16</td>
</tr>
</tbody>
</table>

Random effects Cox proportional hazards model controlling for age, sex, race, smoking, education, marital status, body mass, alcohol, occupational exposure and diet
Alternative Scenarios for Burden of Disease Estimation for Urban Air Pollution

Alternative concentration-response curves for cardiopulmonary deaths

Counterfactual level of 7.5 µg/m³

Base Case, PM$_{2.5}$ Max=50
PM$_{2.5}$ Max=30
Linear Extrapolation
Log-linear Extrapolation
Percent change in mean daily number of child and infant deaths associated with 10 units of particles
Estimation of attributable deaths and DALYs

1. Calculate region specific relative risk

\[ RR_{2.5} = \exp \left[ CR \times (X - 7.5) \right] \]

where \( CR \) is slope of the C-R function (\( \beta \) coefficient) and \( X \) is regional population weighted mean PM.

2. Calculate Attributable Fraction (AF)

\[ AF = \frac{P(RR-1)}{P(RR-1)+1} \]

where \( P \) is proportion exposed, i.e. proportion living in cities

3. Calculate attributable deaths and DALYs

\( (AF \times \text{regional totals}) \)
## Estimated Burden of Urban Air Pollution Worldwide

(95% confidence intervals)

<table>
<thead>
<tr>
<th></th>
<th>AF (%) (x 10³)</th>
<th>Deaths (%) (x 10³)</th>
<th>YLL (%) (x 10³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPD</strong></td>
<td>3 (1, 6)</td>
<td>712 (245, 1,107)</td>
<td>4,666 (1,695, 7,700)</td>
</tr>
<tr>
<td><strong>Lung Cancer</strong></td>
<td>5 (1, 9)</td>
<td>62 (10, 114)</td>
<td>572 (92, 1,063)</td>
</tr>
<tr>
<td><strong>ARI (&lt;5 yr.)</strong></td>
<td>1 (-1, 3)</td>
<td>26 (-24, 66)</td>
<td>863 (-799, 2,228)</td>
</tr>
</tbody>
</table>
Fraction of Deaths Attributable to Urban Air Pollution by Region

![Bar chart showing the fraction of deaths attributable to urban air pollution by region. The chart compares different regions such as AfD, AfE, AmrA, AmrB, AmrD, EmrB, EmrD, EurA, EurB, EurC, SearB, SearD, WprA, WprB, and World. The bars represent LCA, CPD, and ARI<5 yrs categories.]
Mortality attributable to leading risk factors

- High blood pressure
- Tobacco
- High cholesterol
- Underweight
- Unsafe sex
- Low fruit and vegetable intake
- Overweight and obesity
- Physical inactivity
- Alcohol
- Unsafe water, sanitation, and hygiene
- Indoor smoke from solid fuels
- Iron deficiency
- Urban air pollution
- Zinc deficiency
- Vitamin A deficiency
- Contaminated health care injections
- Occupational airborne particulates
- Occupational risk factors for injury
- Lead exposure
- Illicit drugs

Mortality in thousands (Total 55.86 million)

Ezzati et al. 2002; WHO 2002
AMR-B attributable mortality

Attributable mortality in thousands (total 2.58 million)

- High blood pressure
- Overweight and obesity
- Alcohol use
- Smoking and oral tobacco use
- High cholesterol
- Low fruit and vegetable consumption
- Physical inactivity
- Unsafe sex
- Unsafe water, sanitation and hygiene
- Urban air pollution
- Iron deficiency
- Underweight

Ezzati et al. 2002; WHO 2002
Uncertainties that we quantified

• Sampling variability
• Choice of PM$_{2.5}$/PM$_{10}$
• Choice of concentration-response function: coefficients and extrapolation
• Choice of counterfactual of level
• YLDs vs. YLL
• Cities under 100,000 K
Sensitivity of Attributable Mortality Estimates

- Trunc at 30
- Full linear
- Log-linear
- Base 2.5/10
- Min 3
- Min 15
- Av ACS coeff

% relative to base case

CP
LungCa
Uncertainties that we did not quantify

- No estimates of YLDs for some potentially important health outcomes, e.g., LBW, asthma morbidity

- No estimates for potentially important pollutants, e.g., ozone

- Effects of exposure at finer spatial scales (e.g., due to proximity to vehicular traffic)
Summary results

• Substantial disease burden associated with risk factors such as under-nutrition, poor water and sanitation, and indoor air pollution remain, especially in the poorest developing countries

• Simultaneously risks from a number of factors such as smoking, alcohol, and obesity are becoming increasingly global

• Some risks, like urban air pollution and lack of contraception are major causes of burden in specific regions

• The burden of disease due to urban air pollution is likely to have been underestimated
Unavoidable Disease Burden

Exposure reduction at $T_0$

Attributable and avoidable burden

Past $T_0$ Future $T_x$

Disease Burden

Unavoidable

c

d

0%

25%

50%

75%

100%
(Theoretical minimum)
What determines the health effects of air pollution as economies grow?

- Number of people in cities
- Sources of air pollution
- Total pollution
- Susceptibility
An Increasingly Urban Population
(data from UN/UN Centre for Human Settlements 1995-2002)
Number of people at high CV risk globally in 2000
(A Rogers 2005)

>175 million people at 25%+ risk of a major CV event in the next decade, by WHO subregion

Legend:
- AfrD: very low child and adult mortality
- AfrE: low child and adult mortality
- AmrA: low child, high adult
- AmrB: high child, high adult
- AmrD: high child, very high adult
- EmrB: WprA
- EmrD: WprB

- EurA: 38 m
- EurB: 12 m
- EurC: 46 m
- SearB: 19 m
- SearD: 5 m
- WprA: 7 m
- WprB: 4 m
Estimates of benefits
(Source: US EPA RIA, 2000)

Number of Annual Cases for All of US 2030

- Mortality: 8,300
- Hospital Admissions: 5,600
- Emergency Room Visits: 2,100
- New cases of chronic bronchitis: 5,500
- New cases of bronchitis in children: 17,600
- Acute asthma attacks: 361,400
- Acute respiratory symptoms e.g.: new cases of croup, pneumonia: 386,000
- Restricted activity days: 9.5 million
Reductions in deaths after sulphur restriction in Hong Kong 1990
Hedley AJ et al. 2002

- All causes: 1.8% reduction
- Cardiovascular: 1.6% reduction
- Respiratory: 4.2% reduction
Obrigado

¡Gracias!

Thank You!

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