How Environmental Health Risks Change with Development: With Special Attention to China

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Nobel Laureate, 2007
(at the 0.03% level)

Beijing Forum 2007
Peking University, Nov 2-4
Environment and Health

• It is quite clear that health issues are very important for general environmental control.
  – Outrage over unhealthy community environments led to modern environmental movement.
  – Most regulations officially based on health criteria
• Natural tendency to think that dirty, ugly, smelly conditions are unhealthy
• Our ability to detect very low exposures and small risks has improved dramatically.
• Sometimes hard to admit, however, that evidence of environmental degradation and risk does not necessarily translate into significant health damage
• In a world with many priorities, we need to show how important environmental risk factors are in the total health picture
Environment and Health (cont.)

• On the one hand, figuring actual health impact often involves a quite different perspective than general environmental quality
  • Exposure rather than environmental quality
  • Vulnerable/sensitive populations, including age and sex

• On the other hand, making the case for a major impact on health requires using different metrics than the environmental health community normally does and remembering that

  Risk does not equal burden
Plan of talk: How does one answer questions about the importance of environmental risk factors for health?

– One compared with another, e.g., water versus air pollution?
– Environmental risk factors compared to other important risk factors, such as poor nutrition, smoking, etc.?
– How do environmental health risks tend to change as countries develop?
  • Does environment tend to become more or less important?
  • Do some types of environmental risk rise while others fall?
– How does climate change affect these relationships?
What is health?

• “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.”
  – First of nine principles on first page of World Health Organization Constitution adopted in NYC in July 1946 by 61 nations
  – “spiritual well-being” added in 1999 by World Health Assembly, which at that time had 191 member states

• http://www.ldb.org/iphw/whoconst.htm
Environmental Health Effects

- Example of outdoor air pollution
  - Asthma attacks
  - Missing workdays
  - Missing school days
  - Days with cough
  - Emergency room visits
  - Hospital admissions
  - Physician visits
  - Medication use
  - Daily death rate
  - Lung function
  - Self-reported health status
  - Etc.

- How can these be compared across time, cities, countries, age groups, sectors (e.g., transport versus power plants), etc.?
- Let alone compared with the health impacts from completely different risk factors, such as water pollution, lead exposure, high cholesterol, unsafe sex, etc.?
Single Universal Measure of Ill-health?

• Death is most common
  – Easy to determine
  – Commonly tabulated

• Severe problems as a measure
  – Everyone dies
  – Health never achieved
  – Age is clearly important

• Deaths + Illness = ?
Combined Measure

• What else to use?
  – Money? Are you kidding?
  – Is used in legal and other realms, but not appropriate for public health

• Most fundamental deprivation is loss of time:
  – Same potential life length shared by all humans
  – The degree to which a person does not achieve this life length is a measure of ill-health
  – Can be used for disabilities, as well, but need to weight relative severity of disabilities as well as tabulate their duration
Quality Adjusted Life Years

QALY

• Basically the number of fully healthy life years lost to a particular disease or risk factor.

• Considers the age at which the disease or death occurs and the duration and severity of any disability created.

• Type of QALY used here is the Disability Adjusted Life Year (DALY), which is used widely in international health assessments.
Disability Adjusted Life Year
The DALY, a kind of QALY

- Principle #1: The only differences in the rating of a death or disability should be due to age and sex, not to income, culture, location, social class.
- Principle #2: Everyone in the world has right to best life expectancy in world
- DALY = YLL + YLD
  - Years of Lost Life (due to mortality)
  - Years Lost to Disability (due to injury & illness)
Finally, a $C^4$ Database in Health
(Which we have had in many other fields for long periods)

- **Combined** mortality and morbidity: lost life years
- **Complete**
  - Much of the world unrepresented in past databases
  - Many important disabilities unaccounted
- **Consistent** definitions of disease states
- **Coherent**
  - Deaths by disease need to add to total
    - By age and sex
    - Match with demographic stats
  - No natural discipline, i.e. no import stats from the afterlife tabulating how many died of what
<table>
<thead>
<tr>
<th>Code</th>
<th>Cause</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>All Causes</td>
<td>1419525563</td>
<td>225552079</td>
</tr>
<tr>
<td>1001</td>
<td>Communicable, maternal, perinatal and nutritional conditions</td>
<td>128432071</td>
<td>189358903</td>
</tr>
<tr>
<td>1002</td>
<td>Infectious and parasitic diseases</td>
<td>356032071</td>
<td>0</td>
</tr>
<tr>
<td>1003</td>
<td>Tuberculosis</td>
<td>287359003</td>
<td>8238631</td>
</tr>
<tr>
<td>1004</td>
<td>HIV/AIDS</td>
<td>159234298</td>
<td>30029638</td>
</tr>
<tr>
<td>1005</td>
<td>Maternal, perinatal and nutritional conditions</td>
<td>159234298</td>
<td>30029638</td>
</tr>
<tr>
<td>1006</td>
<td>Birth asphyxia and birth trauma</td>
<td>159234298</td>
<td>30029638</td>
</tr>
<tr>
<td>1007</td>
<td>Other maternal conditions</td>
<td>159234298</td>
<td>30029638</td>
</tr>
<tr>
<td>1008</td>
<td>Nutritional deficiencies</td>
<td>159234298</td>
<td>30029638</td>
</tr>
</tbody>
</table>

Global Burden of Disease Database
World Health Organization
Being completely updated
2007-2009
Total Global Deaths in 2002: 57 million

Total Population
LDCs – 4.78 billion
MDCs – 1.45 billion

Just having coherence in mortality is valuable
Chinese Deaths in 2002: Total = 9.1 million

1302 million population
Those diseases each causing more than 2% of total
Diseases that each cause more than 2% of total lost healthy life years
Comparative Risk Assessment Project
2-year 30-institution study
organized by WHO

Disease, injury, and death due to major risk factors calculated by age, sex, and 14 global regions.

Fully Published in 2 vols, Fall 2004
Now being updated for year 2005
WHO-led Program to Develop Global Burden of Disease Estimates for 26 Major Risk Factors

• More policy relevant and, usually, more distal risk factors than disease or cause of death.
• Represent viable interventions for which cost-effectiveness can be determined.
• Common methods and criteria for including evidence used across risk factors.
Risk Factors in WHO Comparative Risk Assessment

- Malnutrition (underweight)
- Micronutrient deficiency (Zn, Fe, Vit-A)
- Hypertension
- Cholesterol
- Obesity/BMI
- Lack of fruit & veg
- Physical inactivity
- Lack of contraception
- Unsafe sex
- Unsafe medical injection
- Childhood sexual abuse
- Tobacco (active smoking)
- Illicit drugs
- Alcohol
- Lead (Pb)
- Water/hygiene/sanitation
- Climate change
- Indoor air pollution
- Urban outdoor air pollution
- Occupational hazards (several types)
Attributable Risk?

- The amount of ill-health that would not exist today if the exposure to the risk factor had not occurred in the past.
- Assumes all other risk factors remain constant
- Counter-factual level important, i.e., what lower exposure level would have been possible?
Comparative Risk Assessment Method

Exposure Levels: Past actual and past counterfactual

Exposure-response Relationships (risk)

Disease Burden by age, sex, and region

Attributable Burden by age, sex, and region
Rural Energy in China: 2004
Rural population ~ 65% of populations

Total
- Crop wastes: 33%
- Coal: 35%
- Wood: 21%
- Biogas: 1%
- Electricity: 7%
- Kerosene: 2%

Households
- Crop wastes: 44.3%
- Coal: 12.9%
- Wood: 36.6%
- Biogas: 1.2%
- Electricity: 3.7%
- Kerosene: 0.1%

70% of total

Ministry of Agriculture
Ministry of Agriculture
National Bureau of Statistics
National Bureau of Statistics
Rural energy situation is typically complex:
Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

- Small particles, CO, NO₂
- Hydrocarbons
  - 25+ saturated hydrocarbons such as \textit{n-hexane}
  - 40+ unsaturated hydrocarbons such as \textit{1,3 butadiene}
  - 28+ mono-aromatics such as \textit{benzene & styrene}
  - 20+ polycyclic aromatics such as \textit{benzo(α)pyrene}
- Oxygenated organics
  - 20+ aldehydes including \textit{formaldehyde & acrolein}
  - 25+ alcohols and acids such as \textit{methanol}
  - 33+ phenols such as \textit{catechol & cresol}
  - Many quinones such as \textit{hydroquinone}
  - Semi-quinone-type and other radicals
- Chlorinated organics such as \textit{methylene chloride} and \textit{dioxin}

Pollution and health effects of indoor fuel smoke exposure in China*

- Lung cancer
- Respiratory illnesses
- Lung function impairment
- Immune system weakening
- CO poisoning
- Endemic arsenism and fluorosis

*120+ publications from studies conducted in China
Lung Cancer and Indoor Coal Use in China: Review of All Studies (~20)

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR (95% CI)</td>
<td>1.79 (1.18-2.72)</td>
<td>1.17 (1.02-1.35)</td>
<td>1.86 (1.48-2.35)</td>
</tr>
<tr>
<td></td>
<td>1.51 (0.97-2.46)</td>
<td>1.94 (1.09-3.47)</td>
<td>2.55 (1.58-4.10)</td>
</tr>
</tbody>
</table>

*Adjusted for smoking and chronic respiratory disease.

Interpretation:
Women who live in households using coal have about 2 times more lung cancer compared to those living with other fuels.

(Smith et al. 2004)
### Children’s Respiratory Illness

(Salo et al. 2004, Zheng et al. 2002)

<table>
<thead>
<tr>
<th>Odds Ratios</th>
<th>Coal for cooking/ heating</th>
<th>Coal for heating</th>
<th>Coal for cooking w/o vent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheezing w/ colds</td>
<td>1.57 (1.07-2.29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheezing w/o cold</td>
<td>1.44 (1.05-1.97)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>1.5 (1.1-1.9)</td>
<td>2.3 (1.5-3.5)</td>
<td></td>
</tr>
</tbody>
</table>

Other illnesses reported include: rhinitis, faucitis, tonsillitis, and pneumonia (Cheng et al. 2002, Zhou et al. 1994).
Lifetime exposure to heating coal smoke and health outcomes children (Qian and Zhang et al, 2004)

n = 7,058 school children in four Chinese cities.
## Adults’ Respiratory Illnesses

*(Zhou et al. 1995)*

<table>
<thead>
<tr>
<th>Odds Ratios</th>
<th>“Smoky” coal vs. “smokeless” coal</th>
<th>“Smokeless” coal vs. wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortness of breath</td>
<td>1.73</td>
<td></td>
</tr>
<tr>
<td>Cough</td>
<td>3.30</td>
<td>1.35</td>
</tr>
<tr>
<td>Phlegm</td>
<td>4.23</td>
<td>1.67</td>
</tr>
</tbody>
</table>

*Coal and passive smoking together increase prevalence rates of chest illness, cough, phlegm, and shortness of breath in women (Pope and Xu 1993).*
Health Benefits of Fuel/stove Intervention

Best published studies in the world were done by examining introduction of improved coal stoves in China
Improved Stoves Brought to Xuanwei County in early 1980s

• The reduction in particle levels was ~a factor of about three.

• Reduction in lung cancer was ~40% in men and ~45% in women. (Journal of the National Cancer Institute)

• Reduction in COPD rates was also significant at about 50% in both men and women (British Medical Journal)

• Reduction in lung cancer and COPD took 10 years to fully develop after IAQ improvement.
Diseases for which we have epidemiological studies, but very few in China

- Chronic obstructive lung disease
- Interstitial LD
- Cancer (lung, NP, cervical, aero-digestive)
- Blindness (cataracts, trachoma)
- Tuberculosis
- Heart disease?

ALRI/ Pneumonia (meningitis)

Asthma

Low birth weight & stillbirth

Early infant death

Cognitive Effects?
Health Effects of Indoor Biomass Combustion: Major impacts based on systematic reviews and meta-analyses of dozens of studies

Use of biomass fuels in households increases risk of

- Chronic Obstructive Pulmonary Disease in adult women by a factor of 3.2 (95% CI: 2.3-4.8).
- Pneumonia in children under 5 years old by a factor of 2.0 (95% CI: 1.7-2.5).
National Household Solid Fuel Use, 2000

Smith et al.
2004
Estimated Particle Concentration in World Cities (pop=100,000+)
Cumulative distribution of particle concentrations in cites
Selected World Regions

PM10 Concentrations

- North America
- Western Europe
- India
- China
Fraction of mortality attributable to outdoor air pollution

LCA  CPD  ARI<5 yrs
DALYs attributable outdoor AP

(world total 6,404,000)

China
Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

- Underweight
- Unsafe sex
- Blood pressure
- Tobacco
- Alcohol
- Unsafe water/sanitation-E*
- Child cluster vaccination
- Road traffic accidents
- Cholesterol
- Indoor smoke-E
- Overweight
- Low fruit and veg
- Occupational (5 kinds)-E
- Lead (Pb)-E
- Urban outdoor air-E
- Climate change-E

Percent of All DALYs in 2000

- 4.9 million deaths/y
- 1.6 million deaths/y
- 800,000 deaths/y

World Health Reports – 2002,
2001
Chinese Burden of Disease from Top 10 Risk Factors
Plus Selected Other Risk Factors

Percent of all lost life years

0% 1% 2% 3% 4% 5% 6% 7%

- Alcohol
- Blood pressure
- Tobacco
- Underweight
- Occupational hazards (5 kinds)
- Indoor smoke from solid fuels
- Overweight
- Road traffic accidents*
- Low fruit & vegetables
- Cholesterol
- Unsafe water/sanitation
- Urban outdoor air pollution
- Lead (Pb) pollution
- Physical inactivity
- Unsafe sex
- Climate change

380,000
Premature deaths per year

Pneumonia in children: 21,000
COPD in women: 342,000
Lung cancer in women: 18,000

252,000
premature deaths per year
The Environmental Risk Transition

- Risk
- Development

Traditional Risk
The Environmental Risk Transition

- Traditional Risk
- Modern Risk
The Environmental Risk Transition

- Traditional Risk
- Modern Risk
- Risk Overlap
The Risk Overlap

- Risk Genesis: new types of risk created
- Risk Transfer: attempts to control one type can make other types worse
- Risk Synergism: risk of one type changes sensitivity to other risks
The Environmental Risk Transition

Severity

Household Sanitation

Urban Pollution

Increasing Wealth

Shifting Environmental Burdens

Local → Community
Immediate → Delayed
Risks to Human → Risks to Life Support Systems
Health

Severity
Household Risks-$PPP

- Indoor Air Pollution from Solid Fuels
- Unsafe Water and Sanitation
- Malaria
- Total

DALYs per thousand

$PPP per capita

0 10000 20000 30000 40000
Household Risks-$PPP

- Indoor Air Pollution from Solid Fuels
- Unsafe Water and Sanitation
- Malaria
- Total

DALYs per thousand vs. $PPP per capita graph.
Addictions (Tobacco, drugs, alcohol)
Diet and Physical Inactivity
Burden of Ill-health by Region

- Established Market Economies
- Former Socialist
- China
- Latin America
- Middle East/North Africa
- World
- SE Asia & Islands
- India
- Sub-Saharan Africa

Annual lost life-days per capita

"Environmental" Burden = 25-40% of total worldwide
Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

- Underweight
- Unsafe sex
- Blood pressure
- Tobacco
- Alcohol
- Unsafe water/sanitation-E*
- Child cluster vaccination
- Road traffic accidents
- Cholesterol
- Indoor smoke-E
- Overweight
- Low fruit and veg
- Occupational (5 kinds)-E
- Lead (Pb)-E
- Urban outdoor air-E
- Climate change-E

Percent of All DALYs in 2000

150,000 deaths/y
This map shows estimated mortality (per million people) attributable to climate change by the year 2000. Map is a density-equalizing cartogram in which the sizes of the 14 WHO regions are proportional to the increased mortality.

Patz et al. 2007
Distribution of Natural Debt by Country: Carbon in Cumulative CO₂ emissions

Patz et al. 2007
Distribution of Health Impacts from Climate Change
(Experiencing versus Imposing)

Smith and Rodgers

China
Distribution of Health Impacts from Climate Change
(Ratio: Imposing/Experiencing)

Rich countries impose >500 times more risk than they receive.

Poor countries receive >16 times more health risk than they impose.

China = 3.7x

>8000x different!!
WHO Comparative Risk Assessment – 2004
Climate Change Health Impacts as of 2000

- Diarrhea – 2.4% of global burden
- Malaria – 2%; 6% in some regions
- 17% of protein-energy malnutrition
- 7% of dengue fever in some rich countries
- 150,000 deaths, 99% in poor countries (46% in South Asia)
- 0.4% of all DALYs
- Most (88%) of impact in children under 5
- Basically acts as a multiplier of other environmental risks
- Since these are highest at the household level in developing countries, that is where the burden will mostly occur
<table>
<thead>
<tr>
<th>Negative impact</th>
<th>Positive impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very high confidence</strong></td>
<td></td>
</tr>
<tr>
<td>Malaria: contraction and expansion, changes in transmission season</td>
<td></td>
</tr>
<tr>
<td><strong>High confidence</strong></td>
<td></td>
</tr>
<tr>
<td>Increase in malnutrition</td>
<td></td>
</tr>
<tr>
<td>Increase in the number of people suffering from deaths, disease and injuries from extreme weather events</td>
<td></td>
</tr>
<tr>
<td>Increase in the frequency of cardio-respiratory diseases from changes in air quality</td>
<td></td>
</tr>
<tr>
<td>Change in the range of infectious disease vectors</td>
<td></td>
</tr>
<tr>
<td>Reduction of cold-related deaths</td>
<td></td>
</tr>
<tr>
<td><strong>Medium confidence</strong></td>
<td></td>
</tr>
<tr>
<td>Increase in the burden of diarrhoeal diseases</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 8.3.** Direction and magnitude of change of selected health impacts of climate change (confidence levels are assigned based on the IPCC guidelines on uncertainty, see [http://www.ipcc.ch/activity/uncertaintyguidancenote.pdf](http://www.ipcc.ch/activity/uncertaintyguidancenote.pdf)).

IPCC WGII, 2007
Household Sanitation

Urban Pollution

Greenhouse-gas emissions

The Full Environmental Risk Transition

Severity

Increasing Wealth

Shifting Environmental Burdens

Local → Global
Immediate → Delayed
Risks to Human → Risks to Life Support Systems
Health
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published Sept 13, 2007 (370: 5-83)

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Electricity generation and health,

Woodcock J, Banister D, Edwards P, Prentice AM, Roberts I,
Energy and transport,

Wilkinson P, Smith KR, Beevers, Tonne C, Oreszczyn T,
Energy, energy efficiency, and the built environment,

McMichael AJ, Powles JW, Butler CD, Uauy R,
Food, food production, energy, climate change, and health,

Haines A, Smith KR, Anderson D, Epstein P, McMichael A, Roberts I,
Wilkinson P, Woodcock J, Woods J,
Policies for accelerating access to clean energy, improving health, advancing development, and mitigating climate change,
Thank you

Publications available at
http://ehs.sph.berkeley.edu/krsmith/