The Global Burden of Disease attributable to Ambient Air Pollution

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on behalf of the GBD Ambient Air Pollution Core Group and
the GBD Collaboration
London Fog

Effect of Pollution Episode on Mortality (London, England)

Particulate Matter (µg/m³)

Total Deaths Per Day

PM

Deaths

December, 1962
Severe smog and air pollution in Beijing, where hospitals reported increases of up to 30% in the number of patients reporting breathing problems.

Photograph: HAP/Quirky China News / Rex Feat
Global Burden of Disease

- A *systematic scientific* effort to quantify the *comparative magnitude of health loss* for 187 countries from 1990 to present.
- Covering 291 diseases and injuries, 1,160 sequelae of these diseases and injuries, and 67 risk factors or clusters of risk factors
- GBD study initiated in 2007 funded by Bill and Melinda Gates Foundation
  - Core Team at Institute of Health Metrics & Evaluation, University of Washington, Seattle
- Summary papers published in the Lancet
The Global Burden of Disease Study 2010


Summary

Background: Quantification of the disease burden caused by different risks informs prevention by providing an account of health loss attributable to that provided by a disease-by-disease analysis. Complete revision of global burden of disease caused by risk factors has been done since a comparative risk assessment in 2000, and no previous analysis has assessed changes in burden attributable to risk factors over time.

Methods: We estimated deaths and disability-adjusted life years (DALYs) sum years lived with disability (YLD) and years of life lost (YLL) attributable to the effects of 67 risk factors and clusters of risk factors for 21 regions in 1990 and 2010. We estimated exposure distributions for each year, region, sex, and age group, and relative risks per unit of exposure by systematically reviewing and synthesising published and unpublished data. We used these estimates, together with estimates of cause-specific deaths and DALYs from the Global Burden of Disease Study 2010, to calculate the burden attributable to each risk factor exposure compared with the theoretical minimum-risk exposure. We incorporated uncertainty in disease burden, relative risks, and exposures into estimates of attributable burden.

Findings: In 2010, the three leading risk factors for global disease burden were high blood pressure (7.9% [95% uncertainty intervals 7.1–8.7]), tobacco smoking including second-hand smoke (6.3% [5.5–7.3]), and alcohol use (5.5% [5.0–5.9]). In 1990, the leading risks were childhood overweight (7.9% [6.9–8.9]), household air pollution from solid fuels (6.8% [5.8–8.3]), and tobacco smoking including second-hand smoke (6.2% [5.3–7.2]). Dietary risk factors and physical inactivity collectively accounted for 10% (95% CI 9.2–10.8) of global DALYS in 2010, with the most prominent dietary risks being diets low in fruits and those high in sodium. Several risks that primarily affect childhood communicable diseases, including unimproved water and sanitation and childhood micronutrient deficiencies, fell in rank between 1990 and 2010, with unimproved water
GBD 2010 Team

488 authors from 303 institutions in 50 countries
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Comparative Risk Assessment: Methods

• Calculate the proportion of deaths or disease burden holding other independent factors unchanged

• Counterfactual analysis: What if risk exposure was at a different level - e.g., lower PM$_{2.5}$ or normal blood pressure or BMI?

• 79 risk factors and clusters of risk factors

• 20 age groups, both sexes, 187 countries, and for 1990, 2005, 2010, 2013
Estimating the Global Burden of Disease due to Ambient Air Pollution

Exposure to Outdoor Air Pollution

Worldwide Health Evidence

Concentration –Response Relationships

Baseline Incidence

Country-Specific Mortality, Disease

Global Burden, DALYs, Mortality
PM ground-level measurements (2005)

- Measurements: North America, Europe, Australasia
- Estimates (from PM$_{10}$): Asia, Latin America
- No info: 7 / 21 GBD region
Global estimates of PM$_{2.5}$ at 10km x 10km scale

Combined estimates from satellites (AOD), chemical transport models and ground-level measurements

Estimates include contribution of all sources of PM$_{2.5}$

Figure 1.
2005 population-weighted regional estimated average PM$_{2.5}$

Distributions of selected regional 2005 estimated PM$_{2.5}$ by urban and rural areas

- 1.4 million grid cells in total
- Linked to global gridded population (including urban-rural indicators)
- Allows for country-level burden estimation

**Figure 2.** Brauer M, et al. *Env Sci Technol* 2012
Estimated 2010 levels of PM$_{2.5}$ in China
Diseases affected by air pollution are the top 5 causes of the global burden of disease in 2010 (Lozano R et al. 2012)

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Mean rank (95% UI)</th>
<th>% change (95% UI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ischaemic heart disease</td>
<td>1-0 (1 to 1)</td>
<td>35 (29 to 39)</td>
</tr>
<tr>
<td>2 Stroke</td>
<td>2-0 (2 to 2)</td>
<td>26 (14 to 32)</td>
</tr>
<tr>
<td>3 COPD</td>
<td>3-4 (3 to 4)</td>
<td>-7 (-12 to 0)</td>
</tr>
<tr>
<td>4 Lower respiratory infections</td>
<td>3-6 (3 to 4)</td>
<td>-18 (-24 to -11)</td>
</tr>
<tr>
<td>5 Lung cancer</td>
<td>5-8 (5 to 10)</td>
<td>48 (24 to 61)</td>
</tr>
<tr>
<td>6 HIV/AIDS</td>
<td>6-4 (5 to 8)</td>
<td>396 (323 to 465)</td>
</tr>
<tr>
<td>7 Diarrhoea</td>
<td>6-7 (5 to 9)</td>
<td>-42 (-49 to -35)</td>
</tr>
<tr>
<td>8 Road injury</td>
<td>8-4 (5 to 11)</td>
<td>47 (18 to 86)</td>
</tr>
<tr>
<td>9 Diabetes</td>
<td>9-0 (7 to 11)</td>
<td>93 (68 to 102)</td>
</tr>
<tr>
<td>10 Tuberculosis</td>
<td>10-1 (8 to 13)</td>
<td>-18 (-35 to -3)</td>
</tr>
<tr>
<td>11 Malaria</td>
<td>10-3 (6 to 13)</td>
<td>21 (-9 to 56)</td>
</tr>
<tr>
<td>12 Cirrhosis</td>
<td>11-8 (10 to 14)</td>
<td>33 (25 to 41)</td>
</tr>
<tr>
<td>13 Self-harm</td>
<td>14-1 (11 to 20)</td>
<td>32 (8 to 49)</td>
</tr>
<tr>
<td>14 Hypertensive heart disease</td>
<td>14-2 (12 to 18)</td>
<td>48 (39 to 56)</td>
</tr>
<tr>
<td><strong>15 Preterm birth complications</strong></td>
<td><strong>14-4 (12 to 18)</strong></td>
<td><strong>-28 (-39 to -17)</strong></td>
</tr>
<tr>
<td>16 Liver cancer</td>
<td>16-9 (14 to 20)</td>
<td>63 (49 to 78)</td>
</tr>
<tr>
<td>17 Stomach cancer</td>
<td>17-0 (13 to 22)</td>
<td>-2 (-10 to 5)</td>
</tr>
<tr>
<td>18 Chronic kidney disease</td>
<td>17-4 (15 to 21)</td>
<td>82 (65 to 95)</td>
</tr>
<tr>
<td>19 Colorectal cancer</td>
<td>18-5 (15 to 21)</td>
<td>46 (36 to 63)</td>
</tr>
<tr>
<td>20 Other cardiovascular and circulatory cancer</td>
<td>19-7 (18 to 21)</td>
<td>46 (40 to 55)</td>
</tr>
</tbody>
</table>
Needed: a risk model for PM$_{2.5}$ exposure over the entire global range.
A model for estimating the global attributable burden: Integrated exposure-response function (IER)

- All cohort studies of PM$_{2.5}$ and mortality from chronic disease have been conducted in the US and Western Europe
- New models needed to estimate exposure-response functions at high levels of PM in Asia, other regions
- IERs estimate E-R functions using results of studies of second-hand smoke (SHS), household air pollution (HAP), and active tobacco smoking (ATS) (Burnett R et al. 20114 EHP)
- Key model assumptions:
  - Risk is a function of PM$_{2.5}$ inhaled dose regardless of source (Pope et al. 2009; 2011)
  - Consistent with risk observed in current cohort studies
  - Predict risk for highest PM$_{2.5}$ concentrations consistent with risks from SHS, HAP, active smoking

From: Pope CA et al. EHP 2011
Integrated Exposure Response Function – IER

\[ RR_{IER}(z) = \begin{cases} 1, & z < z_{cf} \\ 1 + \alpha(1 - e^{-\gamma(z-z_{cf})^\delta}), & z \geq z_{cf} \end{cases} \]

Accommodates variety of shapes even within ambient range
Theoretical Minimum Risk Exposure Distribution (TMRED)

- The availability of convincing evidence from epidemiological studies that support a continuous reduction in risk of disease
- A distribution that is theoretically possible at the population level
- Assumed no benefit below lowest observed concentrations in ambient air pollution cohort studies
- Also assumed that estimates of risk below the 5th percentile of exposure distribution are too unstable to clearly identify shape
- GBD (2012) assumed TMRED was a Uniform distribution between minimum and 5th percentiles of cohorts studies
  - U(5.8 µg/m³, 8.8 µg/m³)
  - Mean 7.3 µg/m³

Shape of c-r function sensitive to TMRED
GBD risk functions predict risks from recent Chinese cohort study

Association between long-term exposure to outdoor air pollution and mortality in China: A cohort study
Jie Cao\(^1\), Chunxue Yang\(^b\,\,\,c\,\,\,d\), Jianxin Li\(^d\), Renjie Chen\(^b\,\,\,c\), Bingheng Chen\(^b\), Dongfeng Gu\(^e\,\,\,f\), Haidong Kan\(^b\,\,\,c\,\,\,d\).

Figure 5: Predicted relative risk for changes among PM\(_{2.5}\) quartiles observed in the China Cohort (40, 91, 106, and 127 \(\mu g/m^3\)) for the China Cohort study (Cao et al., 2011; blue diamond) and the Integrated Exposure-Response model (red square) by cause of death with 95% confidence intervals represented by error bars.

Burnett et al. 2013 Submitted
3.2 million deaths and 76 million DALYs
Air Quality is an Important Global Health Issue

[Graph showing various health issues and their impacts on global health, with points labeled for diseases and injuries, risk factors, and specific health conditions like smoking, hypertension, ischemic heart disease, etc.]
Top 20 Mortality Risk Factors in the US, India, and China in 2010

Ambient PM$_{2.5}$ caused an estimated 103,000 deaths

Ambient PM$_{2.5}$ caused an estimated 627,000 deaths

Ambient PM$_{2.5}$ caused an estimated 1,234,000 deaths; 14.9% of all deaths in 2010
Burden of disease attributable to 15 leading risk factors in 2010, expressed as a percentage of Canada DALYs

Among top risk factors (#8 deaths, #11 DALYs)
Canadian Census Cohort Study Design

Mortality
All mentions 2004-

Annual Income Tax

1991 Census Long-Form

Hospital Admissions

Health Surveys

Cancer
CAAQS & Cost Benefit Analysis

- WHO
- CAAQS
- Old US
- New US
- 70% Canadian Population
- 50% Pop
- GBD
  - Not Sure of Effects
  - Below this Level

PM2.5
Outdoor Pollution Exposure and Risk Assessment - OPERA

Exposure
- Oxidative Potential
- PM Mass & Components
- Gases NO2 & O3

Risk Assessment
- Mortality
- Development of Chronic Disease
- Birth Outcomes

Disease Burden Attributed to Pollution Sources

Science Support for Policy Development