Quantifying the Air Pollution Burden of Disease

Bert Brunekreef, PhD
Air pollution kills more people than smoking, German scientists say

4.2 million deaths every year as a result of exposure to ambient (outdoor) air pollution

Does air pollution really kill nearly 9 million people each year?
A look under the hood....

Brunekreef's

NDP TUNE-UP SERVICE

Health Burden
Quantifying the Burden is a Burden

- Numbers of deaths attributed to air pollution
- Years of Life Lost due to air pollution
- Loss of Life Expectancy due to air pollution
- Disability before death, due to air pollution
A few definitions

- Disability Adjusted Life Years (DALY) = Years of Life Lost (YLL) + Years of Life with Disability (YLD)
- YLL = N x LE (N of deaths x Life Expectancy at age of death)
- YLD = I x DW x L (Incidence x Disability Weight x Length of period until death or remission)
- Effects on life expectancy are NOT the same as effects on YLL.....
Quantifying the number of attributable deaths

- Attributable Risk, $AR = \frac{(RR - 1)}{RR}$

  ($RR =$ Relative Risk)

- Exposure Fraction (EF) = Fraction Exposed (=1, everybody in case of air pollution)

- Air Pollution Population Attributable Fraction:
  $PAF = \frac{(EF (RR - 1))}{(1 + EF (RR - 1))}$

- So, when, $RR = 1.1$ and $EF = 1$, then:
  $PAF = \frac{0.1}{1.1} = .09$
Key Questions....

- Which Relative Risk (RR) to use?
- Which Exposure Distribution to use?
- What’s the shape of the Exposure-Response function?
- RR for specific causes of death only or for all natural-cause mortality?
- Threshold?
- Age dependency?
- Recoding of causes of death?
- How to interpret the attributed numbers of deaths?
## Differences between GBD, EEA and WHO for PM2.5

<table>
<thead>
<tr>
<th></th>
<th>GBD</th>
<th>EEA</th>
<th>WHO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exposure</strong></td>
<td>Sat., CTM, Meas., geog. 10x10 km</td>
<td>Airbase 1x1 km</td>
<td>As in GBD</td>
</tr>
<tr>
<td><strong>Threshold</strong></td>
<td>2.4-5.9 μg/m³</td>
<td>0 or 2.5 μg/m³</td>
<td>As in GBD</td>
</tr>
<tr>
<td><strong>Basis</strong></td>
<td>AAP, HAP, SHS, AS</td>
<td>AAP</td>
<td>As in GBD</td>
</tr>
<tr>
<td><strong>Causes</strong></td>
<td>IHD, Stroke, LRI, COPD, Lung CA, diabetes</td>
<td>Natural-cause</td>
<td>As in GBD</td>
</tr>
<tr>
<td><strong>Shape</strong></td>
<td>Curvilinear</td>
<td>Linear</td>
<td>As in GBD</td>
</tr>
<tr>
<td><strong>Age dep. RR</strong></td>
<td>YES (IHD only)</td>
<td>NO</td>
<td>As in GBD?</td>
</tr>
<tr>
<td><strong>COD recoding</strong></td>
<td>YES</td>
<td>NO</td>
<td>??</td>
</tr>
</tbody>
</table>
ESTIMATED NUMBER OF ANNUAL PREMATURE DEATHS ATTRIBUTED TO PM ~ 2017

<table>
<thead>
<tr>
<th></th>
<th>GBD</th>
<th>EEA</th>
<th>WHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NETHERLANDS</td>
<td>6,800</td>
<td>11,200</td>
<td>5,320</td>
</tr>
<tr>
<td>FINLAND</td>
<td>1,600</td>
<td>2,150</td>
<td>1,028</td>
</tr>
<tr>
<td>FRANCE</td>
<td>20,000</td>
<td>34,880</td>
<td>16,294</td>
</tr>
<tr>
<td>EU 28</td>
<td>258,000</td>
<td>399,000</td>
<td></td>
</tr>
</tbody>
</table>
Air quality in Europe — 2017 report

**Refers to:**
ETC/ACM, 2016c, Quantifying the health impacts of ambient air pollution — Methodology and input data, de Leeuw, F. and Horálek, J., Technical Paper 2016/5, European Topic Centre on Air Pollution and Climate Change Mitigation.

**Refers to:**

**Refers to:**
An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure

GBD thousands of deaths attributed to ambient pm, household air pollution and ozone, 2012-2018

<table>
<thead>
<tr>
<th>pollutant</th>
<th>2012</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td>PM</td>
<td>2910</td>
<td>2238</td>
<td>3934</td>
<td>3687</td>
<td>4241</td>
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<tr>
<td>HAP</td>
<td>4580</td>
<td>2857</td>
<td>3280</td>
<td>3267</td>
<td>2854</td>
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<tr>
<td>OZONE</td>
<td>143</td>
<td>133</td>
<td>207</td>
<td>188</td>
<td>254</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4808</td>
<td>6466</td>
<td>6485</td>
<td>6219</td>
<td>4900</td>
</tr>
</tbody>
</table>

|-----------|------|------|------|------|------|------|------|------|------|------|
Assessing the recent estimates of the global burden of disease for ambient air pollution: Methodological changes and implications for low- and middle-income countries

Bart Ostro\textsuperscript{a,*}, Joseph V. Spadaro\textsuperscript{b}, Sophie Gumy\textsuperscript{c}, Pierpaolo Mudu\textsuperscript{c}, Yewande Awe\textsuperscript{d}, Francesco Forastiere\textsuperscript{e}, Annette Peters\textsuperscript{f}
Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter

Richard Burnett\textsuperscript{a}, Hong Chen\textsuperscript{a,b}, Mieczysław Szyszko\textsuperscript{w}, Neal Fann\textsuperscript{c}, Bryan Hubbell\textsuperscript{d}, C. Arden Pope III\textsuperscript{e}, Joshua S. Apte\textsuperscript{f}, Michael Brauer\textsuperscript{g}, Aaron Cohen\textsuperscript{h}, Scott Weichenthal\textsuperscript{i,j}, Jay Coggins\textsuperscript{k}, Qian Di\textsuperscript{l}, Bert Brunekreef\textsuperscript{m}, Joseph Frostad\textsuperscript{n}, Stephen S. Lim\textsuperscript{o}, Haidong Kan\textsuperscript{p}, Katherine D. Walker\textsuperscript{h}, George D. Thurston\textsuperscript{p}, Richard B. Hayes\textsuperscript{q}, Chris C. Lim\textsuperscript{r}, Michelle C. Turner\textsuperscript{s}, Michael Jerrett\textsuperscript{t}, Daniel Krewski\textsuperscript{u}, Susan M. Gapstur\textsuperscript{v}, W. Ryan Diver\textsuperscript{v}, Bart Ostro\textsuperscript{w}, Debbie Goldberg\textsuperscript{x}, Daniel L. Crouse\textsuperscript{y}, Randall V. Martin\textsuperscript{z}, Paul Peters\textsuperscript{aa,bb,cc}, Lauren Pinault\textsuperscript{dd}, Michael Tjepkema\textsuperscript{dd}, Aaron van Donkelaar\textsuperscript{e}, Paul J. Villeneuve\textsuperscript{aa}, Anthony B. Miller\textsuperscript{ee}, Peng Yin\textsuperscript{ff}, Maigeng Zhou\textsuperscript{ff}, Lijun Wang\textsuperscript{ff}, Nicole A. H. Janssen\textsuperscript{gg}, Marten Marra\textsuperscript{gg}, Richard W. Atkinson\textsuperscript{hh,ii}, Hilda Tsang\textsuperscript{ij}, Thuan Quoc Thach\textsuperscript{ij}, John B. Cannon\textsuperscript{e}, Ryan T. Allen\textsuperscript{e}, Jaime E. Hart\textsuperscript{kk}, Francine Laden\textsuperscript{kk}, Giulia Cesaroni\textsuperscript{ll}, Francesco Forastiere\textsuperscript{ll}, Gudrun Weinmayr\textsuperscript{mm}, Andrea Jaensch\textsuperscript{mm}, Gabriele Nagel\textsuperscript{mm}, Hans Concin\textsuperscript{nn}, and Joseph V. Spadaro\textsuperscript{oo}

- **ANALYSIS OF OUTDOOR PM COHORT STUDIES ONLY**

- **41 COHORTS FROM 16 COUNTRIES WITH 20,000,000 SUBJECTS AND 2,500,000 DEATHS**
  - **INCLUDING STUDIES FROM CHINA AT HIGH LEVELS OF EXPOSURE**
  - **INCLUDING STUDIES FROM CANADA AND USA AT LOW LEVELS OF EXPOSURE**

- **FOCUS ON NCD (non communicable diseases) + LRI (lower respiratory illness) (= 99% OF ALL-CAUSE), NON-ACCIDENTAL MORTALITY**

PNAS2018
Fig. 2. Country-specific estimates of excess mortality rates associated with 100% reduction to the counterfactual concentration in population-weighted country average fine particulate matter concentrations by age-adjusted GEMM NCD+LRI vs. IER (blue dots) and GEMM 5 Causes of Death (COD) vs. IER (red dots). Dotted line represents 1:1 association.
Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions

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\textsuperscript{5}Department of Environmental Science, Policy, and Management, University of California, Berkeley, USA

\*These authors contributed equally to this work.

\textsuperscript{a}Estimates based on data from the Global Burden of Disease Study, 2015.

\textsuperscript{b}Estimates based on data from the Global Burden of Disease Study, 2018.
How to interpret the number of attributable deaths?
Imagine...

European Community (1957)
Imagine...

A study

- 6 identical twins, born 1930, in IT, FR, GE, NL, BE, LU
- In 1960, one of each moves to polluted Brussels, the other to clean Texel Island (Marine Research Lab ;-))
- Exact same habits within twins, EXCEPT air pollution
- Studied from 2000 (all alive) - 2015 (all dead)

Findings

- **Brussels:** average age at death, 78
- **Texel:** average age at death 80
- RR=1.25; AF=20%
SURVIVAL IN BRUSSELS AND TEXEL, IDENTICAL TWINS FROM 6 EEC COUNTRIES

- Germany
- Luxembourg
- Netherlands
- Belgium
- France
- Italy

Survival (years)

BRUSSELS

TEXEL

65 70 75 80 85 90
SURVIVAL IN BRUSSELS AND TEXEL, IDENTICAL TWINS FROM 6 EEC COUNTRIES
ABSOLUTE N OF DEATHS DUE TO AIR POLLUTION CANNOT BE EXACTLY ESTIMATED

- Attributable premature deaths vary from $1/6$ (17%) to $6/6$ (100%).
- Attributable Fraction calculation says 20%.

Concepts and pitfalls in measuring and interpreting attributable fractions, prevented fractions, and causation probabilities

Sander Greenland MA, MS, DrPH $^{a,b,*}$

Annals of Epidemiology

2015
Still, the numbers of premature deaths attributed to air pollution are \textit{comparatively} useful

- Attributable premature deaths are simply a function of the Relative Risk, the Exposure Fraction and the total N of deaths in a population

- Hence, N of attributable premature deaths are \textit{comparable} across different risk factors – as long as they are being calculated the same way
Take home messages

• Burden of Disease due to air pollution most often expressed in “attributable numbers of premature deaths”
• These numbers cannot be exactly estimated but are useful to compare burdens of different risk factors to each other
• Some assumptions for BoD calculations are different between GBD, WHO, EEA and GEMM. All estimates have in common that the burden is large, within a factor of ~2
• Methods are still evolving, so prepare for changes in BoD estimates because of this
• New studies keep being published that add to our knowledge of concentration-response functions, so prepare for changes in BoD estimates because of this too