Health impact assessment in the framework of global and regional AQ modelling

Rita Van Dingenen
European Commission, Joint Research Centre
Air pollution and health

• Ambient air pollution (individual) risk is small…but large exposed population = large population risk
  – Smoking: Larger risk, smaller exposed population

• Major impacts are on chronic disease progression

• Diseases impacted by air pollution are multifactorial…
  – Cerebro-vascular diseases,
  – Chronic obstructive pulmonary disease, infections of respiratory airways
  – Lung cancer

• …Air pollution as a contributing risk factor [PM2.5, O3, …]
Components of (air pollution) health impact assessment:

Step 1: estimate population exposure

Spatial distribution of pollutant concentration $C$

Spatial distribution of population $Pop$
Exposure to pollutants (PM2.5)

Population
- CIESIN, Univ. of Columbia

Surface PM2.5 derived from Satellite
- Recent past
- Present
  - Van Donkelaar, Dalhousie Univ.

PMxx Ground-based measurements
- Recent past
- Present
  - WHO database

Surface PM2.5 from CTM
- Past
- Present
- Future
  - JRC TM5-FASST tool
Components of (air pollution) health impact assessment:

Past/present/projected Air quality data (modelled/measured)

Spatial distribution of pollutant concentration $C$

Spatial distribution of population $Pop$

Population exposure $X$

Step 2: estimate risk
Integrated Exposure-Response Functions
(Burnett et al., 2014)

RR=2: doubled risk
RR=1: no additional risk

- RR= relative risk
- Based on AP and smoking
- Threshold
- Non-linear
- Age and sex specific
Relevant death causes for Air Pollution:

- Ischaemic heart disease (IHD) [PM2.5]
- Cerbrovascular disease (stroke) [PM2.5]
- Chronic obstructive pulmonary disease (COPD) [PM2.5] [O3]
- Lung cancer (LC) [PM2.5]
- Accute lower respiratory infections (ALRI) [PM2.5]

Conventional way: log-lin relation

- 1 parameter $\beta$ (cause and pollutant-specific)
- $\beta$ from outdoor AP epi studies in EUR and US
- Used for O3 (respiratory diseases) and PM2.5 (CP, LC)

New approach: Integrated Exposure-Response (IER) functions (Burnett et al., 2014)

- 3 parameters (each cause and pollutant-specific)
- for PM2.5 only, 5 death causes
- Data from outdoor AP epi studies in EUR and US integrated with studies on active and SH smoking $\rightarrow$ extended PM range

$$RR(X) = e^{\beta(X-X_0)} \quad \text{for } X > X_0$$

$$RR = 1 \quad \text{for } X \leq X_0$$
Components of (air pollution) health impact assessment:

Spatial distribution of pollutant concentration $C$

Spatial distribution of population $Pop$

Population exposure $X$

Exposure-response function $RR(X)$

$y_o \times Pop$

Fraction of total mortalities attributable to AP $AF$

Total baseline mortalities

Past/present/projected Air quality data (modelled/measured)

Past/present/projected population data/gridmaps

Epidemiological studies specific for pollutant and health outcome

Baseline total mortality rates $y_o$ for specific relevant health outcome (national health statistics)
Contribution of air pollution (PM2.5) to total cause-specific mortalities as a function of PM2.5 concentration

\[ \Delta \text{mort}_i = A\text{F}_i \times y_{o,i} \times \text{Pop} \]
But... how bad is it really?

Global Burden of Disease:

• Systematic quantification of health loss due to diseases, injuries and risk factors
• Previous assessments: 1990, 2004, 2010, **2013**
• Disease, injury, & risk burden estimates **for 1990 –2013** using comparable methods for 188 countries (+ sub-country analyses)
  – 301 diseases and injuries
  – **Role of 79 risk factors** (including indoor/outdoor air pollution by PM2.5 and O3)
• Global collaboration coordinated by Institute for Health Metrics and Evaluation (IHME) + ~1000 volunteers....
• Annual updates beginning in 2016
GBD methodology for exposure to PM2.5: Fusion of observations – satellite – reduced-form CTM

Final estimates based on average of (1.4 million) grid cell values (SAT, TM5-FASST) calibrated (regression model) with measurements

- 0.1°x 0.1° resolution
- extrapolated to 2013 using 2010-2011 trend in SAT

- Incorporate variance between two estimates and measurements in uncertainty assessment
- Unique contributions from each approach

A lot of room for improvement!
Opportunity for HTAP community to link in (ensemble source-receptors)
Together contribute to 10% of global mortality in 2013 – the 4th highest global risk factor

Lancet. 2015 Sep 10
http://vizhub.healthdata.org/gbd-compare/
High vs. Low income countries

- **Household air pollution**
  - COPD
  - Cardio-Vascular
  - LC
  - LRI

- **Ambient particulate matter**
  - Low income

- **Ozone**
  - High income

- **Ambient particulate matter**
  - Cardio-Vascular
  - LC
  - LRI

- **Household air pollution**
  - COPD

<table>
<thead>
<tr>
<th>Tool</th>
<th>Developing institution</th>
<th>Geographical scope</th>
<th>Health endpoint addressed¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>AirCounts</td>
<td>Abt Associates</td>
<td>Global (42 cities, additional 3000 under development)</td>
<td>Mortality</td>
</tr>
<tr>
<td>AirQ2.2 (update under development)</td>
<td>World Health Organization</td>
<td>Any population with specified size, mortality and morbidity characteristics</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>Aphekom</td>
<td>French Institute of Public Health Surveillance</td>
<td>Global (current version focuses on Europe)</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>Economic Valuation of Air Pollution (EVA)</td>
<td>Aarhus University</td>
<td>Northern hemisphere, continental (e.g. Europe), national, city</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>EcoSense</td>
<td>University of Stuttgart</td>
<td>Europe</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE)</td>
<td>US Environmental Protection Agency</td>
<td>Continental USA and China pre-defined; any other as defined by user</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>Environmental Burden of Disease (EBD) Assessment tool for ambient air pollution</td>
<td>World Health Organization</td>
<td>Global</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>GMAPS²</td>
<td>World Bank</td>
<td>Global</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>IOMLIFET</td>
<td>Institute of Occupational Medicine</td>
<td>Can be used anywhere where there is background mortality data and measured or predicted pollutant concentrations</td>
<td>Mortality and morbidity</td>
</tr>
<tr>
<td>Rapid Co-benefits Calculator</td>
<td>US Environmental Protection Agency, Stockholm Environment Institute</td>
<td>Under development for all countries globally</td>
<td>Mortality</td>
</tr>
<tr>
<td>SIM-Air</td>
<td>Urban emissions</td>
<td>Asia, Africa, Latin America</td>
<td>Mortality</td>
</tr>
<tr>
<td>TM5-FASST</td>
<td>European Commission Joint Research Centre</td>
<td>Global (56 source regions)</td>
<td>Mortality and morbidity</td>
</tr>
</tbody>
</table>

¹ Morbidity may include, for example, cardiovascular diseases, respiratory diseases, hospital admissions, emergency room admissions, days of restricted activity, and work loss days. Not all tools address all morbidity outcomes.
² The model itself is no longer actively maintained and therefore no longer available for download.
WHO global platform on air pollution:

Coordinating/compiling observational data, modeling, methodologies, quality management... for AP health impact assessment

- **Improve spatial and temporal resolution for PM$_{2.5}$ and ozone** estimates, e.g. by better description of urban areas and its emissions

- Consider the use of **regional emission inventories** (e.g. inventory mosaic) in global models, and the use of **emission inventory by source sector**.

- Consider the **development of “ensemble” of models** to improve the simulated concentration data, including exploration of the use of the regional/local modelling that is being conducted by the countries

- Explore feasibility of global models for **other health and climate related air pollutants** and of models describing **pollution in cities (or megacities)**

- Explore the use of top-down **constraints by satellite and in-situ observations** for assessment of pollution trends, spatial and temporal variation and emission ratios such as NO$_2$/reactive hydrocarbons ratios

- Conduct retrospective analysis and **source apportionment** (integrating the air quality modelling data in order to provide information on main sources and sectors contributing to human exposure.
Issues – uncertainty sources

• Pollution exposure level
  – Better grip on modelled PM2.5 (ensemble approach, data fusion, bias corrections...)
  – Global CTM model resolution does not capture PM gradients near emission sources \(\rightarrow\) downscaling techniques (e.g. Land Use Regression, Satellite, nesting with regional models)
  – Estimate of household (indoor) pollution and exposure
  – Contribution of natural sources (mineral dust)

• Air pollutants exist as a complex mixture
  – Compound/source - specific toxicity?
  – Residual water in measured PM (\(\rightarrow\) included in ER functions?)
  – Other metrics/components? [NO2, ...]

• Projected baseline mortalities for future scenarios
  – Consistency between present-day risk rates and projected mortality rates?
Health impact assessment in future AP scenarios?

Present-day health studies and statistics:

- Total IHD deaths observed
- IHD RR(PM_{2.5}) observed
- AF=(RR-1)/RR
- IHD deaths attributed to PM2.5

Implicit assumption: Exposure-response functions and baseline mortalities are inherently consistent.

How to deal with future projections? Usual practice:
- Mortality trends estimated from socio-economic drivers (WHO, International Futures), not modulated with air quality policies.
- apply present-day ER-functions
- → loss of internal consistency!

→ Involve AQ scenarios/model results in methodology for mortality projections?
Thanks to:

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- Susan Anenberg (Env. Health Analytics, Washington DC)

And thank you!