Health impact assessment of particulate matter in Estonia and the external costs

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What is Health Impact Assessment (HIA)

• Methodology to evaluate the health impacts of policy scenarios or actions to reduce environmental exposures

  – according to WHO, “combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population”

• HIA involves the quantification of the expected burden of disease due to an environmental risk factor (e.g. outdoor air pollution) in a specific population
Design of HIA

• Altogether three sub-projects
  – 2007 – Tallinn assessment
  – 2008 – Tartu, Kohtla-Järve, Narva, Pärnu assessment
  – 2011 – Estonian assessment

• For HIA had to know:
  – the exposure to air pollution (PM in our case);
  – baseline morbidity/mortality;
  – exposure response rates from previous epidemiological studies.

• For calculation of external costs value of the Year of Life Lost (YLL) and cost of hospitalization
Modelled annual average PM$_{2.5}$ concentrations

Modelling was made by Estonian Environmental Research Centre
“Population count data”
(500x500m)
Population of Tartu

Legend
Number of population
- 9 - 1743
- 1744 - 4398
- 4399 - 7189
- 7190 - 12700
- 12701 - 29691
Population average exposure to PM$_{2.5}$
Baseline mortality & morbidity

- Statistical Office and Estonian Health Insurance Fund data
  - Total mortality (A00-Y98)
  - Respiratory hospitalization (J00-J99)
  - Cardiovascular hospitalization (I00-I99)
- Also we had to know baseline life expectancy for life-tables model
Exposure-response functions

• Relative risks from epidemiological studies
  – Total mortality RR=1.06 (PM$_{2.5}$ – 10 µg/m$^3$) (Pope et al., 2002)
  – Respiratory hospitalization RR=1.0114 (PM$_{10}$ – 10 µg/m$^3$) (Atkinson et al., 2004)
  – Cardiovascular hospitalization RR=1.0073 (PM$_{10}$ – 10 µg/m$^3$) (COMEAP, 2006)
Calculation of long-term exposure induced premature mortality cases

- The following equation was used:

\[ \Delta Y = (Y_o \times pop) \times (e^{\beta \times X} - 1) \]

- where \( Y_0 \) is the baseline rate; \( pop \) the number of exposed persons; \( \beta \) the exposure-response function (relative risk) and \( X \) the estimated exposure.
WHO AirQ - tool for calculating

1. attributable cases because of short-term exposure

2. YLL and decrease of life expectancy because of long-term exposure
Calculation of YLL and decrease of life expectancy
Life tables

• Life table shows, for each age, what the probability is that a person of that age will die or survive before their next birthday
  – The population age structure and age-specific mortality data is needed for calculation
  – The summary statistics, such as life expectancy, can be derived – age-specific mortality rates are converted into a survival curve
• Years of Life lost – basically sum of decreases of life expectancies in society
Long-term exposure health impacts

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual premature mortality cases</th>
<th>Years of Life Lost in a year</th>
<th>Decrease of life expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallinn</td>
<td>296 (76-528)</td>
<td>3859 (1023-6636)</td>
<td>0.64 (0.17-1.10)</td>
</tr>
<tr>
<td>Tartu</td>
<td>64 (17-111)</td>
<td>838 (221-1449)</td>
<td>0.55 (0.16-1.15)</td>
</tr>
<tr>
<td>Kohtla-Järve</td>
<td>18 (5-31)</td>
<td>257 (62-408)</td>
<td>0.38 (0.08-0.55)</td>
</tr>
<tr>
<td>Narva</td>
<td>37 (10-64)</td>
<td>534 (138-908)</td>
<td>0.49 (0.13-0.85)</td>
</tr>
<tr>
<td>Pärnu</td>
<td>36 (9-63)</td>
<td>546 (139-908)</td>
<td>0.47 (0.14-0.80)</td>
</tr>
<tr>
<td>Estonia</td>
<td>600 (155-1061)</td>
<td>8312 (2234-15608)</td>
<td>0.41 (0.11-0.71)</td>
</tr>
</tbody>
</table>
Years of Life Lost

Kaotatud eluastad aastas
- 0 - 10
- 11 - 20
- 21 - 50
- 51 - 100
- 101 - 3900

Map showing the distribution of years of life lost across different areas in Estonia.
Decrease of life expectancy in Tallinn neighbourhoods
Calculation of short-term exposure induced morbidity effects - hospitalizations
Daily averages of PM$_{10}$ in Tallinn, Tartu and Pärnu
### Short-term exposure health impacts

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of annual respiratory hospitalizations</th>
<th>Number of annual cardiovascular hospitalizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallinn</td>
<td>71 (41-103)</td>
<td>204 (128-260)</td>
</tr>
<tr>
<td>Tartu</td>
<td>58 (32-85)</td>
<td>71 (46-90)</td>
</tr>
<tr>
<td>Kohtla-Järve</td>
<td>16 (9-23)</td>
<td>19 (12-24)</td>
</tr>
<tr>
<td>Narva</td>
<td>33 (18-47)</td>
<td>32 (20-40)</td>
</tr>
<tr>
<td>Pärnu</td>
<td>27 (15-39)</td>
<td>38 (24-48)</td>
</tr>
<tr>
<td>Estonia</td>
<td>312 (188-460)</td>
<td>555 (358-706)</td>
</tr>
</tbody>
</table>
Cost of life and life-year (1)

• Two principal approaches for calculation
  – Willingness To Pay (WTP)
    • How much would a person be willing to pay to reduce health risk -> the bigger perceived risk, the higher WTP
  – Personal contribution to national GDP
    • Based on working hours, income, compensation for lost working hours, GDP per capita, etc.
Cost of life and life-year (2)

- **Value of Statistical Life**
  
  \[ VSL = \sum_{n} \frac{WTP_n}{\Delta sN} \]
  
  – WTP of the n-th person, N - exposed population, \( \Delta s \) - change in risk

- **Value of LifeYear**
  
  \[ VOLY = \frac{VSL_A}{T_A} \]
  
  – VSL at age A, T- loss of years at age A
Practical approach for study

• No WTP studies in Estonia
  – However, a metaanalysis by Miller (2000) showed that WTP-based VSL of a country is approximately equal to 120 times GDP per capita
  – Sensitivity analysis for VSL used +/- 30% of the multiplier 120

• No discounting or age weighting used in VOLY calculation in accordance to national BoD and other riskfactor-attributable BoD studies

• Hospitalisation costs included
  – direct treatment costs by health insurance
  – sick-leave compensation by health insurance
  – lost contribution to national GDP for days in hospital
Intermediate cost results

- **VSL**: €1.24m (0.86m-1.61m)
  - $4.0m in USA in 1997
  - $2.7m in UK in 1997
- **VOLY**: €45 486 (31 840-59 132)
- Cost of hospitalisation case
  - €1 916 for pulmonary disease
  - €1 328 for „internal“ disease
- Average length of hospitalisation 6.1 days
- Average compensation for lost working days €16.17
## Costs in counties

<table>
<thead>
<tr>
<th>County</th>
<th>VSL</th>
<th>VOLY</th>
<th>Cost per 100 000 pop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(EUR, millions)</td>
<td>(EUR, millions)</td>
<td>(EUR, millions)</td>
</tr>
<tr>
<td>Hiiu</td>
<td>2,5</td>
<td>1,1</td>
<td>15,8</td>
</tr>
<tr>
<td>Saare</td>
<td>8,7</td>
<td>3,8</td>
<td>15,9</td>
</tr>
<tr>
<td>Lääne</td>
<td>7,5</td>
<td>3,6</td>
<td>19,8</td>
</tr>
<tr>
<td>Tartu</td>
<td>100,5</td>
<td>42,8</td>
<td>21,0</td>
</tr>
<tr>
<td>Valga</td>
<td>12,4</td>
<td>5</td>
<td>22,2</td>
</tr>
<tr>
<td>Rapla</td>
<td>13,7</td>
<td>5,5</td>
<td>23,3</td>
</tr>
<tr>
<td>Võru</td>
<td>14,9</td>
<td>6,1</td>
<td>24,9</td>
</tr>
<tr>
<td>Põlva</td>
<td>12,4</td>
<td>5,3</td>
<td>25,9</td>
</tr>
<tr>
<td>Viljandi</td>
<td>22,4</td>
<td>9,1</td>
<td>26,1</td>
</tr>
<tr>
<td>Järva</td>
<td>13,7</td>
<td>6,2</td>
<td>27,5</td>
</tr>
<tr>
<td>Pärnu</td>
<td>44,7</td>
<td>22,2</td>
<td>28,1</td>
</tr>
<tr>
<td>Jõgeva</td>
<td>16,1</td>
<td>6,8</td>
<td>29,6</td>
</tr>
<tr>
<td>Lääne-Viru</td>
<td>28,6</td>
<td>12,9</td>
<td>30,2</td>
</tr>
<tr>
<td>Ida-Viru</td>
<td>109,2</td>
<td>53,9</td>
<td>35,0</td>
</tr>
<tr>
<td>Harju</td>
<td>338,8</td>
<td>193,8</td>
<td>38,5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>744,6</td>
<td>378,1</td>
<td>31,5</td>
</tr>
</tbody>
</table>
## Costs in main cities

<table>
<thead>
<tr>
<th>City</th>
<th>VSL Cost (EUR, millions)</th>
<th>VOLY Cost (EUR, millions)</th>
<th>Cost per 100 000 pop (EUR, millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tartu</td>
<td>79.4</td>
<td>34.1</td>
<td>17.8</td>
</tr>
<tr>
<td>Kohtla-Järve</td>
<td>24.8</td>
<td>13.7</td>
<td>29.3</td>
</tr>
<tr>
<td>Pärnu</td>
<td>27.3</td>
<td>15.2</td>
<td>33.2</td>
</tr>
<tr>
<td>Narva</td>
<td>48.4</td>
<td>23.8</td>
<td>34.6</td>
</tr>
<tr>
<td>Tallinn</td>
<td>301.5</td>
<td>175.5</td>
<td>44.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>481.4</strong></td>
<td><strong>262.3</strong></td>
<td><strong>31.96</strong></td>
</tr>
</tbody>
</table>
Hospitalisation costs

- **Direct treatment costs**
  - Pulmonary disease €0.6m
  - CVD €0.73m

- **Compensation for hospitalisation days**
  - Pulmonary disease €5 041
  - CVD €8 974

- **Lost productivity**
  - Pulmonary disease €0.24m
  - CVD €0.42m

- **Total**: €0.84m and €1.17m
Conclusions

• All together particulate matter will cause:
  – On average around 600 premature death annually
  – It is more than 8000 years of life lost in a year
  – The average decrease of life expectancy per resident is ~5 months, in main cities ~8 months (in more polluted areas > 1 year)
  – The average decrease per premature death is ~13 years
  – Particulate pollution will cause more than 300 respiratory and ~550 cardiovascular hospitalization in a year
  – The external cost are between 378-744 million EUR in a year through premature death and ~2 million through hospitalization costs
Perspectives

• Compared to 2008 change in particle levels
• In recent HIAs exhaust particle effects have assessed separately
  – e.g. Energiamajanduse arengukava
• Ozone health effects will add ~1/10 to the air pollution health effects
  – Ozone HIA in progress
• Additional health effects related to benzene in Eastern Estonia that cannot described by PM$_{2.5}$
  – Preliminary results from study in oil shale region
• National WPT study could be added
• Extended sources of direct/indirect costs could be used
• Individual level data could be used for cost calculation
• Eestikeelsed aruanded
http://rahvatervis.ut.ee/
  – Orru et al., 2009. Environmental Health, 8, 7.
  – Kesanurum et al., 2014. Air Pollution Modelling and its Application (47 - 51). Springer

Thank you!