Local city report

SEVILLE

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Summary

Great efforts have been invested worldwide to better understand and mitigate the impact of air pollution on human health. However, the debate about safe standards is still open. Aphekom, a multi-centre project funded by the European Commission (GA 2007105), aimed to describe the potential health benefits that would be achieved by meeting the World Health Organization air quality guidelines (WHO-AQG) for PM$_{10}$, fine particles (PM$_{2.5}$) and ozone. Short-term impacts of ozone and PM$_{10}$ on mortality and morbidity, as well as the long-term impact of PM$_{2.5}$ on mortality, life expectancy (LE) and monetary health benefits were quantified based in published concentration-response functions and economic values. Pollutants and health outcome data were recorded for the period 2004-2006.

Although the average annual mean of PM$_{10}$ for the study period did not exceed the legislative limit value in Europe (40 $\mu$g/m$^3$) in the city of Seville, our findings show that, in the short-term, compliance with WHO-AQG of 20 $\mu$g/m$^3$ would prevent each year more than 45 attributable deaths (6/100,000), and about 55 (8/100,000) and 34 (5/100,000) hospital admissions for respiratory and cardiovascular diseases, respectively in Seville. On the other hand, and although the impact of the levels of ozone on health registered in the city of Seville were not very high for the study period, an improvement in the precedents of this pollutant would avoid around 9 premature deaths and would also carry the reduction of some cases hospital admissions for respiratory causes, especially among elderly people.

Larger health benefits were recorded when considering a decrease in PM$_{2.5}$ concentrations at the long-term. The compliance with WHO-AQG of 10$\mu$g/m$^3$ in PM$_{2.5}$ annual mean would avoid more than 435 deaths (97/100,000) in Seville each year, accounting for a monetary health benefit of more than €719 millions annually. This decrease could add up to 10.2 months of life expectancy for persons 30 year of age and older.

Ours findings support the need to revise current air quality legislative limit values, especially in the case of fine particles PM$_{2.5}$. On the other hand, our results show that transportation keeps being the most relevant source of air pollution in Seville. Changes in policies for reducing sulphur content of fuels exerted a very sharp decrease in atmospheric SO$_2$ concentrations related to traffic. More actions measurement needs to be taken in this direction to decrease current particulate matter concentrations to safer standards.

Acronyms

**Aphekom**: Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe

**HIA**: health impact assessment

**O$_3$**: ozone

**PM$_{10}$**: particulate matter with an aerodynamic diameter <10 $\mu$m

**PM$_{2.5}$**: particulate matter with an aerodynamic diameter <2.5 $\mu$m

Introduction

Much has been done in recent years in European cities to reduce air pollution and its harmful effects on health. Yet gaps remain in stakeholders’ knowledge and understanding of this continuing threat that hamper the planning and implementation of measures to protect public health more effectively.

Sixty Aphekom scientists have therefore worked for nearly 3 years in 25 cities across Europe to provide new information and tools that enable decision makers to set more effective European, national and local policies; health professionals to better advise vulnerable individuals; and all individuals to better protect their health.
Ultimately, through this work the Aphekom project hopes to contribute to reducing both air pollution and its impact on health and well being across European cities.

Chapter 1. Standardised HIA in 25 Aphekom cities

Health impact assessments (HIA) have been used to analyze the impact of improving air quality on a given population’s health. Using standardised HIA methods, the preceding Apheis project (1) (www.apheis.org) showed that large health benefits could be obtained by reducing PM levels in 26 European cities totalling more than 40 million inhabitants (2;3). Apheis thus confirmed that, despite reductions in air pollution since the 1990s, the public health burden of air pollution remains of concern in Europe.

Specifically in the case of the city of Seville, the HIA conducted during the third phase of Apheis project (exposure and mortality data for year 2000), showed that from a short-term perspective about 8 total deaths, 5 cardiovascular deaths, 2 respiratory deaths, 11 hospital admissions for respiratory diseases and 7 hospital admissions for cardiac diseases, could have been avoided annually if daily means of PM$_{10}$ would have been kept under 50 μg/m$^3$. In the same way, if daily levels of PM$_{2.5}$ would have been reduced by 3.5 μg/m$^3$, about 17 total deaths (of which 11 cases are cardiovascular deaths and 3 are respiratory deaths), 21 hospital admissions for respiratory diseases and 15 hospital admissions for cardiac diseases, would have been avoided annually.

Larger health benefits were recorded in the HIA-calculation under Apheis-3 when considering a decrease in PM$_{10}$ and PM$_{2.5}$ concentrations for year 2000 in the city of Seville at the long-term. In this way, the compliance with the 1999/30/EC Directive limit value for 2010 of 20μg/m$^3$ in annual mean levels of PM$_{10}$ would have avoided over 673 mortality cases. In the same way, if annual mean levels of PM$_{2.5}$ would have been reduced to 15 μg/m$^3$, 675 mortality cases (of which 476 cases are cardiopulmonary deaths and 69 are lung cancer deaths) could have been prevented.

During year 2001, in the framework of ENHIS-1 project, HIA calculations were focused on the short-term effects of PM$_{10}$ on hospital respiratory admissions in people under 15 year, as well as the long-term effects of PM$_{10}$ on postneonatal mortality. The short-term effects of O$_3$ on emergency room visits for asthma in people under 18 years, and on total mortality in general population was also studied. In this context, for the city of Seville, the reduction of the annual average levels and daily mean values of PM$_{10}$ in 2001 to 20μg/m$^3$ would have prevented 1.25 total postneonatal deaths, and 11.07 hospital respiratory admissions, respectively. Regarding short-term effects of O$_3$ over summer, each reduction by 10μg/m$^3$ of the daily maximum 8-hour moving average concentrations would have delayed 8.58 deaths per year in the general population, 4.61 from cardiovascular diseases, and 1.94 from respiratory causes. In terms of hospital admissions, this would represent 0.16 respiratory admissions in the adult population and 1.22 in the population over 64 years.

Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana, London, Lyon, Malaga, Marseille, Paris, Rome, Rouen, Seville, Stockholm, Strasbourg, Toulouse, Valencia and Vienna. In each participating centre, the project analysed the short-term impacts of ozone and PM$_{10}$ on mortality and morbidity, as well as the long-term impacts of PM$_{2.5}$ on mortality and life expectancy in populations 30 years of age and older.

This work shows that a decrease to 10 μg/m$^3$ of long-term exposure to PM$_{2.5}$ fine particles (WHO’s annual air-quality guideline) could add up to 22 months of life expectancy for persons 30 years of age and older, depending on the city and its average level of PM$_{2.5}$ (Figure 1).

Hence, exceeding the WHO air-quality guideline on PM$_{2.5}$ leads to a burden on mortality of nearly 19,000 deaths per annum, more than 15,000 of which are caused by cardiovascular diseases.

Aphekom also determined that the monetary health benefits from complying with the WHO guideline would total some €31.5 billion annually, including savings on health expenditures, absenteeism and intangible costs such as well being, life expectancy and quality of life.
1.1. Description of the study area for **SEVILLE**

Seville, located in southern Spain, is the political and financial capital of the autonomous community of Andalusia and of the province of Seville. It is situated on the plain of the River Guadalquivir, with an average elevation of 7 metres (23 ft) above sea level and a total surface of 140.8 km². The flatness of the city is bolstered by the generally low level of its buildings, especially in the city centre. According to the Spanish Institute for Statistics, (in Spanish, INE), the population of the city of Seville was 704,198 as of 2010, ranking as the fourth largest city of Spain. The population of the metropolitan area (urban area plus 46 satellite towns) was 1,508,605 as of 2010 (INE estimate). For this reason, the city and its metropolitan area have an important radial system of communication infrastructures.

Agriculture represents less than 1.3% of the workers of the city. Industry contributes up to 28% of the economic output of Seville. It is well established in the metropolitan area, stimulated by the various industrial parks, the presence of good infrastructure and the proximity of the complexes of the Bays of Cádiz, Algeciras, and Huelva. The service sector employs 83.5% of the working population of Seville. It represents a significant share of the local economy and is centred on tourism, trade and financial services.

Seville is served by a bus network which runs buses throughout the city as well as outlying areas surrounding Seville. El Metrocentro Tranvia, working since 2008, is a tram line consisting of four stops (1.2 Km), that covers partially the old city centre. On April 2, 2009, the city opened its first metro line that covers 18 km with 22 stops from Ciudad Expo to Montequinto, crossing the city of Seville from one side to the other of the metropolitan area. The “Sevici community bicycle program” has integrated...
bicycles into the public transport network. Across the city, bicycles are available for hire at low cost and green bicycle lanes can be seen on most major streets.

Figure 2 represents a section of the metropolitan area that includes the city of Seville plus some satellite towns (San Juan Aznalfarache, Tomares, Castilleja de la Cuesta, Alcalá, Dos Hermanas, etc.). The grey colour corresponds to urban soil, the light green to urban parks and the intense green to metropolitan parks (Consejería de Obras Públicas y Vivienda, 2009)

Figure 2 – Map of the Metropolitan area of Seville

The Aphekom project has defined the study area so that data from local air-quality monitoring can provide a good estimate of the average exposure of the population in the study area, taking into account local land use, daily commuting and meteorology.

Figure 3 represents an orthophoto of the studied area in the city of Seville, with a representation of the census geographic units (delimited by yellow lines) and the location of the air pollution monitoring stations used in the present study (red points).
Climatology

Seville has a Mediterranean climate (Köppen et al., 2006), with semi-arid climate influences. The annual average temperature is 18.6 °C (65 °F). Winters are mild, with average maximum temperatures of 15.9 °C (61 °F) and minimum of 5.2 °C (41 °F). Summers are blazing hot, with daily average highs of 35.3 °C (96 °F). Average minimum temperatures in July are 19.4 °C (67 °F) and every year the temperature exceeds 40 °C (104 °F) on several occasions. Winds are very mild normally.

Precipitation varies from 600 to 800 mm (23.5–31.5 in) per year, concentrated in the period October to April. December is the wettest month, with an average rainfall of 95 millimetres (4 in). On average there are 52 days of rain, 120.75 days of sun and four days of frost per year. Average morning relative humidity: 84%, average evening relative humidity: 46%.

Figure 4: Climate data for Seville

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average high °C (°F)</strong></td>
<td>15.9 (60.6)</td>
<td>17.9 (64.2)</td>
<td>21.2 (70.2)</td>
<td>22.7 (72.9)</td>
<td>26.4 (79.5)</td>
<td>31.0 (87.8)</td>
<td>35.3 (95.6)</td>
<td>35.0 (95)</td>
<td>31.6 (88.9)</td>
<td>25.6 (78.1)</td>
<td>20.1 (68.2)</td>
<td>16.6 (61.9)</td>
<td>24.9 (76.8)</td>
</tr>
<tr>
<td><strong>Daily mean °C (°F)</strong></td>
<td>10.6 (51.1)</td>
<td>12.2 (54)</td>
<td>14.7 (58.5)</td>
<td>16.4 (61.5)</td>
<td>19.7 (67.5)</td>
<td>23.9 (75)</td>
<td>27.4 (81.3)</td>
<td>27.2 (81)</td>
<td>24.5 (76.1)</td>
<td>19.6 (67.3)</td>
<td>14.8 (58.6)</td>
<td>11.8 (53.2)</td>
<td>18.6 (65.5)</td>
</tr>
<tr>
<td><strong>Average low °C (°F)</strong></td>
<td>5.2 (41.4)</td>
<td>6.7 (44.1)</td>
<td>8.2 (46.8)</td>
<td>10.1 (50.2)</td>
<td>13.1 (55.6)</td>
<td>16.7 (62.1)</td>
<td>19.4 (66.9)</td>
<td>19.5 (67.1)</td>
<td>17.5 (63.3)</td>
<td>13.5 (56.3)</td>
<td>9.3 (48.7)</td>
<td>6.9 (44.4)</td>
<td>12.7 (54.9)</td>
</tr>
<tr>
<td><strong>Precipitation</strong> mm (inches)</td>
<td>65 (2.56)</td>
<td>54 (2.13)</td>
<td>38 (1.5)</td>
<td>57 (2.24)</td>
<td>34 (1.34)</td>
<td>13 (0.51)</td>
<td>2 (0.08)</td>
<td>6 (0.24)</td>
<td>23 (0.91)</td>
<td>62 (2.44)</td>
<td>84 (3.31)</td>
<td>95 (3.74)</td>
<td>533 (20.98)</td>
</tr>
<tr>
<td><strong>Avg. precipitation days (≥ 1 mm)</strong></td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>52</td>
</tr>
<tr>
<td><strong>Sunshine hours</strong></td>
<td>179</td>
<td>183</td>
<td>224</td>
<td>234</td>
<td>287</td>
<td>312</td>
<td>351</td>
<td>328</td>
<td>250</td>
<td>216</td>
<td>160</td>
<td>164</td>
<td>2,898</td>
</tr>
</tbody>
</table>

(Source: Spanish National Meteorological Agency reproduced from Wikipedia)
Population in the study area

During the study period, the population of the municipality of Seville was 704,154 inhabitants (335,993 men and 368,161 women) according to the population census published for year 2005 by INE. The analysis of the population state by age for this period shows a greater concentration of people in the strata level of 30 to 64 year of age, with a total percentage of 47.87%. The still greater proportion of people under 30 years (36.54%) than above 65 years of age (15.59%) indicates a trend of demographic growth, possibly linked to the high immigration rates registered in the whole Andalusia over that period.

1.2. Sources of air pollution and exposure data

Sources

Principal sources of air pollution were described in detail in the previous Apheis city report (www.apheis.org). Table 1 shows an update of the main sources of air pollution.

Table 1 – Main sources of air pollution (tons/year). Data for year 2005

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Road</th>
<th>Domestic</th>
<th>Industry</th>
<th>Other sources (transportation other than road, incineration of garbage...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>19</td>
<td>238</td>
<td>117</td>
<td>815</td>
</tr>
<tr>
<td>NOₓ</td>
<td>3715</td>
<td>211</td>
<td>120</td>
<td>540</td>
</tr>
<tr>
<td>Primary PM₂₅</td>
<td>343</td>
<td>184</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Primary PM₁₀</td>
<td>406</td>
<td>197</td>
<td>19</td>
<td>56</td>
</tr>
</tbody>
</table>

(Source: Environment Department of the Regional Government of Andalusia)

Transportation constitutes the main source of air pollution in Seville and its metropolitan area: 81% of NOₓ and 60% of PM₁₀ and PM₂₅ came from traffic sources. In the case of SO₂ the contribution of this source has changed drastically after the implementation of the fuel policy, decreasing from a 13% in 2004 to only 2% in 2005 and 2006.

Specific meteorological conditions like Saharan dust intrusions may have a punctual influence on maximum PM₁₀ levels but not on annual mean. This source of air pollution represents less than 2% of PM₁₀ annual mean.

Exposure data

The Surveillance System for Air Pollution is run by the Department of Environment of the Regional Government of Andalusia in collaboration with the Town Council of Seville.

As recommended in the Methodological Guidelines updated from that published in the Apheis-1 report, data were selected from urban or suburban background monitoring stations having at least 75% of valid values. During the study period (2004-2006), Seville had 7 air pollution automatic monitoring stations but only three of them (Bermejales, Centro and Santa Clara) were catalogued as background urban or suburban stations, and recorded PM₁₀, and/or O₃ measurements. Those stations are different from the ones used in previous Apheis city reports. The Air Quality Authorities at the Regional Government, in order to better characterize human exposure to ambient air pollution, run a passive diffusion tubes campaign in Seville over the period 2002-2003 and established a new distribution for the air quality surveillance system. The proposed new location for the stations ensures a reasonable homogenous exposure measurements representative of the urban area of the city,
where more than 80% of the population resides. Figure 3 represents the location of the monitoring stations used in this HIA report with red points.

Automated method was used for PM$_{10}$ measurements (beta-radiation attenuation, UNE-EN 12341-1999) and for O$_3$ measurements (ultraviolet photometry, UNE 77 221:2000). PM$_{2.5}$ data have been calculated from PM$_{10}$ data, using the Apheis conversion factor of 0.7.

The whole study period covered a total of 1095 days from January 1$^{st}$ 2004 till December 31$^{st}$ 2006. For the city of Seville valid data for O$_3$ were registered for the entire study period (Figure 5), but unfortunately, valid data for daily mean PM$_{10}$ concentrations were available only for 788 days, with a percentage of days with valid data of 81.42%, 41.10%, and 93.15% for years 2004, 2005 and 2006, respectively. Construction operations in the proximity of the monitoring stations made impossible to record valid measurements of PM$_{10}$ during a great part of year 2005 (Figure 6), and data from this year were dismissed in the final HIA calculations. The same approach was applied to PM$_{2.5}$ (Figure 7).

Table 2 shows the descriptive statistics of the three pollutants for the whole study period and the study area. The quality of air regarding PM$_{10}$ concentrations evolved positively from an annual mean value of 42 μg/m$^3$ in 2004 to 24 μg/m$^3$ in year 2006. However, more efforts need to be implemented since the fixed legal limit (Directive 1999/30/EC) for the daily mean concentration of PM$_{10}$ of 50 μg/m$^3$ was exceeded in 14.1% of days with valid data (mostly over year 2004. See Figure 6). Maximum daily mean concentrations of PM$_{10}$ in the study period reached the level of 197 μg/m$^3$ registered over summer 2004.

The situation looks more severe when considering the World Health Organization Air Quality Guidelines (WHO-AQG) for human health protection that proposed an annual mean value of 20 μg/m$^3$ for PM$_{10}$ and 10 μg/m$^3$ for PM$_{2.5}$. According to these scenarios, in the city of Seville the average annual mean of PM$_{10}$ and PM$_{2.5}$ in the study period exceed WHO-AQG standards in 1.7 and 2.3 times, respectively.

The daily maximum 8-hour moving average concentrations for O$_3$ did not exceed the legal limit (Directive 2002/3/EC) of 120 μg/m$^3$ in any moment of the study period (Table 2). However, considering the more protective standard of WHO-AQG established in 100 μg/m$^3$, maximum 8-hour moving average concentrations for O$_3$ were exceeded in 30 occasions during 2004 and in 31 days over 2006, normally during the summer periods.

Table 2 – Daily mean levels, standard deviation and 5$^{th}$ and 95$^{th}$ percentiles for air pollutants for the study period (2004-2006)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Daily mean (μg/m$^3$)</th>
<th>Standard deviation (μg/m$^3$)</th>
<th>5$^{th}$ percentile (μg/m$^3$)</th>
<th>95$^{th}$ percentile (μg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone (daily 8h max)</td>
<td>50.03</td>
<td>23.78</td>
<td>14.79</td>
<td>87.67</td>
</tr>
<tr>
<td>PM10 (daily average)</td>
<td>32.07</td>
<td>21.15</td>
<td>10.00</td>
<td>74.65</td>
</tr>
<tr>
<td>PM2.5 (daily average)</td>
<td>22.45</td>
<td>14.81</td>
<td>7.00</td>
<td>52.26</td>
</tr>
</tbody>
</table>
Figure 5 – Ozone concentration in the study area- City of Seville

Figure 6 – PM10 concentration in the study area-City of Seville
1.3. Health data

Mortality data for the study period (2004-2006) comes from the Regional Registry of Mortality, coded according to the International Classification of Diseases (ICD10). The group to be studied was restricted to city residents only. There were no missing data, and a quality control program was applied.

In the autonomous community of Andalusia most of the population is covered by the regional health system, although some people use private health services. Hospital admissions data on respiratory and cardiovascular causes come from the Andalusian Health Services Information Service, also coded using the International Classification of Diseases (ICD10). It is considered that the coverage for years 2004-2006 represented around 95% of the admissions in the city. Only admissions for residents of the city of Seville were selected. The diagnosis used was the one that motivated the admission reflected in the discharge report.

Table 3 shows annual mean number and annual rates of the health outcomes included in this HIA report: total mortality and cardiovascular mortality in population aged 30 years and over, and total mortality excluding external causes and cardio-respiratory hospitalisations in general population.

The average number of deaths among people aged 30 years and over in Seville for the period 2004-2006 was 5832 (annual rate 1305 per 100,000), among which cardiovascular causes accounted for approximately 44% of the total. Regarding hospital admissions, data shows that respiratory diseases affect extensively people aged 65 years and over (≥ 65 yrs), with almost 35% of all hospital admissions for those causes.
Table 3 – Annual mean number and annual rate per 100 000 deaths and hospitalizations for the study period (2004-2006)

<table>
<thead>
<tr>
<th>Health outcome</th>
<th>ICD9</th>
<th>ICD10</th>
<th>Age</th>
<th>Annual mean number</th>
<th>Annual rate per 100 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-external mortality*</td>
<td>&lt; 800</td>
<td>A00-R99</td>
<td>All</td>
<td>5652</td>
<td>803</td>
</tr>
<tr>
<td>Total mortality</td>
<td>&lt; 800</td>
<td>A00-Y98</td>
<td>&gt; 30</td>
<td>5832</td>
<td>1305</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td>390-429</td>
<td>I00-I52</td>
<td>&gt; 30</td>
<td>2522</td>
<td>564</td>
</tr>
<tr>
<td>Cardiac hospitalizations</td>
<td>390-429</td>
<td>I00-I52</td>
<td>All</td>
<td>4345</td>
<td>617</td>
</tr>
<tr>
<td>Respiratory hospitalizations</td>
<td>460-519</td>
<td>J00-J99</td>
<td>All</td>
<td>3700</td>
<td>525</td>
</tr>
<tr>
<td>Respiratory hospitalizations</td>
<td>460-519</td>
<td>J00-J99</td>
<td>15-64 yrs</td>
<td>1432</td>
<td>203</td>
</tr>
<tr>
<td>Respiratory hospitalizations</td>
<td>460-519</td>
<td>J00-J99</td>
<td>≥ 65 yrs</td>
<td>1283</td>
<td>182</td>
</tr>
</tbody>
</table>

* Non-external mortality excludes violent deaths such as injuries, suicides, homicides, or accidents.

1.4. Health impact assessment

Aphekom chose different scenarios to evaluate the health impacts of short- and long-term exposure to air pollution. The scenarios are detailed below for each air pollutant.

NOTE: Under no circumstances should HIA findings for the different air pollutants be added together because the chosen air pollutants all represent the same urban air pollution mixture and because their estimated health impacts may overlap.

The HIA method is detailed in Annex 1.

1.4.1. Short-term impacts of PM$_{10}$

For PM$_{10}$, we first considered a scenario where the annual mean of PM$_{10}$ is decreased by 5 $\mu$g/m$^{3}$, and then a scenario where the PM$_{10}$ annual mean is decreased to 20 $\mu$g/m$^{3}$, the WHO annual air quality guideline (WHO-AQG). The results are presented in Table 4 and 5 and illustrated in Figure 8.

Reducing annual mean levels of PM$_{10}$ to 20 $\mu$g/m$^{3}$ could lead to a reduction yearly of the total burden of mortality (excluding external causes) and the hospitalisations for respiratory and cardiovascular causes among general population in Seville which is about 2.6 times greater than the reduction that could be achieved by reducing the annual mean levels of PM$_{10}$ in the study period only by 5 $\mu$g/m$^{3}$.

Table 4 – Potential benefits of reducing annual PM$_{10}$ levels on total non-external* mortality

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Annual number of attributable deaths avoided</th>
<th>Annual number of attributable deaths avoided per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease by 5 $\mu$g/m$^{3}$</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Decrease to 20 $\mu$g/m$^{3}$</td>
<td>45</td>
<td>6</td>
</tr>
</tbody>
</table>

* Non-external mortality excludes violent deaths such as injuries, suicides, homicides, or accidents.
Table 5 – Potential benefits of reducing annual PM$_{10}$ levels on hospitalisations

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Respiratory hospitalisations</th>
<th>Cardiac hospitalisations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total annual number</td>
<td>Annual number</td>
</tr>
<tr>
<td></td>
<td>of attributable admissions</td>
<td>of attributable admissions</td>
</tr>
<tr>
<td></td>
<td>avoided</td>
<td>avoided per 100 000</td>
</tr>
<tr>
<td>Decrease by 5 μg/m$^3$</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Decrease to 20 μg/m$^3$</td>
<td>55</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 8 – Potential benefits of reducing annual PM$_{10}$ levels on mortality and on hospitalisations

1.4.2. Short-term impacts of ozone

For ozone, WHO set two guideline values for daily the maximum 8-hours mean. The interim target value (WHO-IT1) is set at 160 μg/m$^3$. The purpose of the interim value is to define steps in the progressive reduction of air pollution in the most polluted areas. The second value, the air quality guideline value (WHO-AQG) is set at 100 μg/m$^3$.

We first considered a scenario where all daily values above 160 μg/m$^3$ were reduced to WHO-IT (160 μg/m$^3$), then a scenario where all daily values above 100 μg/m$^3$ were reduced to WHO-AQG (100 μg/m$^3$), and lastly a scenario where the daily mean is decreased by 5 μg/m$^3$. 
Results for each of these scenarios are presented in Tables 6 & 7 and illustrated in Figure 6. Although the impact of the levels of ozone on health registered in the city of Seville were not very high for the study period, an improvement in the precedents of this pollutant would avoid around 9 premature deaths and would also carry the reduction of some cases hospital admissions for respiratory causes, especially among elderly people.

Table 6 – Potential benefits of reducing daily ozone levels on total non-external* mortality

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Total annual number of attributable deaths avoided</th>
<th>Annual number of attributable deaths avoided per 100 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>8h max daily values &gt;160 μg/m³ = 160 μg/m³</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8h max daily values &gt;100 μg/m³ = 100 μg/m³</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decrease by 5 μg/m³</td>
<td>9</td>
<td>1</td>
</tr>
</tbody>
</table>

* Non-external mortality excludes violent deaths such as injuries, suicides, homicides, or accidents.

Table 7 – Potential benefits of reducing daily ozone levels on hospitalizations

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Respiratory hospitalizations (15-64)</th>
<th>Respiratory hospitalizations (&gt;64)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total annual number of attributable admissions avoided</td>
<td>Annual number of attributable admissions avoided per 100 000</td>
</tr>
<tr>
<td>8h max daily values &gt;160 μg/m³ = 160 μg/m³</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8h max daily values &gt;100 μg/m³ = 100 μg/m³</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decrease by 5 μg/m³</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
1.4.3. Long-term impacts of PM$_{2.5}$

For PM$_{2.5}$, we first considered a scenario where the PM$_{2.5}$ annual mean is decreased by 5 $\mu$g/m$^3$, and then a scenario where the PM$_{2.5}$ annual mean is decreased to 10 $\mu$g/m$^3$ (WHO AQG). Results for each of these scenarios are presented in Tables 8 & 9 and illustrated in Figure 10 & 11.

**Table 8 – Potential benefits of reducing annual PM$_{2.5}$ levels on total mortality and on life expectancy (years)**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Total annual number of attributable deaths avoided</th>
<th>Annual number of attributable deaths avoided per 100 000</th>
<th>Gain in life expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease by 5 $\mu$g/m$^3$</td>
<td>167</td>
<td>37</td>
<td>0.3</td>
</tr>
<tr>
<td>Decrease to 10 $\mu$g/m$^3$</td>
<td>435</td>
<td>97</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Table 9 – Potential benefits of reducing annual PM$_{2.5}$ levels on total cardiovascular mortality**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Total annual number of attributable deaths avoided</th>
<th>Annual number of attributable deaths avoided per 100 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease by 5 $\mu$g/m$^3$</td>
<td>139</td>
<td>31</td>
</tr>
<tr>
<td>Decrease to 10 $\mu$g/m$^3$</td>
<td>353</td>
<td>79</td>
</tr>
</tbody>
</table>
Long-term impacts of PM$_{2.5}$

**Figure 10** – Potential benefits of reducing annual PM$_{2.5}$ levels on mortality

Long-term impacts of PM$_{2.5}$

**Figure 11** – Potential benefits of reducing annual PM$_{2.5}$ levels on life expectancy
1.4.4. Economic valuation

These HIAs provide short- and long-term potential benefits on mortality of reducing air pollution as well as the short-term potential benefits on hospitalisations.

Mortality

The monetary values chosen to assess mortality benefits differ depending on the short- or long-term nature of the exposure to air pollution (see Appendix 2). For attributable deaths avoided due to short-term exposure to air pollution the monetary cost was estimated at €86,600. According to this, the monetary health benefits resulted from a reduction in the annual mean level of PM$_{10}$ in the city of Seville by 5 μg/m$^3$ would total some € 1.4 millions annually. This benefit would increase up to € 3.8 millions when considering a reduction in the annual mean level of PM$_{10}$ to 20 μg/m$^3$.

Larger monetary health benefits were recorded when considering a decrease in PM$_{2.5}$ concentrations at the long-term. The compliance with WHO-AQG of 10 μg/m$^3$ in annual mean would account for a monetary health benefit of more than € 719 millions annually.

NOTE: the valuation of mortality benefits is based on stated preferences studies and will use common values for all cities together. Indeed, accounting for differences in country’s GNP per capita seems ethically unacceptable to stand for the valuation of life benefits.

Hospitalisations

The standard cost of illness approach is used for short-term hospitalisations, and consists in applying unit economic values to each case, including direct and indirect costs. The unit economic values will differ across cities, based on specific local market prices for medical resources and wages (see Appendix 2). The economic benefits related to a reduction in air pollution exposure are then computed by multiplying the number of hospitalisations in your city by the corresponding unit economic value.

1.4.5. Interpretation of findings

In this report the APHEKOM team has derived estimates of the health impact of both short- and long-term exposure to particles and ozone. These impacts have been estimated as the numbers of deaths and admissions attributable to air pollution avoided under different reduction scenarios. Further, these benefits have been quantified in monetary terms. Whilst there remains uncertainty in the health impact assessment and in their monetary quantification these results illustrate the magnitude of the potential benefits associated with reductions in air pollution in Seville and more widely across Europe. It should be noted that the benefits reported are not considered to be independent of each other and are therefore not additive across pollutants.

Although the average annual mean of PM$_{10}$ for the study period did not exceed the legislative limit value in Europe (40 μg/m$^3$) in the city of Seville, our findings show that, in the short-term, compliance with WHO-AQG of 20 μg/m$^3$ would prevent each year more than 45 attributable deaths (6/100,000), and about 55 (8/100,000) and 34 (5/100,000) hospital admissions for respiratory and cardiovascular diseases, respectively in Seville. On the other hand, and although the impact of the levels of ozone on health registered in the city of Seville were not very high for the study period, an improvement in the precedents of this pollutant would avoid around 9 premature deaths and would also carry the reduction of some cases hospital admissions for respiratory causes, especially among elderly people.

Larger health benefits were recorded when considering a decrease in PM$_{2.5}$ concentrations at the long-term. The compliance with WHO-AQG of 10μg/m$^3$ in PM$_{2.5}$ annual mean would avoid more than 435 deaths (97/100,000) in Seville each year, accounting for a monetary health benefit of more than € 719 millions annually. This decrease could add up to 10.2 months of life expectancy for persons 30 year of age and older.
Ours findings support the need to revise current air quality legislative limit values, especially in the case of fine particles PM$_{2.5}$. On the other hand, our results show that transportation keeps being the most relevant source of air pollution in Seville. Changes in policies for reducing sulphur content of fuels exerted a very sharp decrease in atmospheric SO$_2$ concentrations related to traffic. More actions measurement needs to be taken in this direction to decrease current particulate matter concentrations to safer standards.

Chapter 2. Health Impacts and Policy: Novel Approaches

Pollutants such as ultrafine particles occur in high concentrations along streets and roads carrying heavy traffic. And evidence is growing that living near such streets and roads may have serious health effects, particularly on the development of chronic diseases. Until now, however, HIAs have not explicitly incorporated this factor.

For this purpose, Aphekom has applied innovative HIA methods to take into account the additional long-term impact on the development of chronic diseases from living near busy roads. We also evaluated the monetary costs associated with this impact.

We first determined that, on average, over 50 percent of the population in the 10 European cities studied lives within 150 metres of roads travelled by 10,000 or more vehicles per day and could thus be exposed to substantial levels of toxic pollutants.

In the cities studied, our HIA showed that living near these roads could be responsible for some 15-30 percent of all new cases of: asthma in children; and of COPD (chronic obstructive pulmonary disease) and CHD (coronary heart disease) in adults 65 years of age and older.
Aphekom further estimated that, on average for all 10 cities studied, 15-30 percent of exacerbations of asthma in children, acute worsening of COPD and acute CHD problems in adults are attributable to air pollution. This burden is substantially larger than previous estimates of exacerbations of chronic diseases, since it has been ignored so far that air pollution may cause the underlying chronic disease as well.
In addition, for the population studied Aphekom estimated an economic burden of more than €300 million every year attributable to chronic diseases caused by living near heavy traffic. This burden is to be added to some €10 million attributable to exacerbations of these diseases.

The economic valuation is not sufficiently robust at the city level from a HIA as well as an economic perspective to allow for local computations.

Chapter 3. Health Impacts of Implemented Policies in Air Pollution

Beyond reviewing the documented benefits to health of the historic Dublin coal ban in 1990 and the recent implementation of congestion charges in London and Stockholm, Aphekom investigated the effects of EU legislation to reduce the sulphur content of fuels (mainly diesel oil used by diesel vehicles, shipping and home heating).

Our analysis in 20 cities showed not only a marked, sustained reduction in ambient SO2 levels but also the resulting prevention of some 2,200 premature deaths valued at €192 million.

Figure 15 – Yearly urban background SO2 averages for 13 Aphekom cities from 1990 to 2004

Figures 16 and Figure 17 show preliminary work done using hourly SO2 data from Vienna, Austria showing seasonal plots for winter (Fig.16) and summer (Fig 17) for a central urban station for the years 1990 to 2000. For example: In Figure 15, SO2 levels are showing a general decreasing trend over time. The two peaks observed consistently throughout all years between 6am and noon and as well between 4pm and 11pm for the winter plots (Fig. 16) suggest that those peaks are mainly caused by traffic due to the morning and evening rush hours and as well due to space heating especially in the evenings. Comparing the two seasons the summer plot (Fig. 17) shows a clear reduction in peak SO2 levels for the mentioned time periods. This might indicate the proportion of SO2 that resulted from
emissions due to heating during the winter months especially as high SO₂ levels are observed for a few consecutive hours from ~5pm up to midnight coinciding with inversion. The smaller peaks are still observed again coinciding with the morning and evening rush hours and also reflecting climatic effects.

Figure 16 – Diurnal plot of winter hourly SO₂ for a central urban station in Vienna 1990-2000

Figure 18 shows a 24hr-plot of hourly SO₂ data from an urban background station in London averaged for the winter months. In comparison to the pattern observed in Fig. 16 for Vienna, where 2 distinct peaks throughout the day for the winter months were observed, here in Fig.18 levels tend to rise markedly in the morning hours and then entering a plateau period with minor variations during day time and declining from 6pm in the evening in 1992 to 1998. One possible explanation for these elevated SO₂ levels during midday might be that it reflects the metropolitan life-style of the city involving constant traffic use. This constant traffic might have been picked up by the urban background measuring station as London Bloomsbury is very central in the city centre.
Figure 17 – Diurnal plot of summer hourly SO₂ for a central urban station in Vienna 1990-2000

Figure 18 – Diurnal plot of winter hourly SO₂ for an urban background station in London 1992-1998
Valuation of the benefits of EU legislation to reduce the sulphur content of fuels

The local estimates are not sufficiently robust at the city level to allow a local HIA so it has been decided to use the meta-results for the local economic valuation. The legislation has two potential effects on mortality: short-term and long-term. It was decided that, to take a conservative standpoint, mortality effects would be considered as short-term effects. The value of a life year (VOLY) was estimated to be €86,600. Our analysis in 20 cities showed not only a marked, sustained reduction in ambient SO2 levels but also the resulting prevention of some 2,200 premature deaths valued at €192 million. The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation.

Chapter 4. Sharing Knowledge and Uncertainties with Stakeholders

Uncertainties perceived by scientists, policy makers and other stakeholders can undermine their confidence in the findings of HIAs. For this reason, Aphekom has developed a method that helps them discuss and share their views on both the uncertainties in HIA calculations and their impact on the decision-making process. In addition, to help decision makers draft policies on air quality and related environmental-health issues, Aphekom has developed a process, based on a deliberation-support tool, that helps frame and structure exchanges between stakeholders working together. Using this process enables them to propose and discuss multiple criteria for evaluating, prioritising and aligning their various needs, and for choosing actions that match their objectives and preferences.

Chapter 5. Overview of findings and local recommendations

Great efforts have been invested worldwide to better understand and mitigate the impact of air pollution on human health. However, the debate about safe standards is still open. Aphekom, a multi-centre project funded by the European Commission (GA 2007105), aimed to describe the potential health benefits that would be achieved by meeting the World Health Organization air quality guidelines (WHO-AQG) for PM10, fine particles (PM2.5) and ozone. Short-term impacts of ozone and PM10 on mortality and morbidity, as well as the long-term impact of PM2.5 on mortality, life expectancy (LE) and monetary health benefits were quantified based in published concentration-response functions and economic values. Pollutants and health outcome data were recorded for the period 2004-2006.

Although the average annual mean of PM10 for the study period did not exceed the legislative limit value in Europe (40 μg/m³) in the city of Seville, our findings show that, in the short-term, compliance with WHO-AQG of 20 μg/m³ would prevent each year more than 45 attributable deaths (6/100,000), and about 55 (8/100,000) and 34 (5/100,000) hospital admissions for respiratory and cardiovascular diseases, respectively in Seville. On the other hand, and although the impact of the levels of ozone on health registered in the city of Seville were not very high for the study period, an improvement in the precedents of this pollutant would avoid around 9 premature deaths and would also carry the reduction of some cases hospital admissions for respiratory causes, especially among elderly people.

Larger health benefits were recorded when considering a decrease in PM2.5 concentrations at the long-term. The compliance with WHO-AQG of 10μg/m³ in PM2.5 annual mean would avoid more than 435 deaths (97/100,000) in Seville each year, accounting for a monetary health benefit of more than €719 millions annually. This decrease could add up to 10.2 months of life expectancy for persons 30 year of age and older.

Ours findings support the need to revise current air quality legislative limit values, especially in the case of fine particles PM2.5. On the other hand, our results show that transportation keeps being the most relevant source of air pollution in Seville. Changes in policies for reducing sulphur content of fuels exerted a very sharp decrease in atmospheric SO2 concentrations related to traffic. More actions
measurement needs to be taken in this direction to decrease current particulate matter concentrations to safer standards.

References


Agencia Estatal de Meteorología. Available at: http://www.aemet.es/es/portada (access on: 04.04.2011)

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Appendix 1 – Health impact assessment

For each specific relationship between health outcomes and pollutants, the health impact function was
\[ \Delta y = y_0 (1 - e^{-\beta \Delta x}) \]

where \( \Delta y \) is the outcome of the HIA
\( y_0 \) is the baseline health data
\( \Delta x \) is the decrease of the concentration defined by the scenario
\( \beta \) is the coefficient of the concentration response function (\( \beta = \log(\text{RR per } 10 \mu g/m^3)/10 \))

The impact of a decrease of the pollutant concentration on the life expectancy was computed using standard abridged (5-year age groups) life table methodology, using the mortality data for each age group. We applied a reduction factor to the mortality rate, noted \( n D_x \), according to
\[ n D_x^{impacted} = n D_x * e^{-\beta \Delta x} \]

\( \Delta x \) is the decrease of the concentration defined by the scenario
\( \beta \) is the coefficient of the concentration response function.

Concentration response functions (CRFs) were selected from the literature, favouring multi-cities studies located in Europe (Table 1).

<table>
<thead>
<tr>
<th>HIA</th>
<th>Health outcome</th>
<th>Ages</th>
<th>RR per 10 ( \mu g/m^3 )</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term impacts of PM10</td>
<td>Non-external mortality</td>
<td>All</td>
<td>1.006 [1.004-1.008]</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>Respiratory hospitalizations</td>
<td>All</td>
<td>1.0114 [1.0062-1.0167]</td>
<td>(5)</td>
</tr>
<tr>
<td></td>
<td>Cardiac hospitalizations</td>
<td>All</td>
<td>1.006 [1.003-1.009]</td>
<td>(5)</td>
</tr>
<tr>
<td>Short-term impacts of O3</td>
<td>Non-external mortality</td>
<td>All</td>
<td>1.0031 [1.0017-1.0052]</td>
<td>(6)</td>
</tr>
<tr>
<td></td>
<td>Respiratory hospitalizations</td>
<td>15-64</td>
<td>1.001 [0.991-1.012]</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>Respiratory hospitalizations</td>
<td>&gt;=65</td>
<td>1.005 [0.998-1.012]</td>
<td>(4)</td>
</tr>
<tr>
<td>Long-term impacts of PM2.5</td>
<td>Total mortality</td>
<td>&gt;30</td>
<td>1.06 [1.02-1.11]</td>
<td>(7)</td>
</tr>
<tr>
<td></td>
<td>Cardiovascular mortality</td>
<td>&gt;30</td>
<td>1.12 [1.08-1.15]</td>
<td>(8)</td>
</tr>
</tbody>
</table>

PM10

For PM10, we first considered a scenario where the annual mean of PM10 is decreased by 5 \( \mu g/m^3 \), and then a scenario where the same PM10 annual mean is decreased to 20 \( \mu g/m^3 \), the WHO air quality guideline (WHO-AQG).

The exposure indicator of PM10 was the annual mean, calculated as the arithmetic mean of the daily concentrations of the selected stations. The corresponding \( \Delta x \) for the two scenarios are:
Scenario 1, $\Delta x = 5 \mu g/m^3$
- Scenario 2, $\Delta x = ([\text{PM10}]_{\text{mean}} - 20 \mu g/m^3)$.  
  $\Delta x = 0$ if $[\text{PM10}]_{\text{mean}} < 20$

Ozone

For ozone, WHO set two values for the daily maximum 8-hours mean. The interim target value (WHO-IT1) is set at 160 $\mu g/m^3$. The purpose of the interim value is to define steps in the progressive reduction of air pollution in the most polluted areas. The air quality guideline value (WHO-AQG) is set at 100 $\mu g/m^3$.

We first considered a scenario where all daily values above 160 $\mu g/m^3$ were reduced to WHO-IT (160 $\mu g/m^3$), then a scenario where all daily values above 100 $\mu g/m^3$ were reduced to WHO-AQG (100 $\mu g/m^3$), and lastly a scenario where the daily mean is decreased by 5 $\mu g/m^3$.

The exposure indicator of ozone was the cumulated sum over defined thresholds, calculated using 8-hours-daily values.

The corresponding $\Delta x$ for the two scenarios are;

- Scenario 1, if $[O_3]_i \geq 160 \mu g/m^3$, $O_i = ([O_3]_i - 160)$
  if $[O_3]_i < 160 \mu g/m^3$, $O_i = 0$
- Scenario 2, if $[O_3]_i \geq 100 \mu g/m^3$, $O_i = ([O_3]_i - 100)$
  if $[O_3]_i < 100 \mu g/m^3$, $O_i = 0$
- Scenario 3, where the ozone yearly mean is decreased by 5 $\mu g/m^3$. $\Delta x = 5 \mu g/m^3$

PM2.5

For PM2.5, we first considered a scenario where the PM2.5 annual mean is decreased by 5 $\mu g/m^3$, and then a scenario where the PM2.5 annual mean is decreased to 10 $\mu g/m^3$ (WHO annual AQG).

The exposure indicator of PM2.5 was the yearly mean, calculated as the arithmetic mean of the daily concentrations of the selected stations. The corresponding $\Delta x$ for the two scenarios are;

- Scenario 1, $\Delta x = 5 \mu g/m^3$
- Scenario 2, $\Delta x = ([\text{PM2.5}]_{\text{mean}} - 10 \mu g/m^3)$
  $\Delta x = 0$ if $[\text{PM2.5}]_{\text{mean}} < 10$

References


Appendix 2 – Economic valuation

Because the air pollution measures as well as epidemiologic data cover the 2004-2006 period for most of the cities, all costs are consequently expressed in euros 2005. Similarly, the average lengths of stay in hospital required for the benefits computations are for 2005.

Valuation of mortality benefits

Regarding mortality, we follow the standard valuation procedure adopted in Cafe (2005), NexExt (2003), ExternE (2000), which consists in using a Value of a Statistical Life (VSL) and a Value of a Life Year (VOLY) derived from stated preferences surveys, hence relying on preference-derived values rather than market-derived values. We chose to rely on values obtained in recent European studies (see final Aphekom report for more details).

The choice of the monetary value to assess mortality benefits associated to a decrease in air pollution level depends on the type of impact.

- **For short-term mortality calculations**, the annual number of deaths postponed per year is used. Because the gains in life expectancy corresponding to each of these postponed deaths can be considered in the range of a few months, certainly lower than one year (Cafe 2005, Vol 2, p. 46), a \textit{VOLY} of \( \text{€86,600} \) is applied to each deaths postponed to compute annual benefits.

- **For long-term mortality calculations**, the magnitude of the gain in life expectancy related to the deaths postponed is considered as higher than a year (see Ezzati et al., 2002; Hurley et al. 2005; Watkiss et al. 2005; or Janke et al., 2009). A \textit{VSL} of \( \text{€1,655,000} \) is applied to each deaths postponed to compute annual benefits.

- **For long-term life expectancy calculations**, an average gain in life expectancy for persons 30 years of age is also computed using life tables and following a cohort until complete extinction. The annual corresponding benefits are obtained by multiplying the average gain in life expectancy by the number of 30-year-old individuals in the city, and by the \textit{VOLY}. This corresponds to the benefits (in terms of life expectancy) 30 year-old people would gain over their lifetime if exposed to the 10 µg/m³ average annual level of PM2.5 (WHO’s Air Quality Guideline) instead of the current existing air pollution level in the city.

Valuation of hospitalisations benefits

The standard cost of illness approach is used for acute hospitalisations, and consists in applying unit economic values approach to each case, including direct medical and indirect costs.

The **direct medical costs** related to cardiac and respiratory hospitalisations are computed as the cost per inpatient day times the average length of stay in hospital. These cost data are taken from CEC (2008) for all twelve countries where the cities analysed in Aphekom are located (see Table 1). The average lengths of stay in days are obtained from the OECD Health Database (2010) for all countries except Romania (which is imputed from the population weighted average lengths of the 11 other countries).

The **indirect costs** are computed as the average gross loss of production per day times twice the average length of stay in hospital. Since we cannot control whether these days were actual working days, we then compute the daily loss of production as the average gross earnings in industry and services (full employment) obtained from Eurostat (2003) for each country, expressed in 2005 and divided by 365 days.

The total medical costs for cardiac and respiratory hospitalisations are obtained by adding together the direct and indirect components.
For instance, based on Table 1, the average direct cost of a cardiac hospital admission is:

\[ 8.5 \text{ days} \times 373 = 3,171 \text{ €} \]

and the corresponding indirect cost related to work loss is:

\[ 2 \times 8.5 \text{ days} \times 73 = 1,241 \text{ €} \]

Overall, the unit economic value related to a cardiac hospital admission is € 4,412.

For city-specific valuation, the last two columns of Table 1 provide average hospitalisation costs computed following the same rationale but using country-specific average lengths of stay, cost per day of hospitalization and daily work loss.

Valuation of the benefits of EU legislation to reduce the sulphur content of fuels

The legislation has two potential effects on mortality: short-term and long-term. It has been decided that, to take a conservative standpoint, mortality effects will be considered as short-term effects. Consequently, a VOLY of €86,600 is applied to each premature death to compute the benefits of the legislation. The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation.

References


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