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

**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 µm

**$PM_{2.5}$**: particulate matter with an aerodynamic diameter <2.5 µm

## 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.

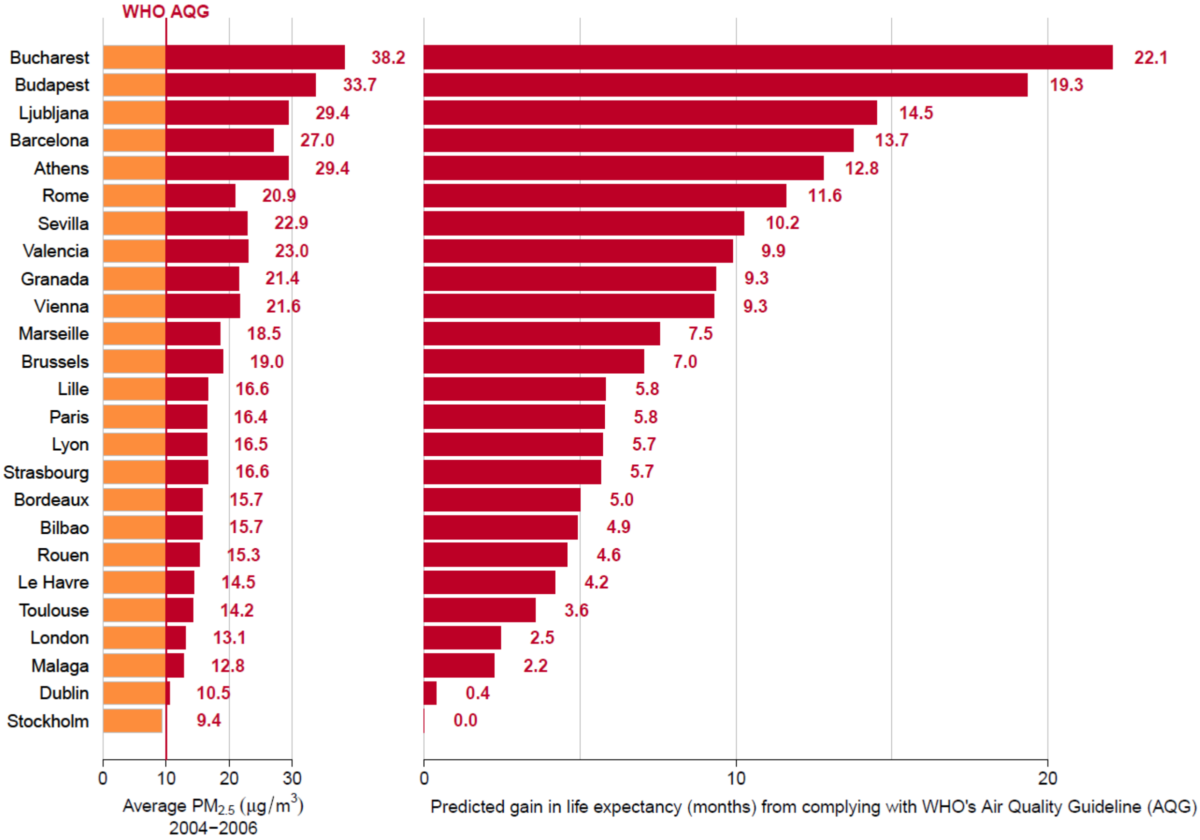
Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana, 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 PM10 on mortality and morbidity, as well as the long-term impacts of PM2.5 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.

**Figure 1: Predicted average gain in life expectancy (months) for persons 30 years of age and older in 25 Aphekom cities for a decrease in average annual level of PM2.5 to 10 µg/m3 (WHO's Air Quality Guideline)**




### 1.1. Description of the study area for *SEVILLE*

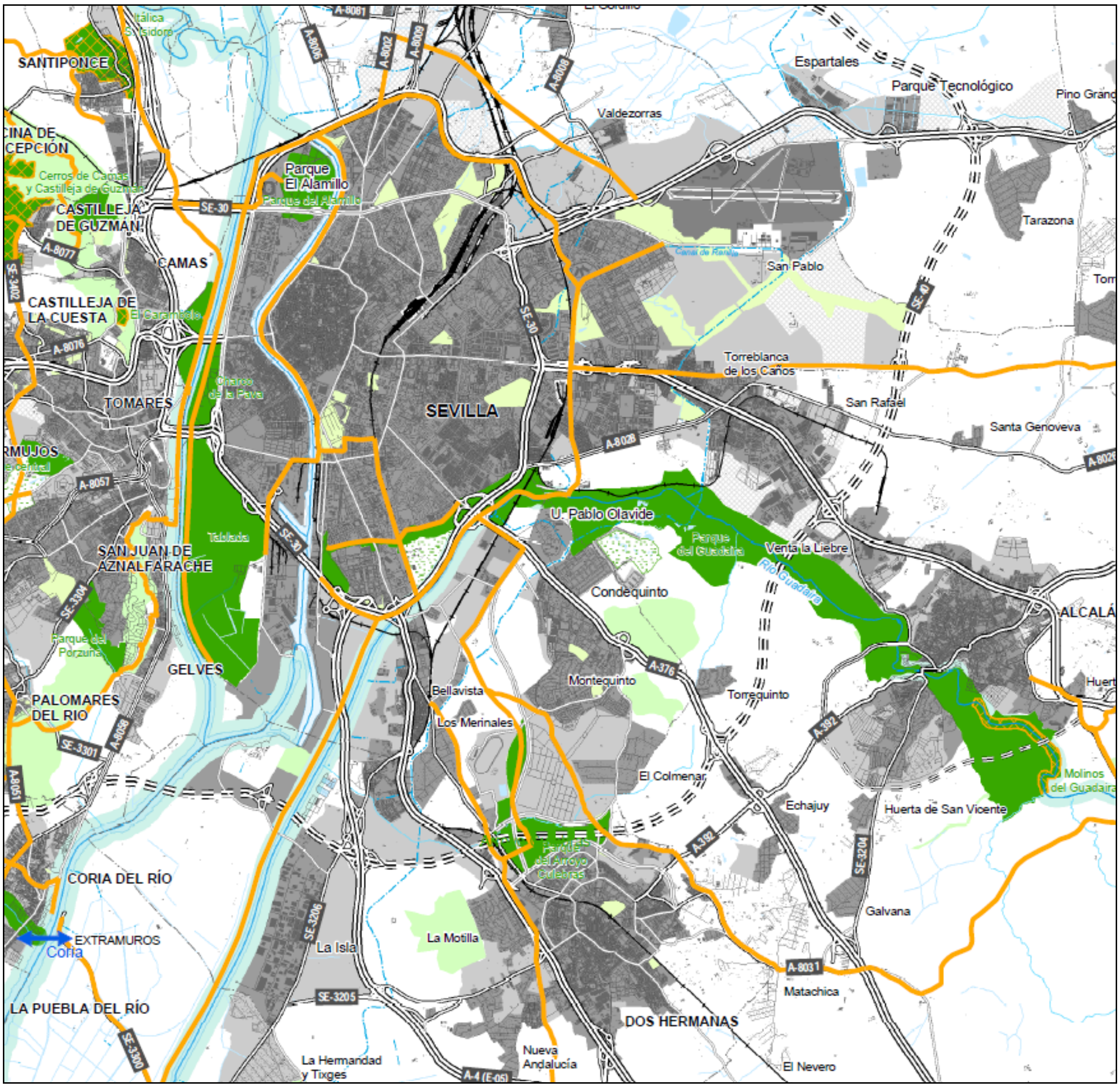
Seville, located in southern Spain, is the political and financial capital of the autonomous community of Andalusia and of the province of Seville. It is situated on the plain of the River Guadalquivir, with an average elevation of 7 metres (23 ft) above sea level and a total surface of 140.8 km$^2$. 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)

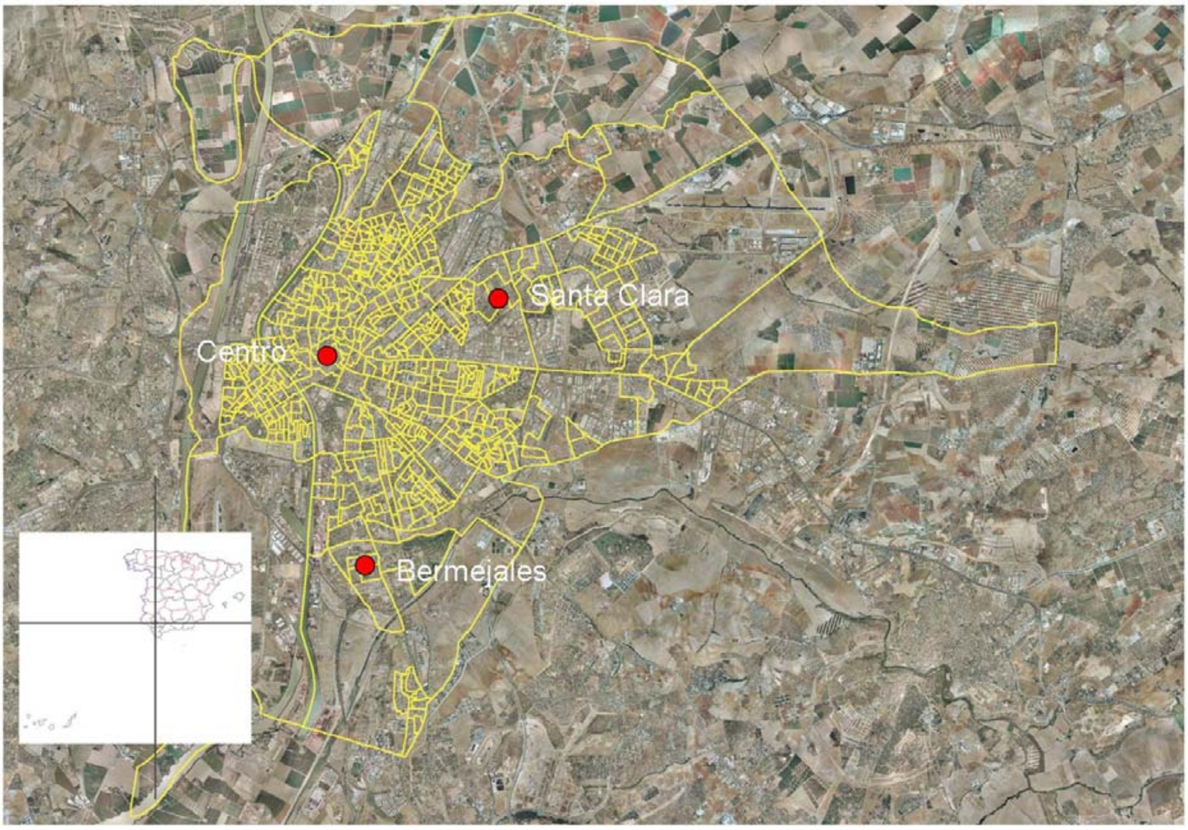
**Figure 2 – Map of the Metropolitan area of Seville**




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).

**Figure 3 – Orthophoto of the study area of the city of Seville**




### 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**

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average high °C (°F) | 15.9 (60.6) | 17.9 (64.2) | 21.2 (70.2) | 22.7 (72.9) | 26.4 (79.5) | 31.0 (87.8) | 35.3 (95.5) | 35.0 (95) | 31.6 (88.9) | 25.6 (78.1) | 20.1 (68.2) | 16.6 (61.9) | 24.9 (76.8) |
| Daily mean °C (°F) | 10.6 (51.1) | 12.2 (54) | 14.7 (58.5) | 16.4 (61.5) | 19.7 (67.5) | 23.9 (75) | 27.4 (81.3) | 27.2 (81) | 24.5 (76.1) | 19.6 (67.3) | 14.8 (58.6) | 11.8 (53.2) | 18.6 (65.5) |
| Average low °C (°F) | 5.2 (41.4) | 6.7 (44.1) | 8.2 (46.8) | 10.1 (50.2) | 13.1 (55.6) | 16.7 (62.1) | 19.4 (66.9) | 19.5 (67.1) | 17.5 (63.5) | 13.5 (56.3) | 9.3 (48.7) | 6.9 (44.4) | 12.7 (54.9) |
| Precipitation mm (inches) | 65 (2.56) | 54 (2.13) | 38 (1.5) | 57 (2.24) | 34 (1.34) | 13 (0.51) | 2 (0.08) | 6 (0.24) | 23 (0.91) | 62 (2.44) | 84 (3.31) | 95 (3.74) | 533 (20.98) |
| Avg. precipitation days (≥ 1 mm) | 6 | 6 | 5 | 7 | 4 | 2 | 0 | 0 | 2 | 6 | 6 | 8 | 52 |
| Sunshine hours | 179 | 183 | 224 | 234 | 287 | 312 | 351 | 328 | 250 | 218 | 186 | 154 | 2,898 |

*(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**

| Pollutant | Road | Domestic | Industry | Other sources (transportation other than road, incineration of garbage…) |
|---|---|---|---|---|
| **$SO_2$** | 19 | 238 | 117 | 815 |
| **$NO_x$** | 3715 | 211 | 120 | 540 |
| **Primary $PM_{2.5}$** | 343 | 184 | 14 | 43 |
| **Primary $PM_{10}$** | 406 | 197 | 19 | 56 |

*(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 $NO_x$ and 60% of $PM_{10}$ and $PM_{2.5}$ came from traffic sources. In the case of $SO_2$ 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 $PM_{10}$ levels but not on annual mean. This source of air pollution represents less than 2% of $PM_{10}$ 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 $PM_{10}$, and/or $O_3$ 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 1st 2004 till December 31st 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 42µg/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 50µg/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 197µg/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 20µg/m$^3$ for $PM_{10}$ and 10µg/m$^3$ for $PM_{2.5}$. According to theses 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 120µg/m$^3$ in any moment of the study period (Table 2). However, considering the more protective standard of WHO-AQG established in 100µg/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 5th and 95 th percentiles for air pollutants for the study period (*2004-2006)***

| Pollutant | Daily mean (µg/m$^3$) | Standard deviation (µg/m$^3$) | *5th percentile* (µg/m$^3$) | *95th percentile* (µg/m$^3$) |
|---|---|---|---|---|
| **Ozone (daily 8h max)** | 50.03 | 23.78 | 14.79 | 87.67 |
| **PM10 (daily average)** | 32.07 | 21.15 | 10.00 | 74.65 |
| **PM2.5 (daily average)** | 22.45 | 14.81 | 7.00 | 52.26 |

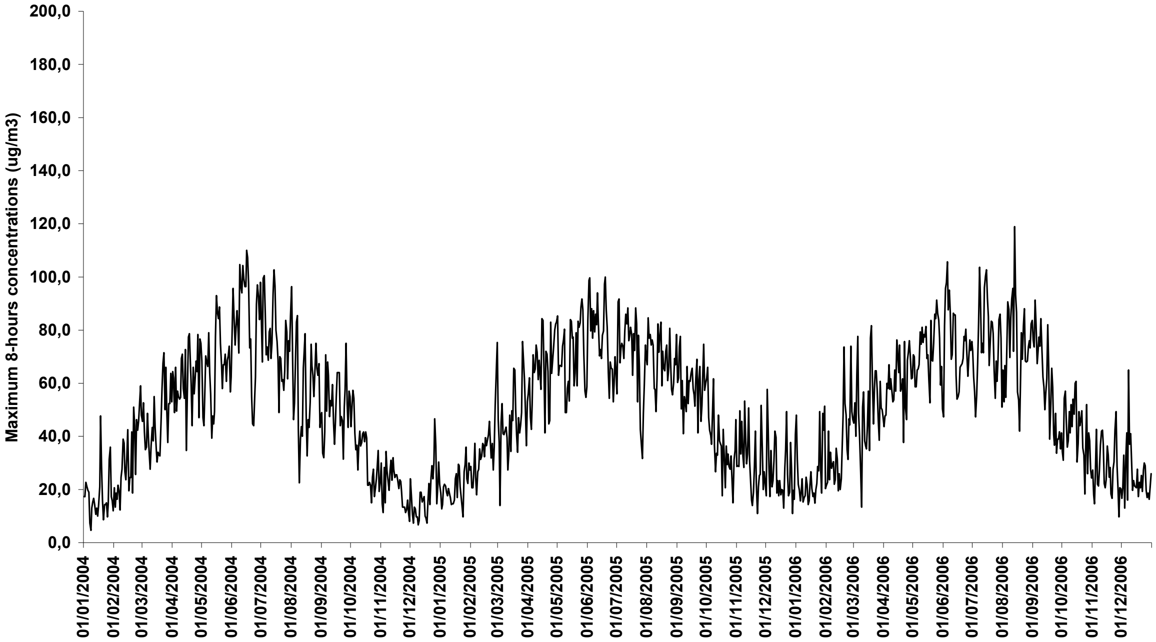



**Figure 5 – Ozone concentration in the study area- City of Seville**

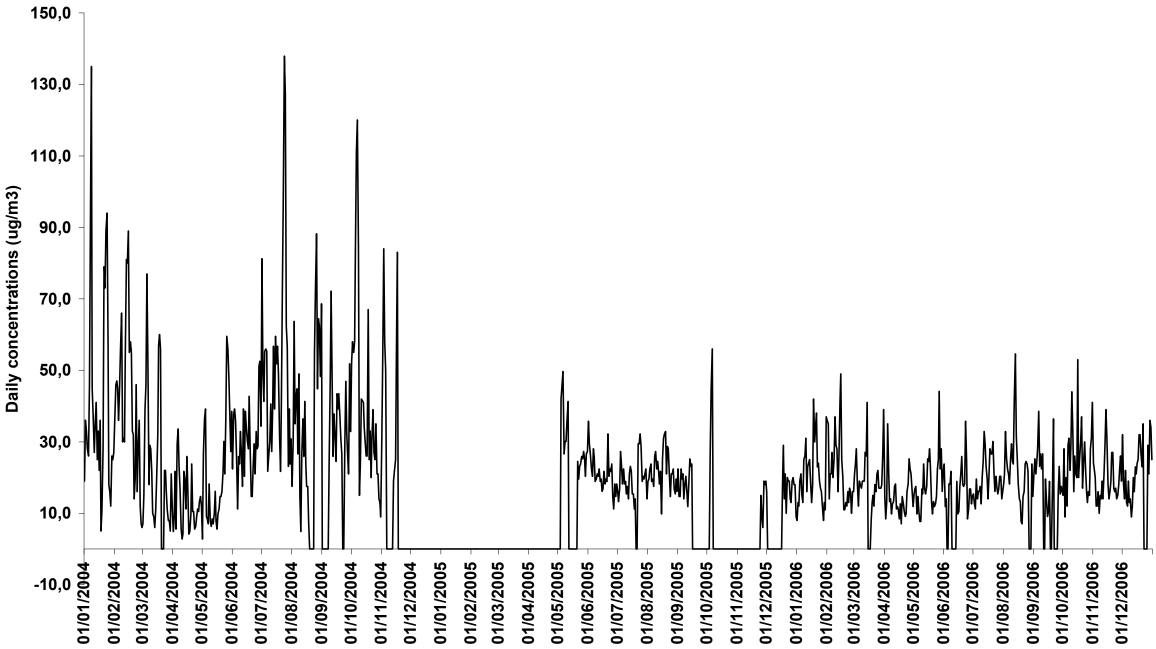



**Figure 6 – PM10 concentration in the study area-City of Seville**

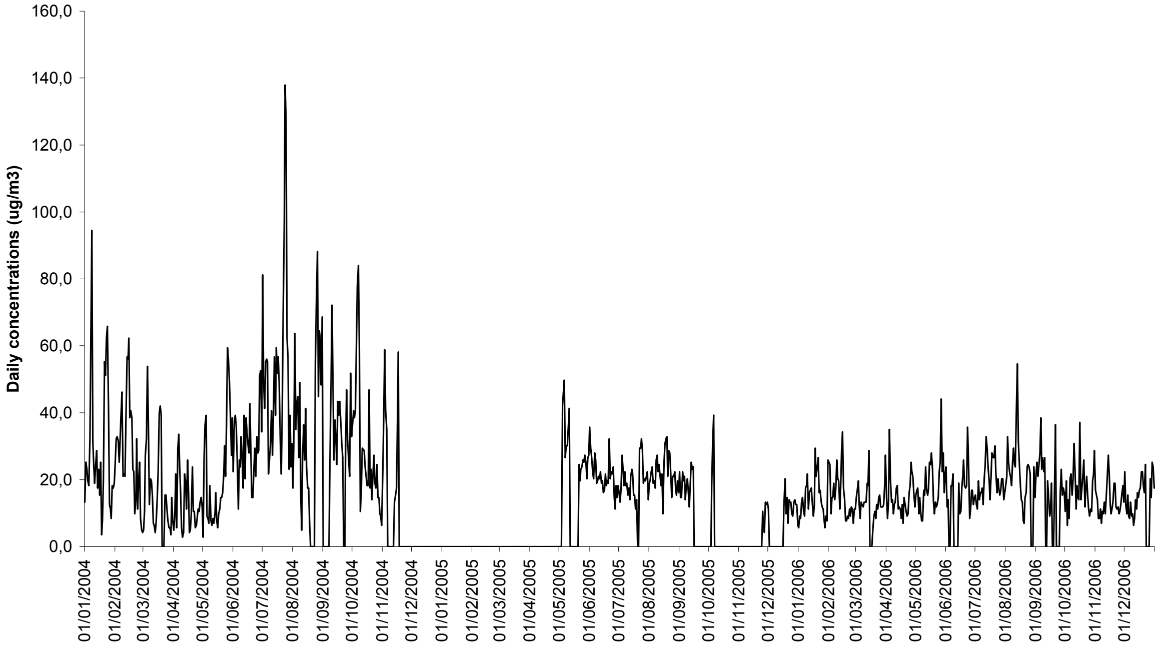



**Figure 7 – PM2.5 concentration in the study area- City of Seville**

### 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)***

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

*** 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 µg/m$^3$, and then a scenario where the $PM_{10}$ annual mean is decreased to 20 µg/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 µg/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 µg/m$^3$.

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

| Scenarios | Annual number of attributable deaths avoided | Annual number of attributable deaths avoided per 100,000 |
|---|---|---|
| **Decrease by 5 µg/m$^3$** | 17 | 2 |
| **Decrease to 20 µg/m$^3$** | 45 | 6 |

*** 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**

| | Respiratory hospitalisations | | Cardiac hospitalisations | |
|---|---|---|---|---|
| **Scenarios** | **Total annual number attributable admissions avoided** | **Annual number of attributable admissions avoided per 100 000** | **Total annual number of attributable admissions avoided** | **Annual number of attributable admissions avoided per 100 000** |
| **Decrease by 5 µg/m$^3$** | 21 | 3 | 13 | 2 |
| **Decrease to 20 µg/m$^3$** | 55 | 8 | 34 | 5 |

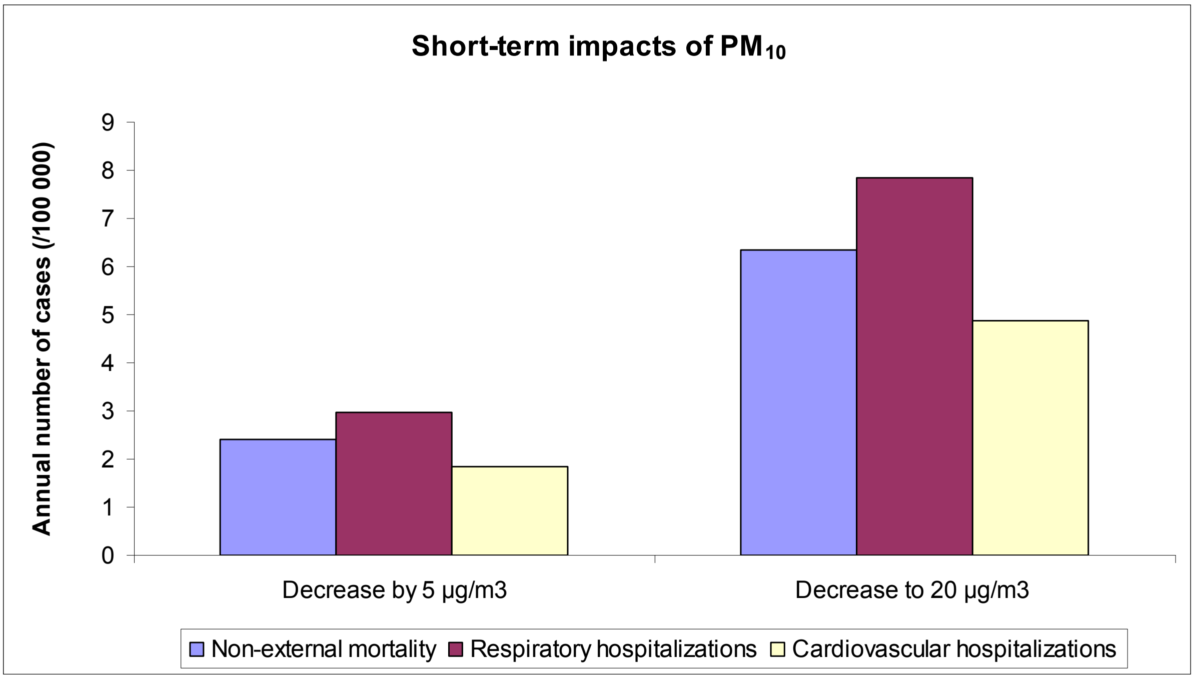



**Figure 8 – Potential benefits of reducing annual $PM_{10}$ levels on mortality and on hospitalisations**

### 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**

| Scenarios | Total annual number of attributable deaths avoided | Annual number of attributable deaths avoided per 100 000 |
|---|---|---|
| 8h max daily values >160 µg/m$^3$ = 160 µg/m$^3$ | 0 | 0 |
| 8h max daily values >100 µg/m$^3$ = 100 µg/m$^3$ | 0 | 0 |
| Decrease by 5 µg/m$^3$ | 9 | 1 |

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

**Table 7 ─ Potential benefits of reducing daily ozone levels on hospitalizations**

| | Respiratory hospitalizations (15-64) | | Respiratory hospitalizations (>64) | |
|---|---|---|---|---|
| Scenarios | Total annual number of attributable admissions avoided | Annual number of attributable admissions avoided per 100 000 | Total annual number of attributable admissions avoided | Annual number of attributable admissions avoided per 100 000 |
| 8h max daily values >160 µg/m$^3$ = 160 µg/m$^3$ | 0 | 0 | 0 | 0 |
| 8h max daily values >100 µg/m$^3$ = 100 µg/m$^3$ | 0 | 0 | 0 | 0 |
| Decrease by 5 µg/m$^3$ | 1 | 0 | 3 | 3 |

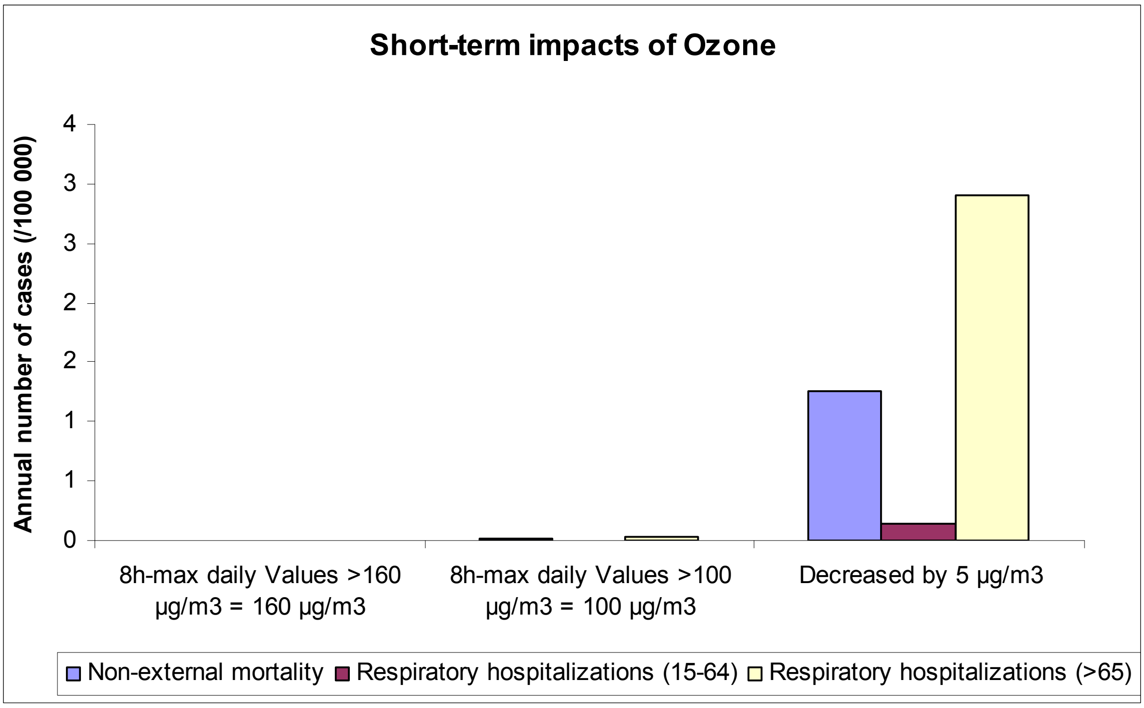



**Figure 9 ─ Potential benefits of reducing daily ozone levels on mortality and on hospitalisations**

### 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 µg/m$^3$, and then a scenario where the $PM_{2.5}$ annual mean is decreased to 10 µg/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)**

| Scenarios | Total annual number of attributable deaths avoided | Annual number of attributable deaths avoided per 100 000 | Gain in life expectancy |
|---|---|---|---|
| **Decrease by 5 µg/m$^3$** | 167 | 37 | 0.3 |
| **Decrease to 10 µg/m$^3$** | 435 | 97 | 0.9 |

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

| Scenarios | Total annual number of attributable deaths avoided | Annual number of attributable deaths avoided per 100 000 |
|---|---|---|
| **Decrease by 5 µg/m$^3$** | 139 | 31 |
| **Decrease to 10 µg/m$^3$** | 353 | 79 |

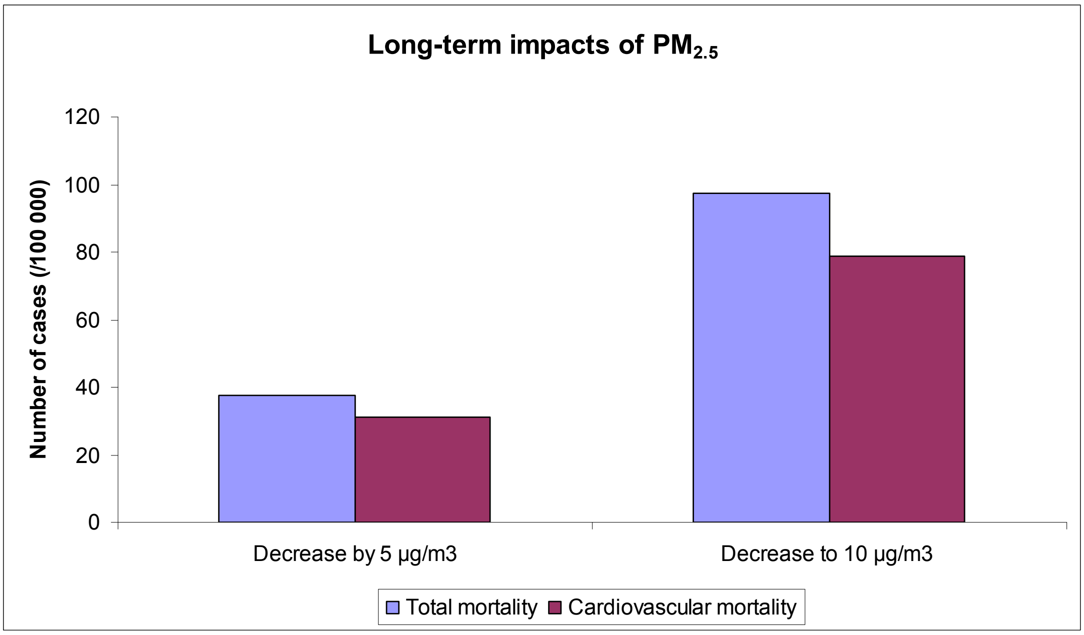



**Figure 10 – Potential benefits of reducing annual $PM_{2.5}$ levels on mortality**

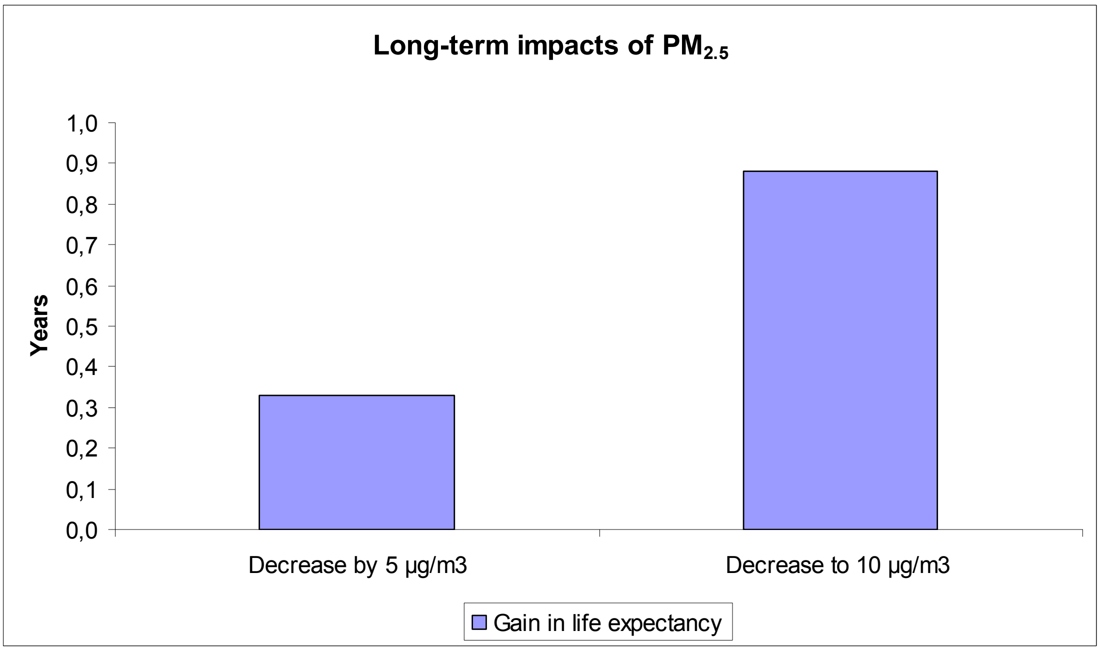



**Figure 11 – Potential benefits of reducing annual $PM_{2.5}$ levels on life expectancy**

### 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.

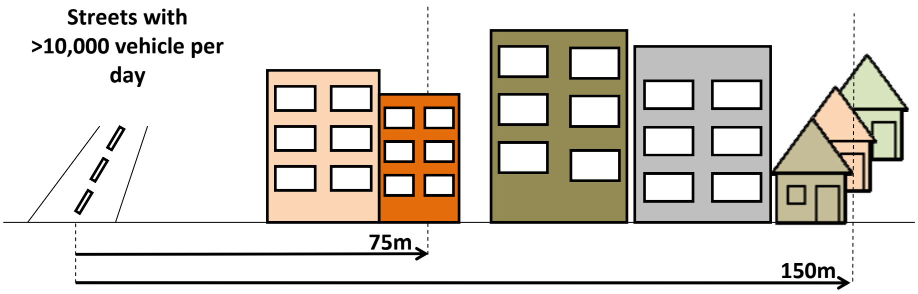
Ours findings support the need to revise current air quality legislative limit values, especially in the case of fine particles $PM_{2.5}$. On the other hand, our results show that transportation keeps being the most relevant source of air pollution in Seville. Changes in policies for reducing sulphur 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.




| City | Population (Million. Hab) | $PM_{10}$ annual average ($ug/m^3$) | % population within 75m (average 29%) | % population within 150m (average 52%) |
|---|---|---|---|---|
| Granada | 0.24 | 34 | 14% | 28% |
| Ljubljana | 0.27 | 32 | 23% | 47% |
| Bilbao | 0.31 | 27 | 29% | 59% |
| Sevilla | 0.7 | 41 | 20% | 38% |
| Valencia | 0.74 | 46 | 44% | 71% |
| Brussels | 1.03 | 29 | 37% | 64% |
| Stockholm | 1.3 | 17 | 14% | 30% |
| Barcelona | 1.53 | 33 | 56% | 77% |
| Vienna | 1.66 | 25 | 36% | 62% |
| Rome | 2.81 | 37 | 22% | 43% |

**Figure 12 – Estimated percentage of people living near busy roads**

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.

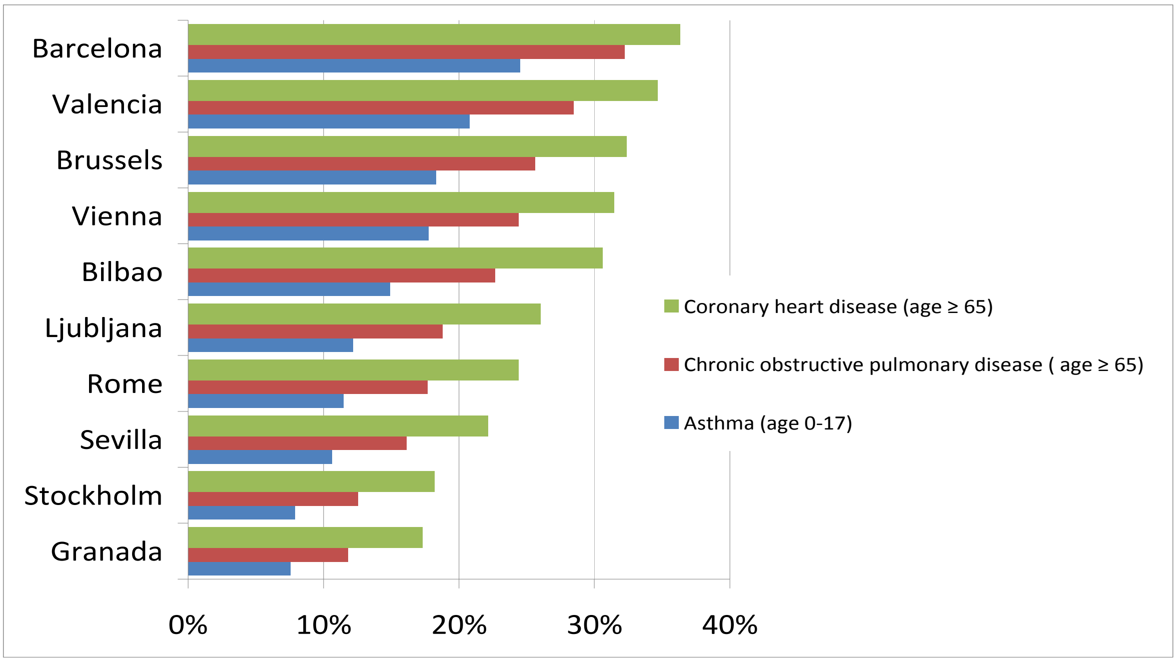



**Figure 13 – Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities**

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.

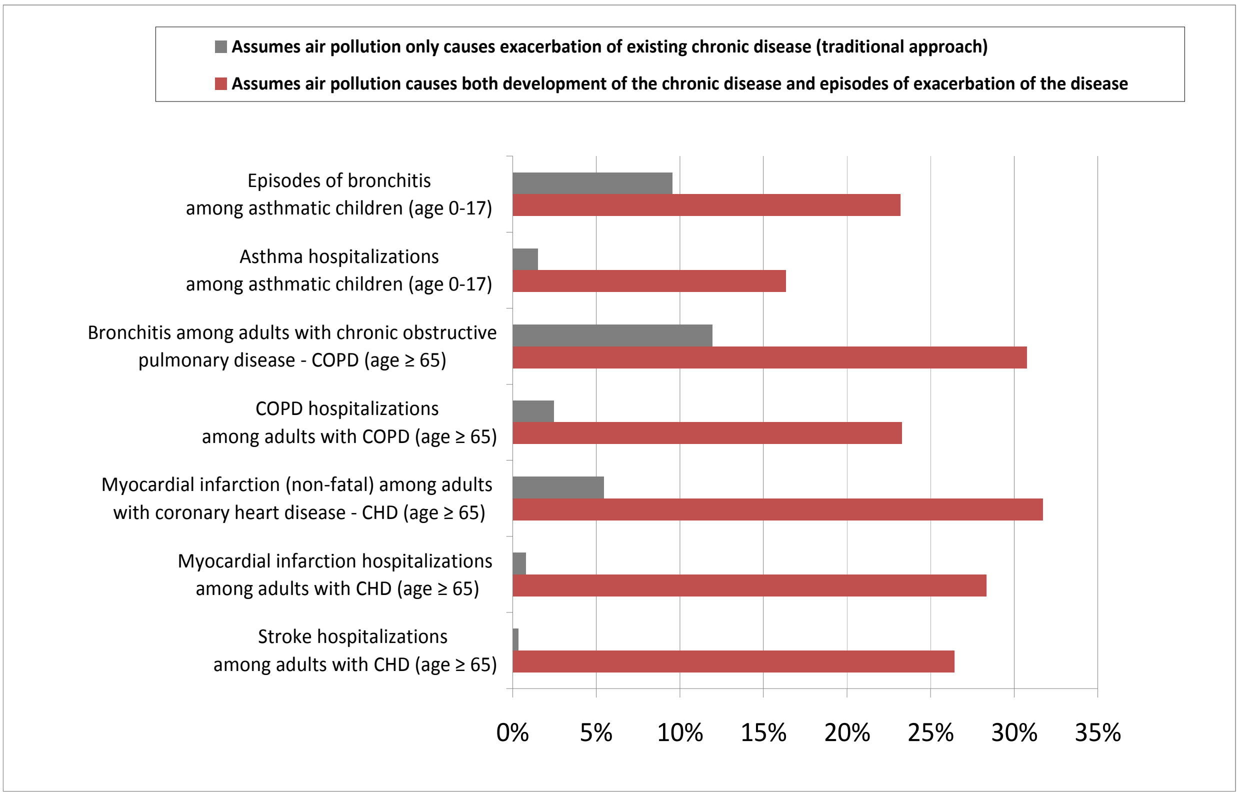



**Figure 14 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom**

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.

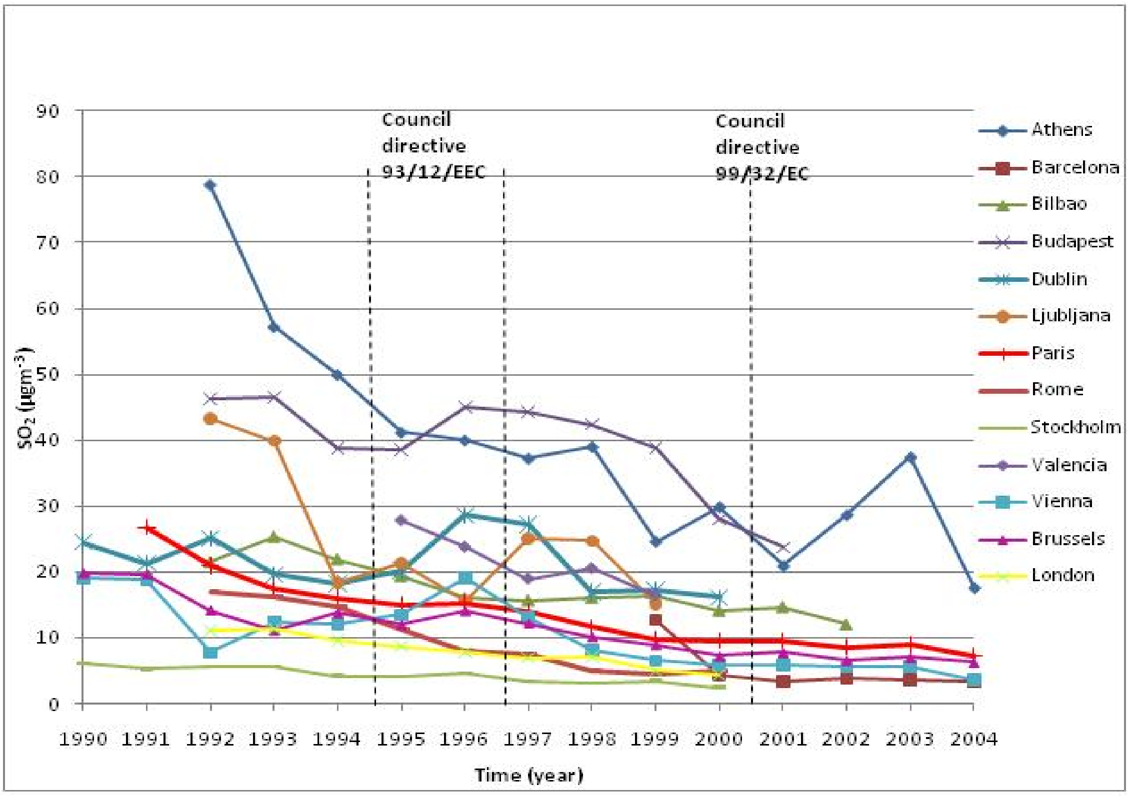



**Figure 15 – Yearly urban background $SO_2$ averages for 13 Aphekom cities from 1990 to 2004**

Figures 16 and Figure 17 show preliminary work done using hourly $SO_2$ 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, $SO_2$ 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 $SO_2$ levels for the mentioned time periods. This might indicate the proportion of $SO_2$ that resulted from emissions due to heating during the winter months especially as high $SO_2$ 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.

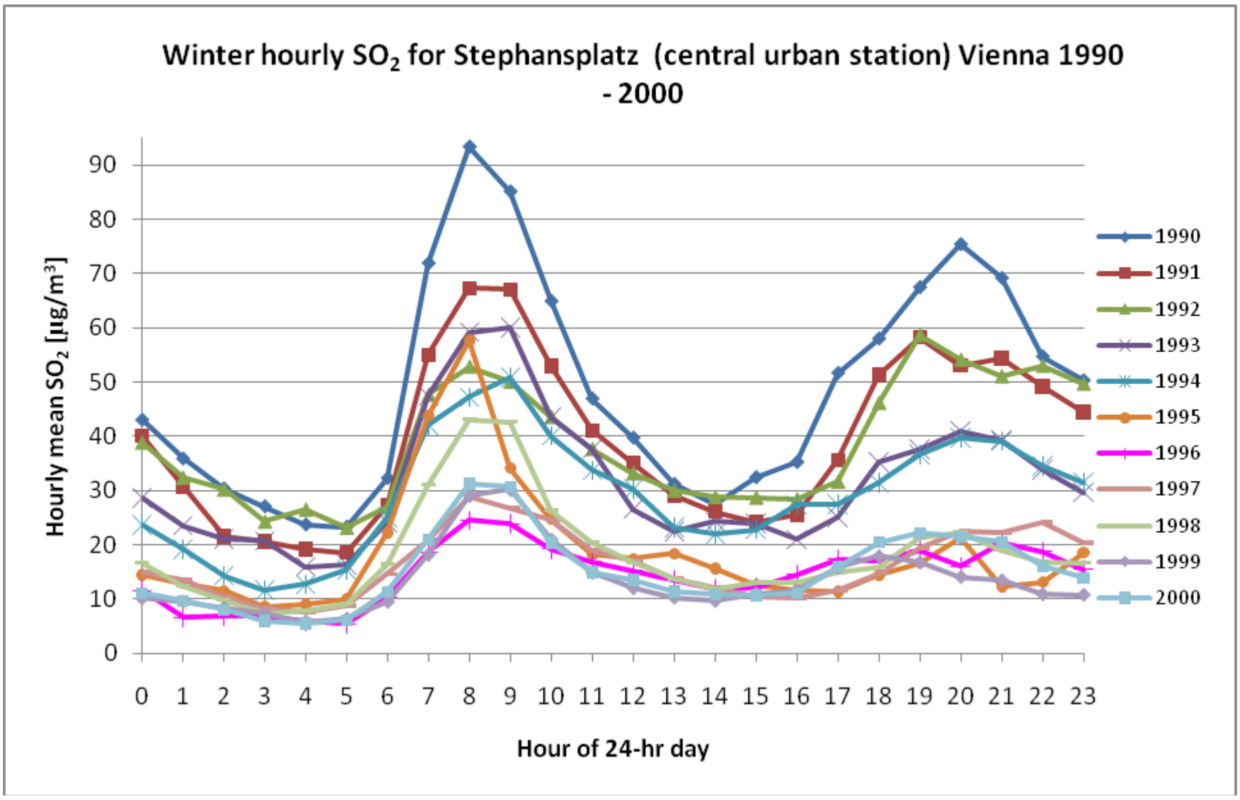



**Figure 16 – Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000**

Figure 18 shows a 24hr-plot of hourly $SO_2$ 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 $SO_2$ 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.

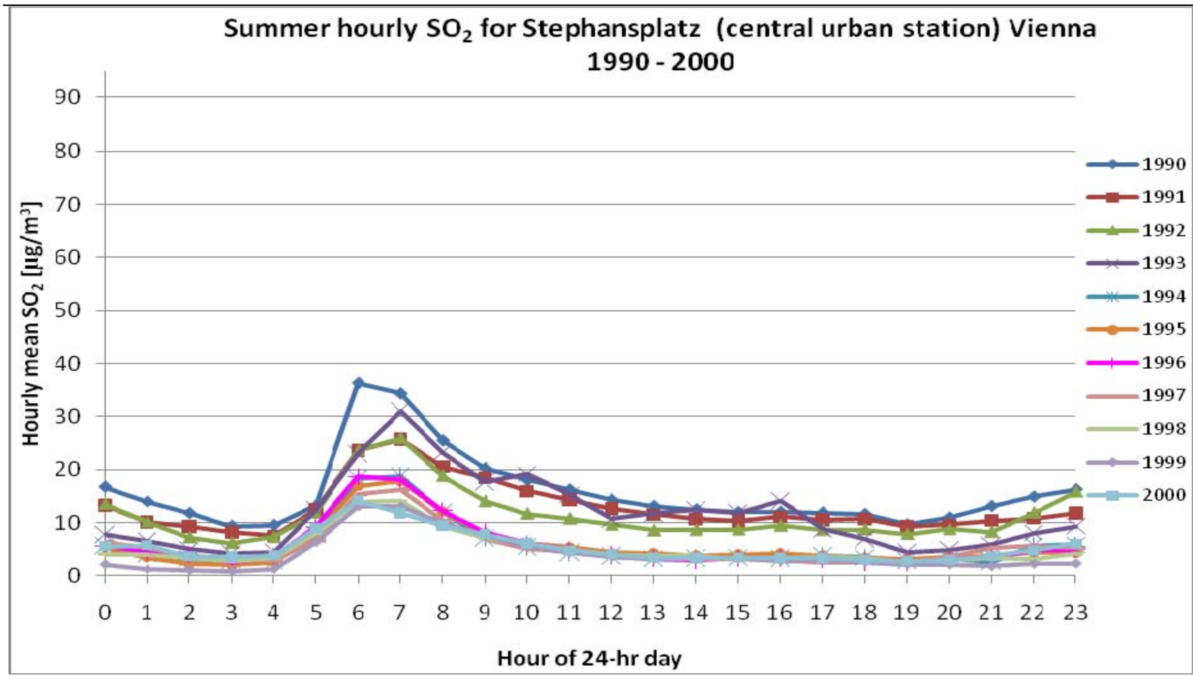



**Figure 17 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000**

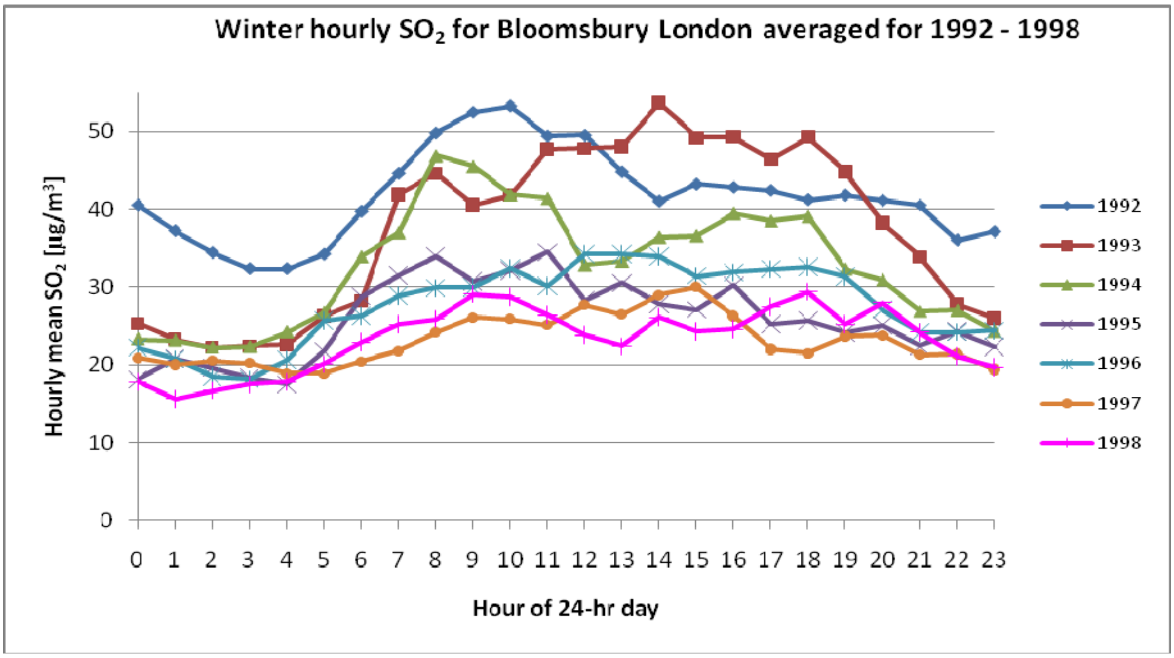



**Figure 18 – Diurnal plot of winter hourly $SO_2$ for an urban background station in London 1992-1998**

**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 $PM_{10}$, 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.

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## Acknowledgements

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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 Δy is the outcome of the HIA
$y_0$ is the baseline health data
Δx is the decrease of the concentration defined by the scenario
β is the coefficient of the concentration response function ( β=log(RR per 10 μg/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 ${}_nD_x$, according to

$${}_nD_x^{impacted} = {}_nD_x * e^{-\beta \Delta x}$$

Δx is the decrease of the concentration defined by the scenario
β 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 10 – Health outcome and relative risks used in the HIA**

| HIA | Health outcome | Ages | RR per 10 μg/m$^3$ | Ref |
|---|---|---|---|---|
| **Short-term impacts of PM10** | Non-external mortality | All | 1.006 [1.004-1.008] | (4) |
| | Respiratory hospitalizations | All | 1.0114 [1.0062-1.0167] | (5) |
| | Cardiac hospitalizations | All | 1.006 [1.003-1.009] | (5) |
| **Short-term impacts of $O_3$** | Non-external mortality | All | 1.0031 [1.0017-1.0052] | (6) |
| | Respiratory hospitalizations | 15-64 | 1.001 [0.991-1.012] | (4) |
| | Respiratory hospitalizations | >=65 | 1.005 [0.998-1.012] | (4) |
| **Long-term impacts of PM2.5** | Total mortality | >30 | 1.06 [1.02-1.11] | (7) |
| | Cardiovascular mortality | >30 | 1.12 [1.08-1.15] | (8) |

**PM10**

For PM10, we first considered a scenario where the annual mean of PM10 is decreased by 5 μg/m$^3$, and then a scenario where the same PM10 annual mean is decreased to 20 μg/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 Δx for the two scenarios are:

- Scenario 1, $\Delta x = 5\ \mu g/m^3$
- Scenario 2, $\Delta x = ([PM10]_{mean} - 20\ \mu g/m^3)$.
  $\Delta x = 0$ if $[PM10]_{mean} < 20$

**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 8hours-daily values.

The corresponding Δx for the two scenarios are;

$$\Delta x = \frac{\sum_{i=1}^{N} O_i}{N}$$

- 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 Δx for the two scenarios are;

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

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# 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 VOLY of €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 *VSL of €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 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/m$^3$ 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.

**Table 1** Average lengths of stay, daily hospitalisation costs and work loss, and total hospitalisations cost per patient.

| Country | Average length of stay in days[a] | | Average cost per day (€ 2005) | | Total costs related to hospitalisation (€ 2005) | |
|---|---|---|---|---|---|---|
| | Circulatory system | Respiratory system | Hosp. all causes[b] | Work loss[c] | Circulatory system | Respiratory system |
| Austria | 8.2 | 6.6 | 319 | 83 | 3,977 | 3,201 |
| Belgium | 9.2 | 8.8 | 351 | 98 | 5,032 | 4,814 |
| France | 7.1 | 7.1 | 366 | 83 | 3,777 | 3,777 |
| Greece | 7.0 | 5.0 | 389 | 48 | 3,395 | 2,425 |
| Hungary | 7.4 | 6.5 | 59 | 18 | 703 | 618 |
| Ireland | 10.5 | 6.9 | 349 | 81 | 5,366 | 3,526 |
| Italy | 7.7 | 8.0 | 379 | 62 | 3,873 | 4,024 |
| Romania | 8.5[d] | 7.4[d] | 57 | 6 | 587 | 511 |
| Slovenia | 8.6 | 7.3 | 240 | 34 | 2,649 | 2,248 |
| Spain | 8.5 | 7.4 | 321 | 55 | 3,664 | 3,189 |
| Sweden | 6 | 5.2 | 427 | 92 | 3,666 | 3,177 |
| United Kingdom | 11.4 | 8.0 | 581 | 116 | 9,268 | 6,504 |
| **Mean[d]** | **8.5** | **7.4** | **373** | **73** | **4,411** | **3,840** |

***Sources:*** *[a] OECD Health Data (2010); [b] CEC (2008), annex 7, cost/bed/day corr; [c] Eurostat (2003); [d] population-weighted average, 2005 population data from OECD Health Data (2010).*

For instance, based on Table 1, the average direct cost of a cardiac hospital admission is:

8.5 days x € 373= € 3,171

and the corresponding indirect cost related to work loss is:

2 x 8.5 days x € 73= € 1,241.

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 deaths to compute the benefits of the legislation.* The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation.

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