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

Local city report

MALAGA

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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 in the city of Malaga did not exceed the legislative limit value in Europe (40 $\mu g/m^3$) nor the WHO-AQC protection limit of 20 $\mu g/m^3$, our results show the reported linear relationship existing between air pollution and health effects in previous research. In this way, short-term reduction of the average annual mean of PM_{10} by 5 $\mu g/m^3$ in the city of Malaga would prevent each year more than 13 attributable deaths (6/100,000), and about 15 (3/100,000) and 7 (1/100,000) hospital admissions for respiratory and cardiovascular diseases, respectively in Malaga. On the other hand, and although the impact of the levels of ozone on health registered in the city of Malaga were not very high for the study period, an improvement in existing concentrations would avoid around 7 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 72 deaths (21/100,000) in Malaga each year among people aged 30 years and over, accounting for a monetary health benefit of more than € 120 millions annually. This decrease could add up to 2.2 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 Malaga. 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. The city of Malaga was not participating in the Apheis project.

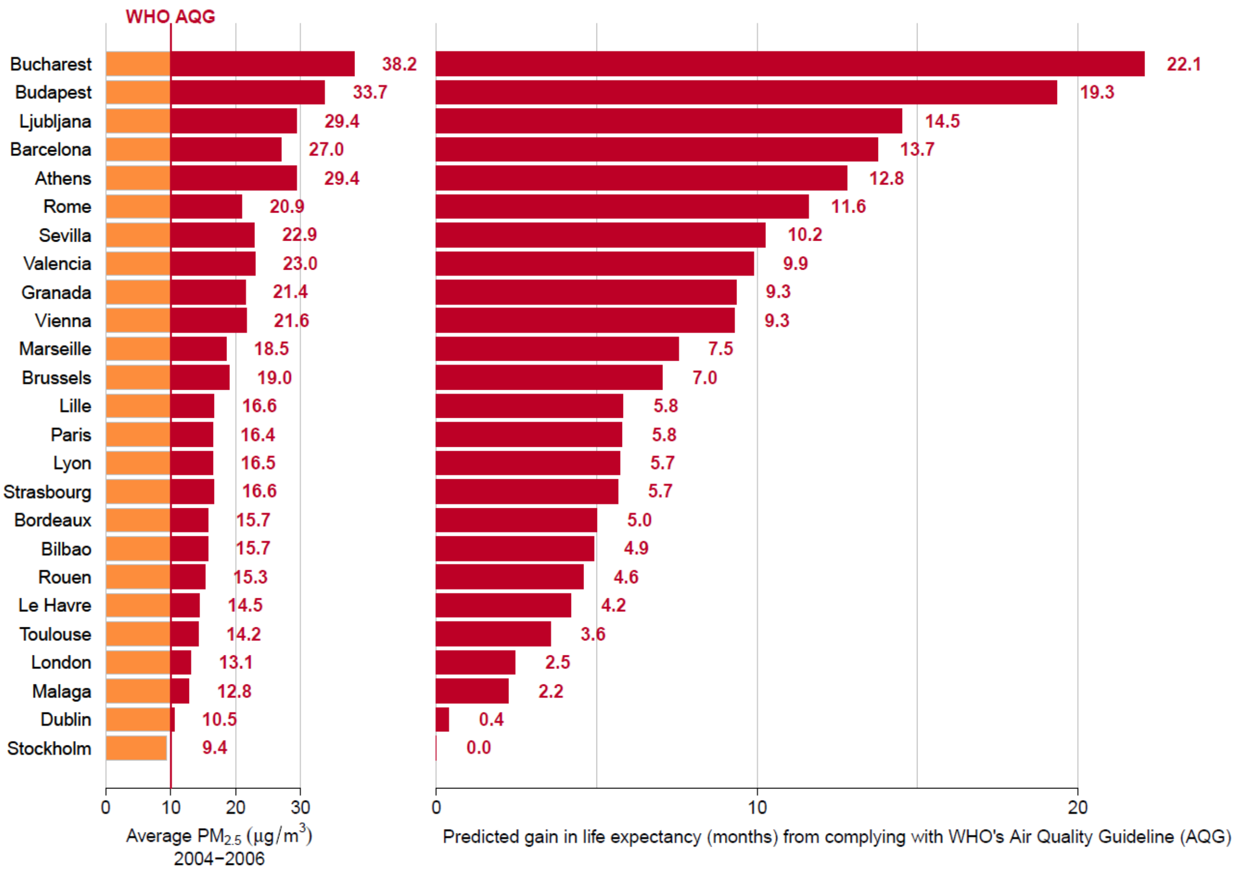
Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana, 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 $\mu g/m^3$ 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 $PM_{2.5}$.

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 $PM_{2.5}$ to 10 µg/m3 (WHO's Air Quality Guideline)



1.1. Description of the study area for *MALAGA*

Malaga is a city located in southern Spain, on the *Costa del Sol* (Coast of the Sun) on the northern side of the Mediterranean Sea, about 130 km north of Africa, with an average elevation of 11 meters above sea level and opens to a large bay surrounded by the southern hills of *Montes de Málaga*. With a total population of 568,305 (data for year 2009 from the Spanish Institute for Statistics, INE), it is the second most populous city of the autonomous community of Andalusia and the sixth largest in Spain. The urban area stretches mostly along a narrow strip of coastline. The Malaga metropolitan area includes additional municipalities located mostly in the mountains area north of the coast and also some on the coast, with a global population of about 1,046,279 (density 1,264 inhabitants / km²) according to INE for year 2009.

Malaga city and the municipalities of the metropolitan area are connected by an extensive road system (including motorways) and by a pubic transportation network (mostly buses), with large commuting rates between the city of Malaga and the surroundings. The Port of Malaga, the second cruise ship port in Spain after Barcelona, enables to carry out communication (tourism) and trading activities of increasingly significant dimension at the international and national level. Malaga airport is the first most important airport in Andalusia and the fourth of Spain by number of passengers. A metro line is currently under construction, and it is expected to start operating during year 2011.

The most important business sectors in Malaga are Tourism, Construction and Technology Services, but other sectors such as Transportation and Logistics are beginning to expand.

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 2 represents an orthophoto of the studied area in the city of Malaga, 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 2 – Orthophoto of the study area of the city of Malaga

Climatology

The climate in Malaga is Subtropical–Mediterranean (Köppen et al., 2006), with very mild winters and warm to hot summers. During the winter, the Malaga Mountains block out the cold weather from the north. Its average annual temperature is 23 °C (73 °F) during the day and 13 °C (55 °F) at night. In the coldest month - January - the temperature ranges from 12 to 20 °C (54 to 68 °F) during the day, 4 to 13 °C (39 to 55 °F) at night. In the warmest month - August - the temperature ranges from 26 to 32 °C (79 to 90 °F) during the day (can rarely be higher temperature), above 20 °C (68 °F) at night. Large fluctuations in temperature are rare. Annual average relative humidity is 66%, ranging from 59% in June to 73% in December. Yearly sunshine hours are between 2,800 and 3,000 per year, one of the highest results in Europe. Rain, with an annual mean of 469.2 mm, occurs mainly in winter, with summer being generally dry. The prevailing winds are from South and South-east with an annual maximum wind speed of 83 km / h. The average pressure is 760.6 mm. For more details see data in Figure 3

Figure 3: Climate data for Malaga

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	16.6 (61.9)	17.7 (63.9)	19.1 (66.4)	21.0 (69.8)	23.8 (74.8)	27.3 (81.1)	29.9 (85.8)	30.3 (86.5)	27.9 (82.2)	23.7 (74.7)	20.0 (68)	17.4 (63.3)	23.0 (73.4)
Daily mean °C (°F)	12.0 (53.6)	12.8 (55)	14.1 (57.4)	15.6 (60.1)	18.7 (65.7)	22.2 (72)	24.8 (76.6)	25.4 (77.7)	23.1 (73.6)	19.0 (66.2)	15.4 (59.7)	12.9 (55.2)	18.0 (64.4)
Average low °C (°F)	7.3 (45.1)	7.9 (46.2)	9.0 (48.2)	10.4 (50.7)	13.4 (56.1)	17.1 (62.8)	19.7 (67.5)	20.5 (68.9)	18.2 (64.8)	14.3 (57.7)	10.8 (51.4)	8.4 (47.1)	13.0 (55.4)
Precipitation mm (inches)	81 (3.19)	55 (2.17)	49 (1.93)	41 (1.61)	25 (0.98)	12 (0.47)	2 (0.08)	6 (0.24)	16 (0.63)	56 (2.2)	95 (3.74)	88 (3.46)	526 (20.71)
Avg. precipitation days (≥ 1 mm)	6	5	4	5	3	2	0	0	2	4	5	6	43
Sunshine hours	172	178	218	229	282	302	338	309	247	213	173	158	2,815

(Source: : Spanish National Meteorological Agency (AEMET) reproduced from Wikipedia)

Population in the study area

During the study period, the population of the municipality of Malaga was 558,287 inhabitants (269,479 men and 288,808 women) according to the population census published for year 2005 by the INE. The analysis of the population state by age for this period shows a greater concentration of people in the strata between 30 and 64 year of age, with a total proportion of 47.5 %. The still greater proportion of people under 30 years (38.5 %) than above 65 (14 %) indicates a trend of demographic growth, possibly linked to the high immigration rates registered in the whole Andalusia over that period.

Commuting

Many people who works or spend a great part of their day time in the city of Malaga, have their residency in the metropolitan belt towns. However, no data is currently available for quantifying this daily commuting rate.

1.2. Sources of air pollution and exposure data

Sources

Road traffic constitutes the main source of air pollution in Malaga: 57% of NO_x and 37 to 44% of PM_{10} and $PM_{2.5}$, respectively, came from traffic sources (Table 1). In the case of SO_2 the contribution of this source is very low (1 %), being more relevant other sources (69 %) like the intensive activity registered at the port or the airport of Malaga.

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.

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

Pollutant	Road	Domestic	Industry	Other sources (transportation other than road, incineration of garbage…)
SO_2	18	67	760	1018
NO_x	3939	188	1368	1431
Primary PM_{10}	343	133	299	141
Primary $PM_{2.5}$	295	126	124	130

Exposure data

The Surveillance System for Air Pollution is run by the Environment Department of the Regional Government of Andalusia.

As recommended in the Methodological Guidelines updated from that published in the Apheis-1 report, data were selected from background urban or suburban monitoring stations having at least 75% of valid values. 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 Malaga during 2004-2005 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. Figure 2 represents the location of the monitoring stations used in this HIA report with red points: Carranque and El Atabal, catalogued as background urban or suburban stations, respectively. Those stations are different from the ones used before the study period, so it was impossible to provide with valid data for the whole period.

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 Malaga valid data for O_3 were registered for 919 days, with a percentage of days with valid data of 56.6 %, 99.5 % and 95.6% for years 2004, 2005 and 2006, respectively (Figure 4). In the case of daily mean PM_{10} concentrations, valid data were available for 541 days, with a percentage of days with valid data of 0 %, 50.1% and 98.1% for years 2004, 2005 and 2006, respectively (Figure 5). According to the methodological criteria mentioned above, ozone data from year 2004 and PM_{10} data for year 2004 and 2005 had to be finally dismissed for HIA calculations purposes. The same approach was applied to $PM_{2.5}$ (Figure 6).

Table 2 shows the descriptive statistics of the three pollutants for the whole study period and the study area. The fixed legal limit (Directive 1999/30/EC) for the daily mean concentration of PM_{10} of 50 µg/m^3 was not exceeded in the entire study period (See Figure 5). Maximum daily mean concentrations of PM_{10} in the study period reached the level of 49 µg/m^3 registered over winter 2005.

Table 2 – Daily mean levels, standard deviation and 5th and 95th percentiles for air pollutants *(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)	68.74	19.14	35.00	99.00
PM_{10} (daily average)	18.90	6.55	9.00	30.00
$PM_{2.5}$ (daily average)	13.23	4.59	6.30	21.00

In the study period, the annual average mean of PM_{10} in the city of Malaga did not exceed either the World Health Organization Air Quality Guidelines (WHO-AQG) for human health protection set-up at an annual mean value of 20µg/m^3. However, the average annual mean of $PM_{2.5}$ in the study period exceeded WHO-AQG standard (10 µg/m^3) in 1.3 times.

The daily maximum 8-hour moving average concentrations for O_3 exceed the legal limit (Directive 2002/3/EC) of 120 µg/m^3 only one day during the study period (Table 2). 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 31 occasions, normally during the summer periods (Figure 4).

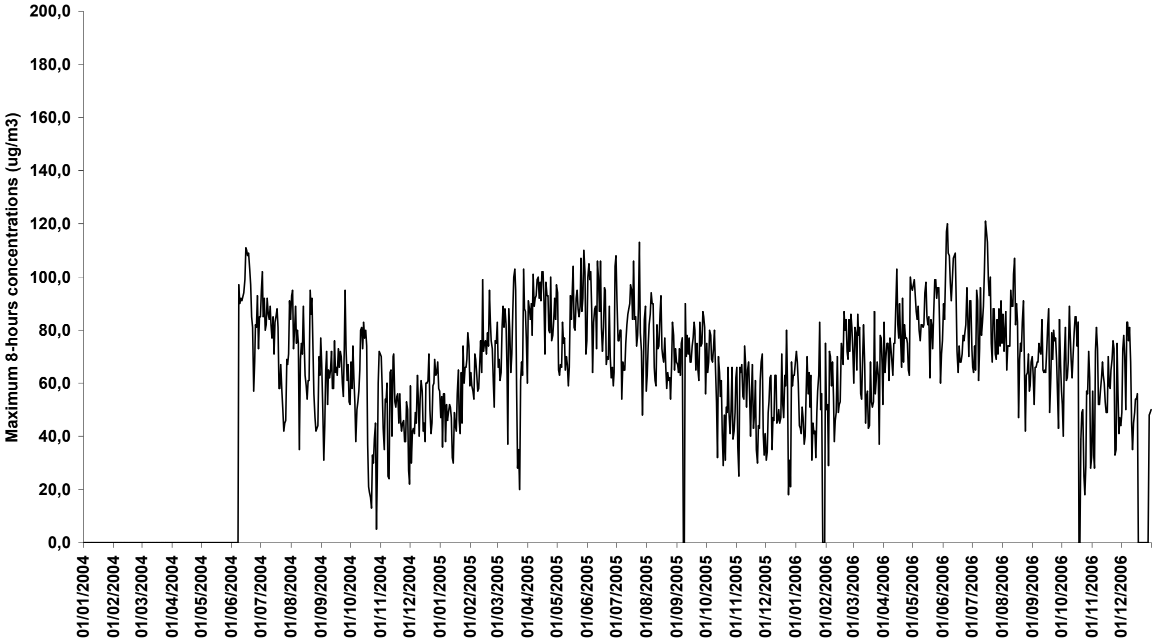


Figure 4 – Ozone concentration in the study area for the city of Malaga

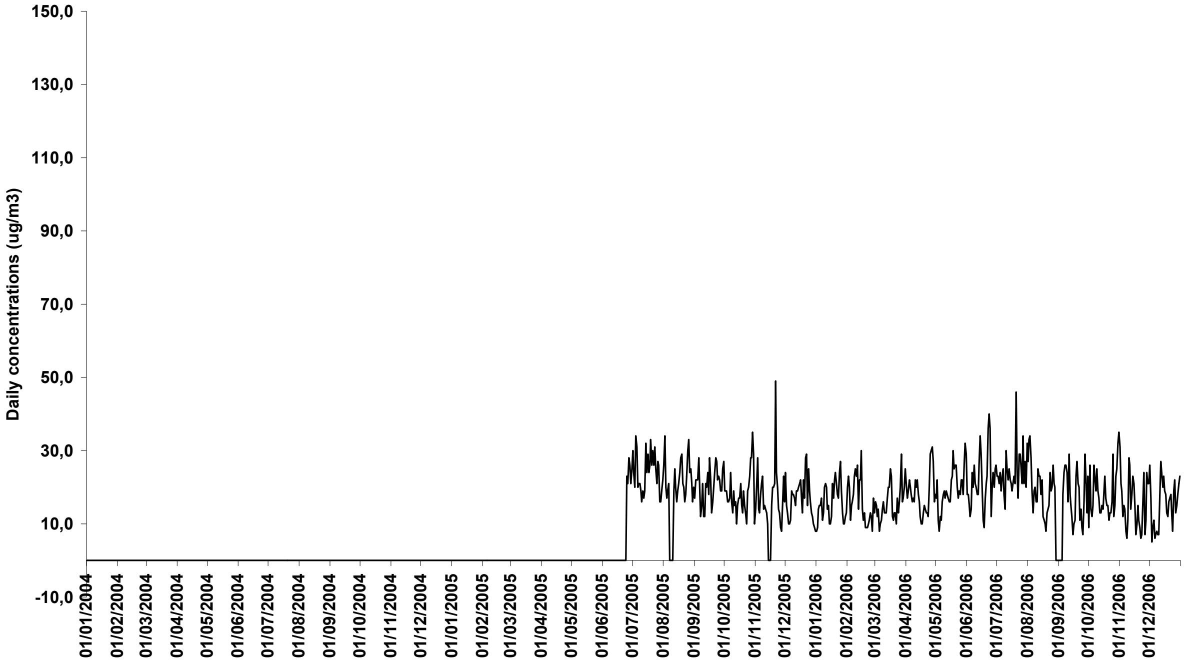


Figure 5 – PM_{10} concentration in the study area for the city of Malaga

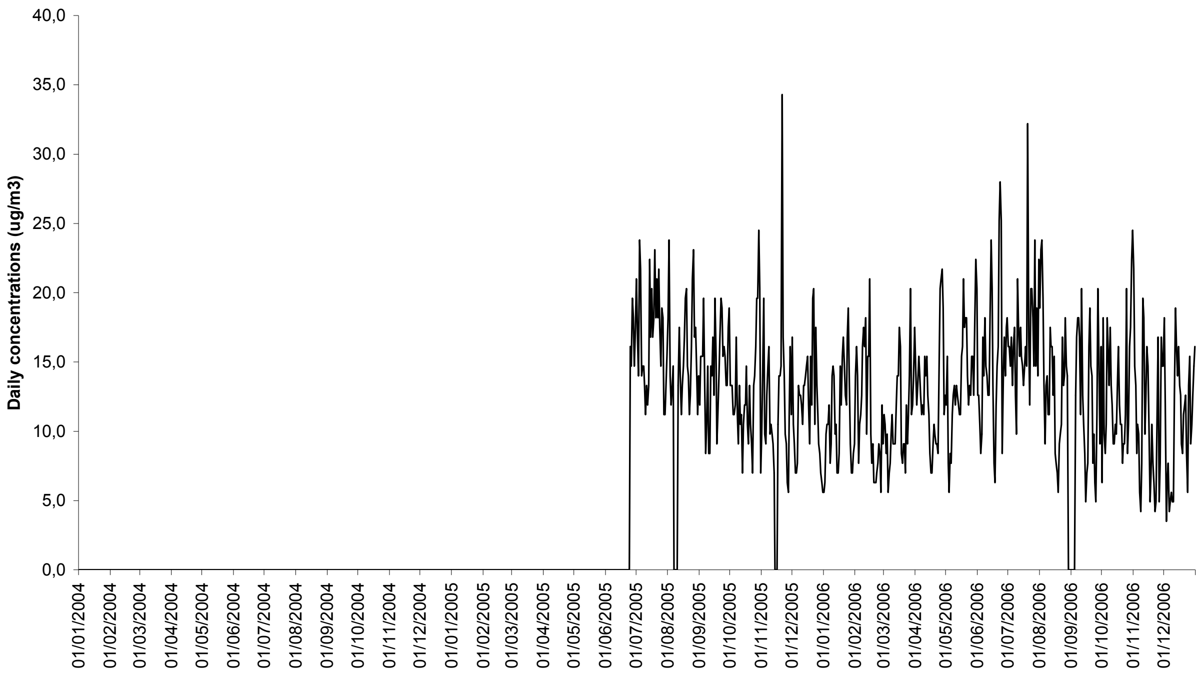


Figure 6 – $PM_{2.5}$ concentration in the study area for the city of Malaga

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 Malaga 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 hospitalizations in general population.

The average number of deaths among people aged 30 years and over in Malaga for the period 2004-2006 was 4491 (annual rate 1308 per 100,000), among which cardiovascular causes accounted for approximately 37% of the total.

Table 3 – Annual mean number and annual rate per 100 000 deaths and hospitalizations *(2004-2006)*

Health outcome	ICD9	ICD10	Age	Annual mean number	Annual rate per 100 000
Non-external mortality*	< 800	A00-R99	All	4395	787
Total mortality	< 800	A00-Y98	> 30	4491	1308
Cardiovascular mortality	390-429	I00-I52	> 30	1680	489
Cardiac hospitalizations	390-429	I00-I52	All	2305	413
Respiratory hospitalizations	460-519	J00-J99	All	2603	466
Respiratory hospitalizations	460-519	J00-J99	15-64	1172	210
Respiratory hospitalizations	460-519	J00-J99	>65	978	175

*** 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 7.

These findings show the reported linear relationship existing between exposure to air pollution and health effects, when decreasing the already low annual mean PM_{10} concentrations in Malaga (below the safe WHO-AQG values of 20 µg/m^3), it would still have a positive input, reducing the number of attributable deaths and hospitalizations in the general population.

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	13	2
Decrease to 20 µg/m^3	0	0

* 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 hospitalizations		Cardiac hospitalizations	
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	15	3	7	1
Decrease to 20 µg/m^3	0	0	0	0

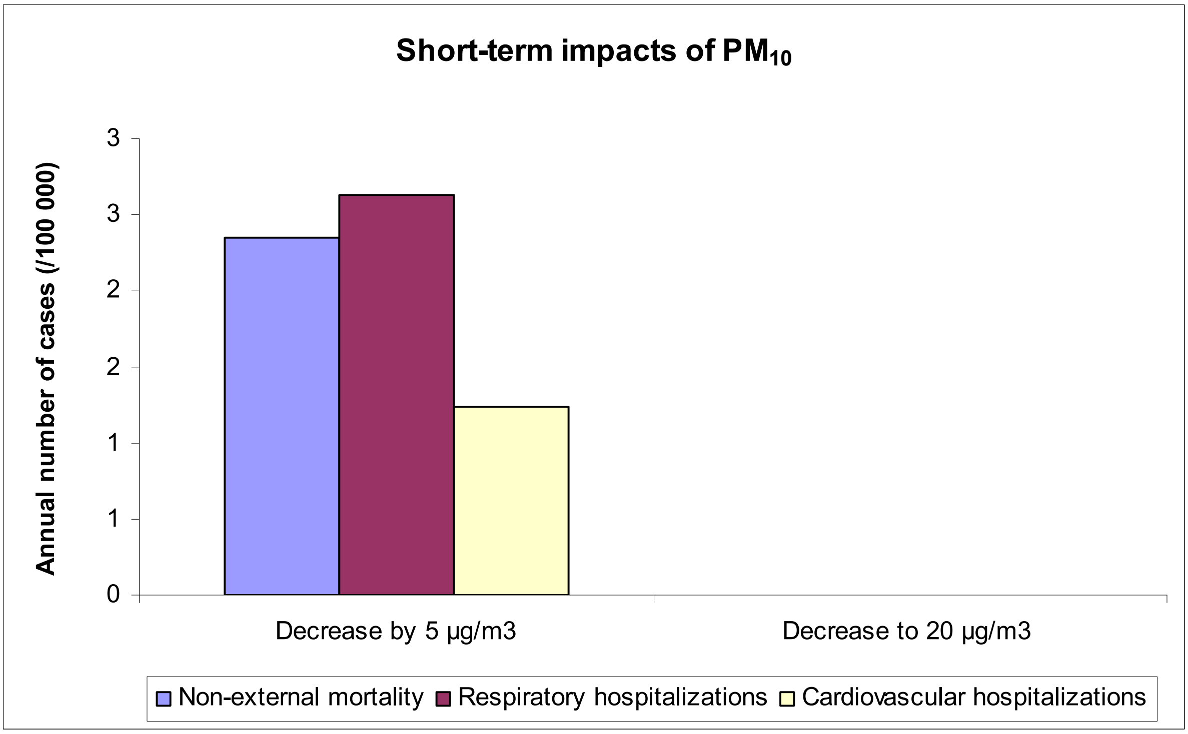


Figure 7 – Potential benefits of reducing annual PM_{10} levels on mortality and on hospitalisations

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 8. Although the impact of the levels of ozone on health registered in the city of Malaga were not very high for the study period, an improvement in existing concentrations would avoid around 7 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	7	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	2	3

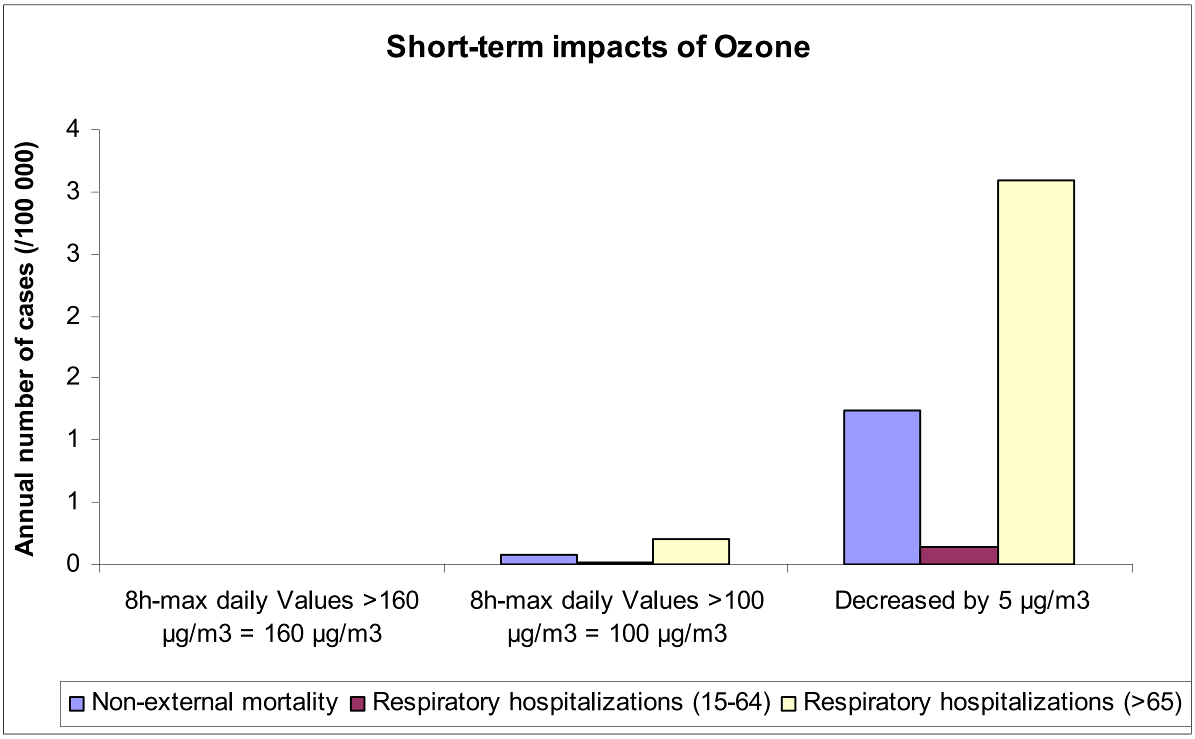


Figure 8 – Potential benefits of reducing daily ozone levels on mortality and on hospitalisations

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 9 & 10.

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	129	38	0.3
Decrease to 10 µg/m^3	72	21	0.2

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	93	27
Decrease to 10 µg/m^3	52	15

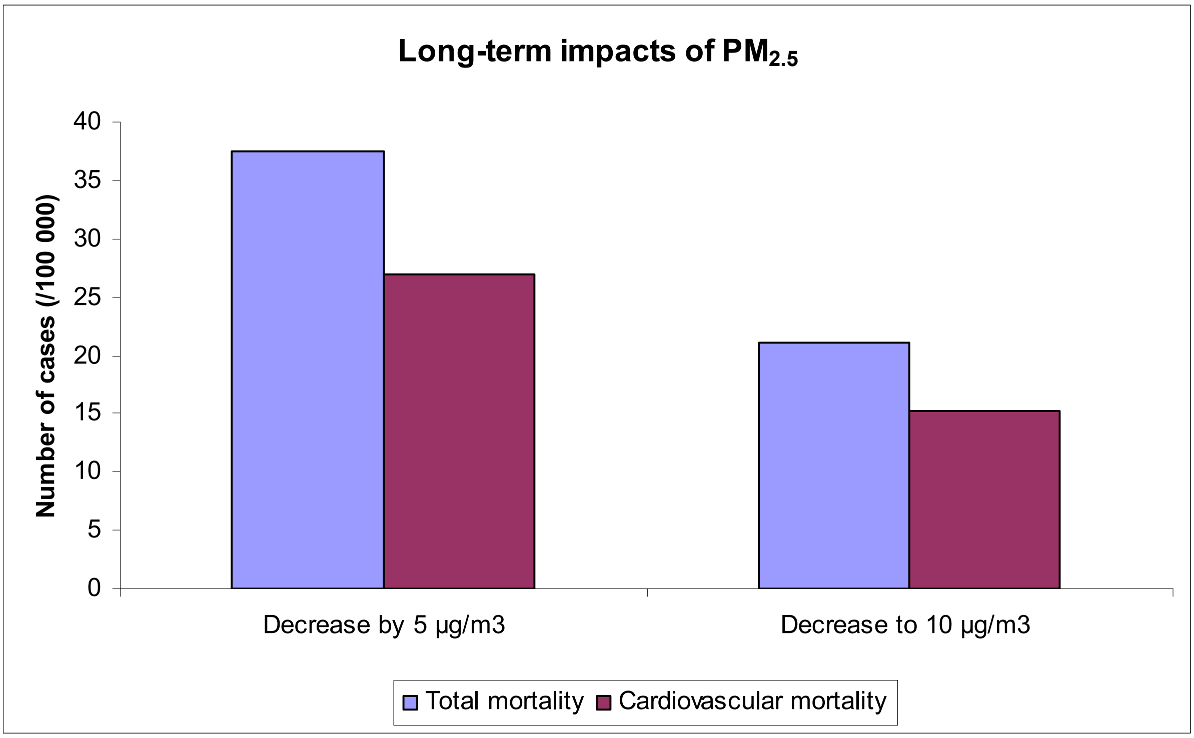


Figure 9 – Potential benefits of reducing annual $PM_{2.5}$ levels on mortality

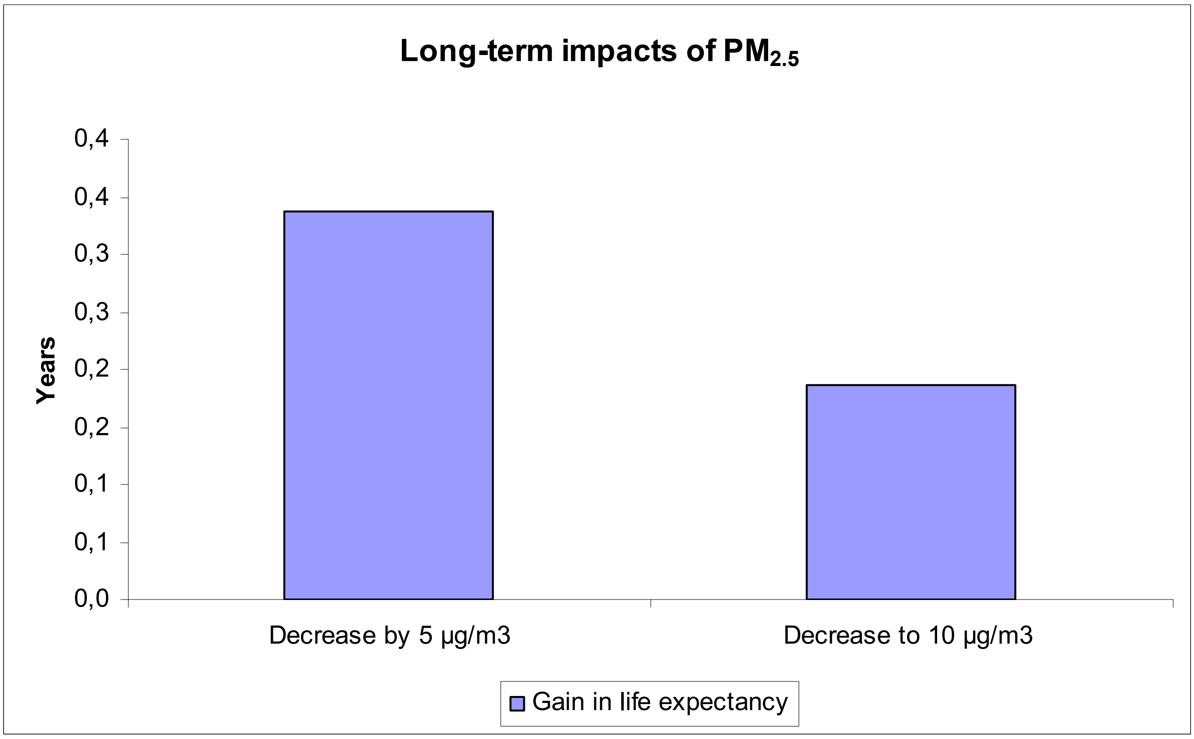


Figure 10 – Potential benefits of reducing annual $PM_{2.5}$ levels on life expectancy

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 Malaga by 5 µg/m^3 would total some € 1.1 millions annually. The benefit considering a reduction in the annual mean level of PM_{10} to 20 µg/m^3 (WHO-AQG) was not possible to be quantified because the actual annual mean PM_{10} in Malaga was below this standard.

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 almost € 120 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 Malaga 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 in the city of Malaga did not exceed the legislative limit value in Europe (40 µg/m^3) nor the WHO-AQC protection limit of 20 µg/m^3, our results show the reported linear relationship existing between air pollution and health effects in previous research. In this way, short-term reduction of the average annual mean of PM_{10} by 5 µg/m^3 in the city of Malaga would prevent each year more than 13 attributable deaths (6/100,000), and about 15 (3/100,000) and 7 (1/100,000) hospital admissions for respiratory and cardiovascular diseases, respectively in Malaga. On the other hand, and although the impact of the levels of ozone on health registered in the city of Malaga were not very high for the study period, an improvement in existing concentrations would avoid around 7 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 72 deaths (21/100,000) in Malaga each year among people aged 30 years and over, accounting for a monetary health benefit of more than € 120 millions annually. This decrease could add up to 2.2 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 Malaga. More actions measurement needs to be taken in this direction to decrease current particulate matter concentrations to safer standards.

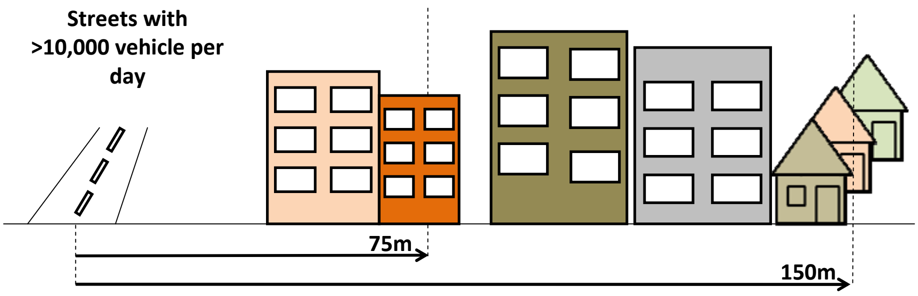
Major uncertainties in this study are related to the exposure characterization over the study period due to changes in the location of the monitoring stations.

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 11 – 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.

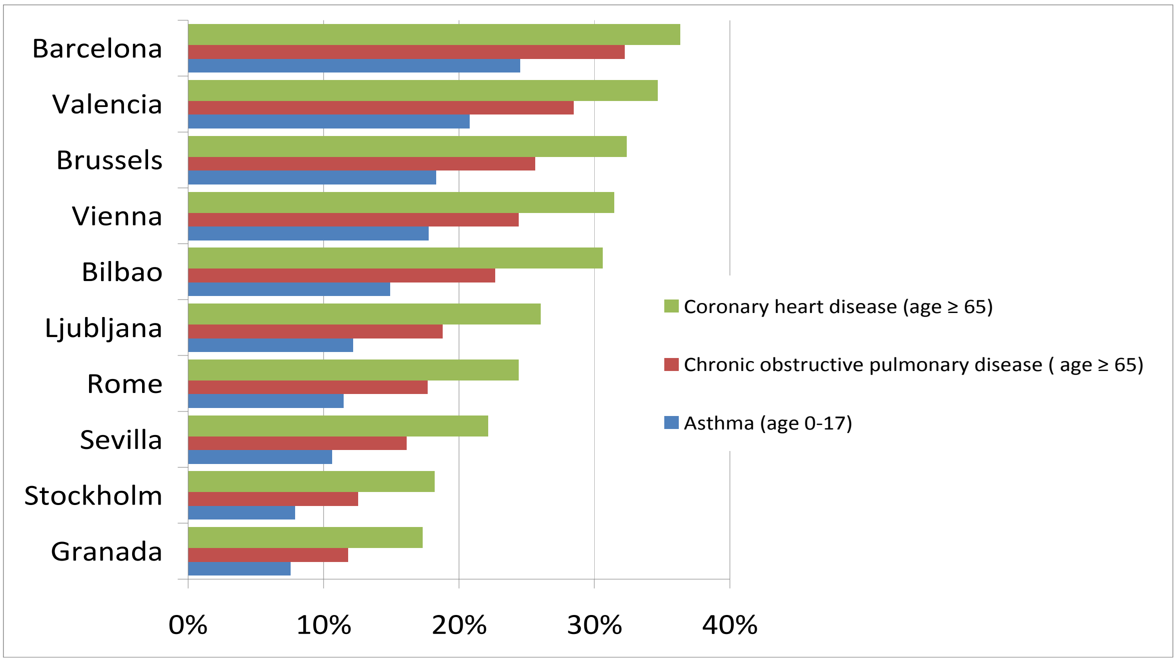


Figure 12 ─ Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

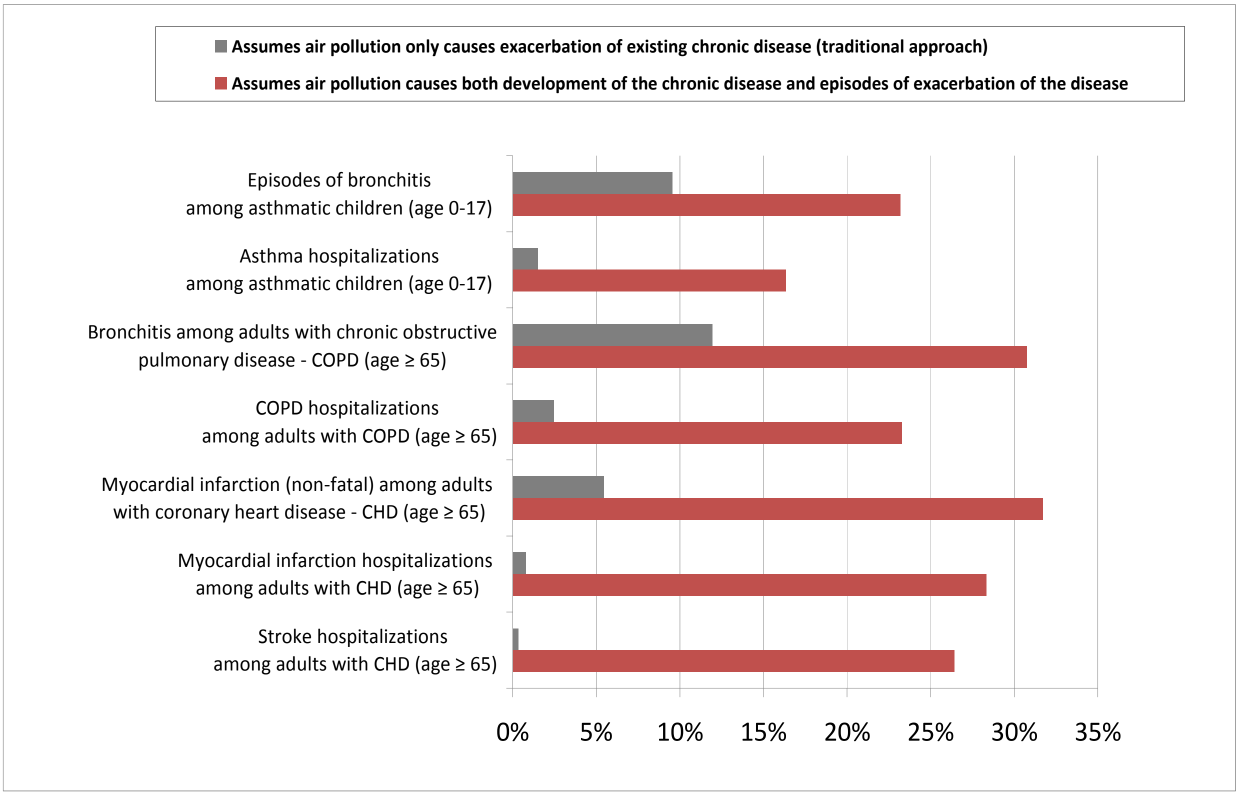


Figure 13 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

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 SO_2 levels but also the resulting prevention of some 2,200 premature deaths valued at €192 million.

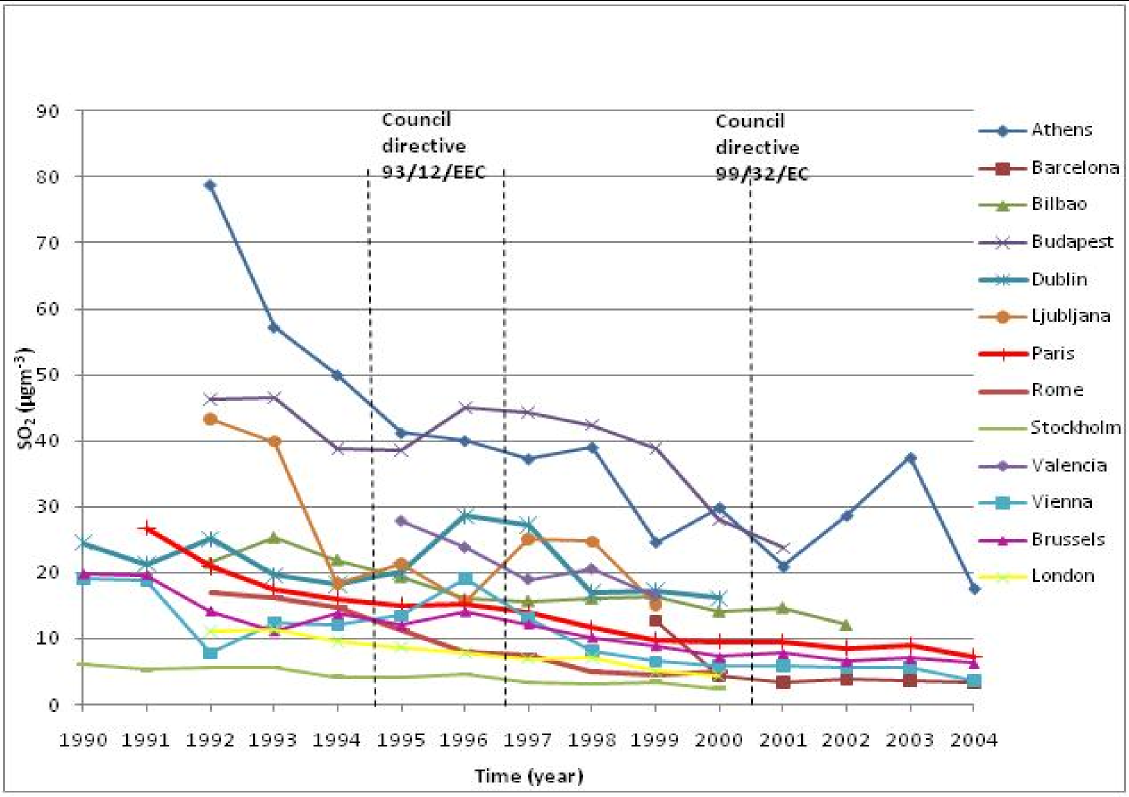


Figure 14 – Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

Figures 15 and Figure 16 show preliminary work done using hourly SO_2 data from Vienna, Austria showing seasonal plots for winter (Fig.15) and summer (Fig 16) 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. 15) 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. 16) 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.

In Fig. 15 the observed winter SO_2 levels for the central urban station in Vienna in 1990 are markedly higher than later years and even though if the peak patterns look like in the other years the observed high SO_2 levels do not necessarily have to be caused by traffic! It is not clear, if these high SO_2 values were reached due to high sulphur content in diesel fuel for vehicles or due to other sources, such as fuel oil combustion, heating, being emitted simultaneously with the traffic related emissions.

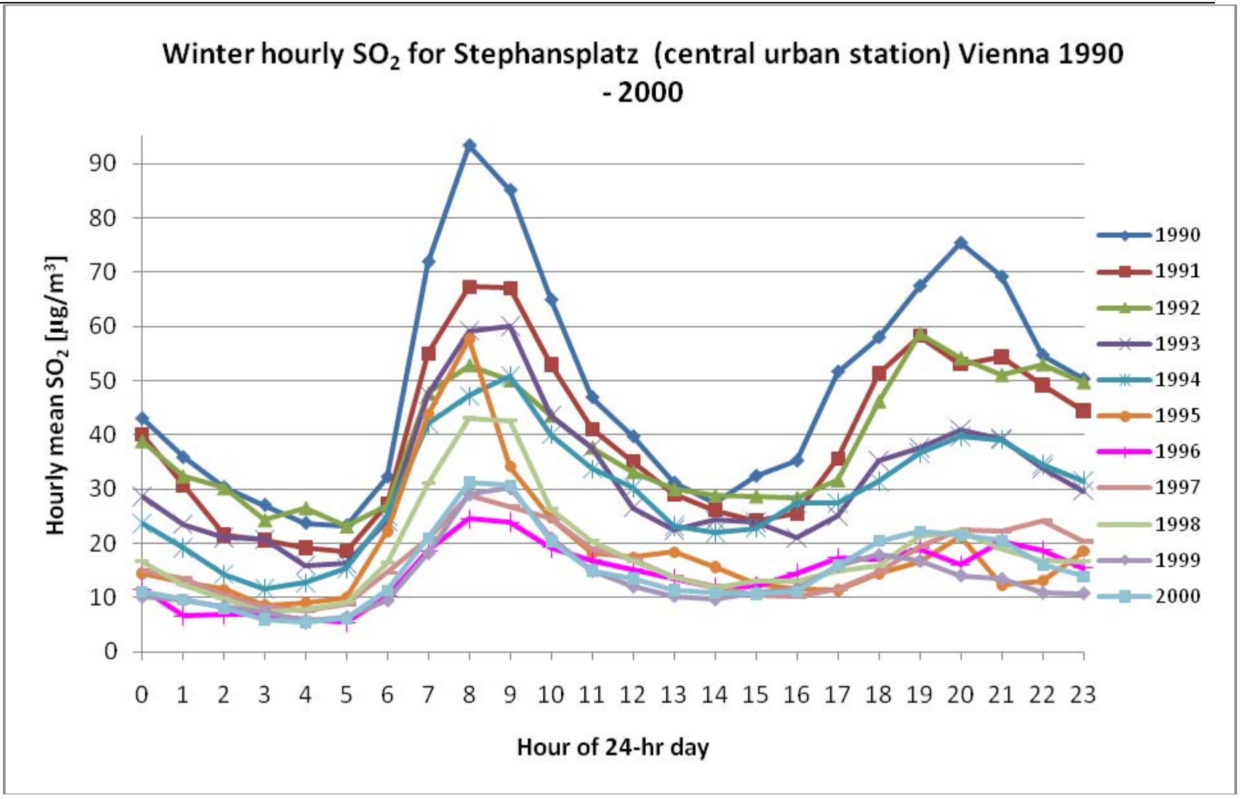


Figure 15 – Diurnal plot of winter hourly SO_2 for a central urban station in Vienna 1990-2000

Figure 17 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. 15 for Vienna, where 2 distinct peaks throughout the day for the winter months were observed, here in Fig.17 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.

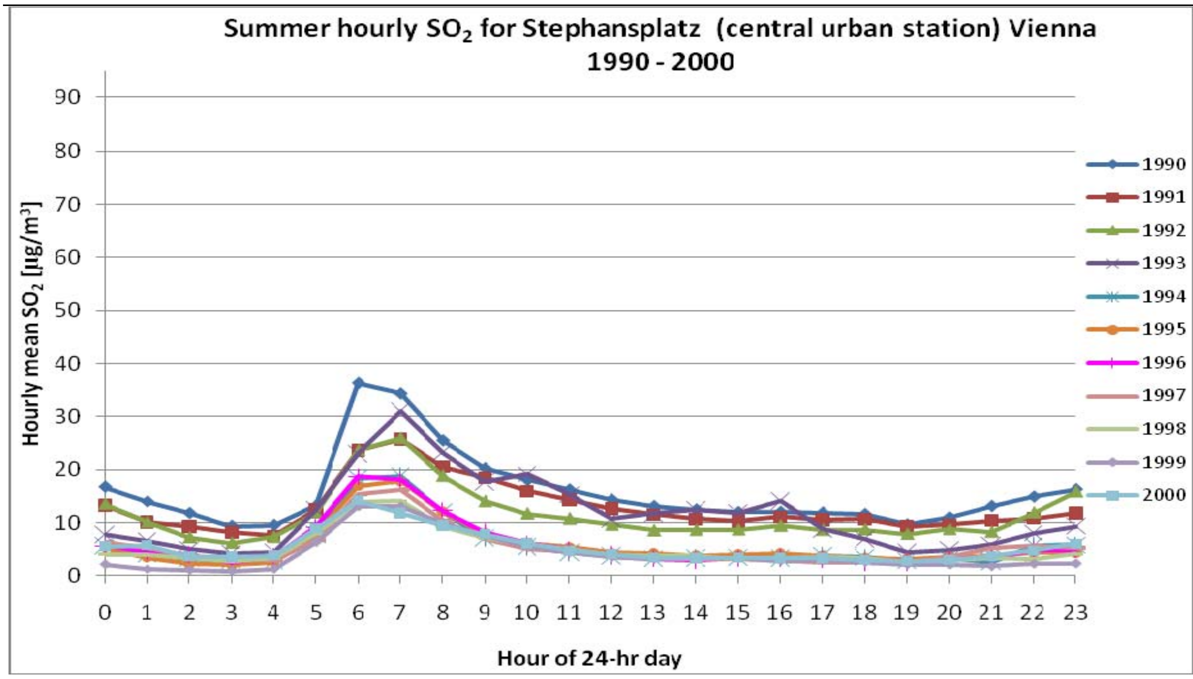


Figure 16 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

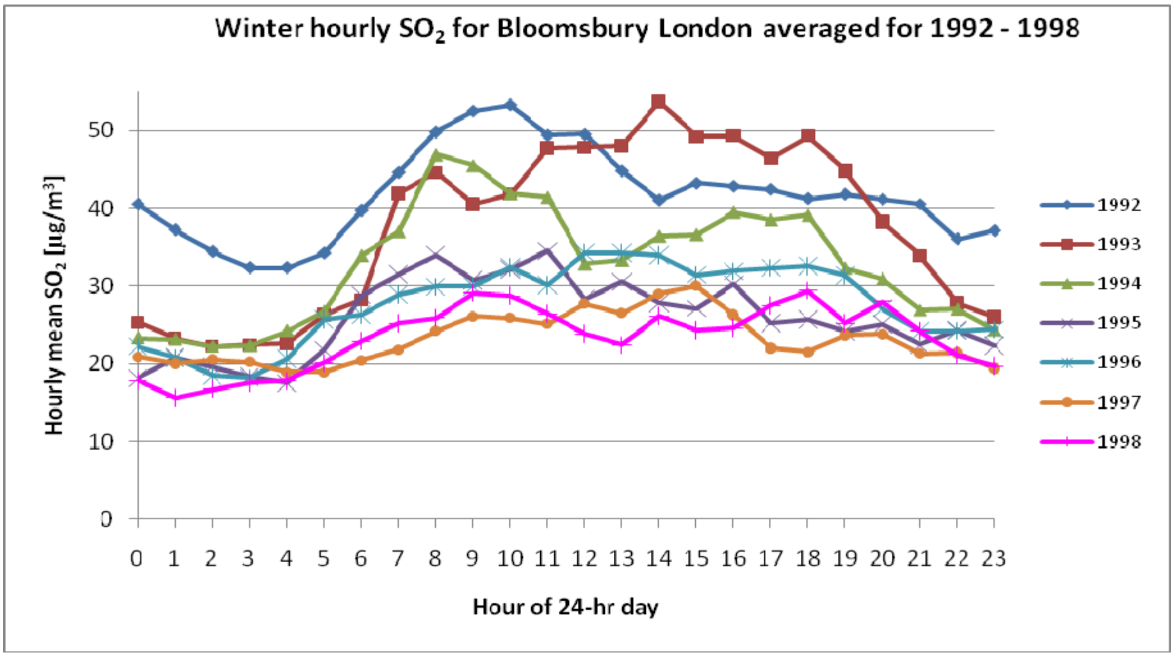


Figure 17 – Diurnal plot of winter hourly SO_2 for an urban background station in London 1992-1998

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 SO_2 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 in the city of Malaga did not exceed the legislative limit value in Europe (40 $\mu g/m^3$) nor the WHO-AQC protection limit of 20 $\mu g/m^3$, our results show the reported linear relationship existing between air pollution and health effects in previous research. In this way, short-term reduction of the average annual mean of PM_{10} by 5 $\mu g/m^3$ in the city of Malaga would prevent each year more than 13 attributable deaths (6/100,000), and about 15 (3/100,000) and 7 (1/100,000) hospital admissions for respiratory and cardiovascular diseases, respectively in Malaga. On the other hand, and although the impact of the levels of ozone on health registered in the city of Malaga were not very high for the study period, an improvement in existing concentrations would avoid around 7 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 72 deaths (21/100,000) in Malaga each year among people aged 30 years and over, accounting for a monetary health benefit of more than € 120 millions annually. This decrease could add up to 2.2 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 Malaga. More actions measurement needs to be taken in this direction to decrease current particulate matter concentrations to safer standards.

Major uncertainties in this study are related to the exposure characterization over the study period due to changes in the location of the monitoring stations.

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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 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 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.

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 $[O_3]_i \geq 160\ \mu g/m^3$, $Oi=([O_3]_i-160)$
  if $[O_3]_i < 160\ \mu g/m^3$, $Oi=0$

- Scenario 2, if $[O_3]_i \geq 100\ \mu g/m^3$, $Oi=([O_3]_i-100)$
  if $[O_3]_i < 100\ \mu g/m^3$, $Oi=0$
- Scenario 3, where the ozone yearly mean is decreased by 5 µg/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 µg/m^3, and then a scenario where the PM2.5 annual mean is decreased to 10 µg/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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To learn more

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