Aphekom

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

Local city report

Valencia

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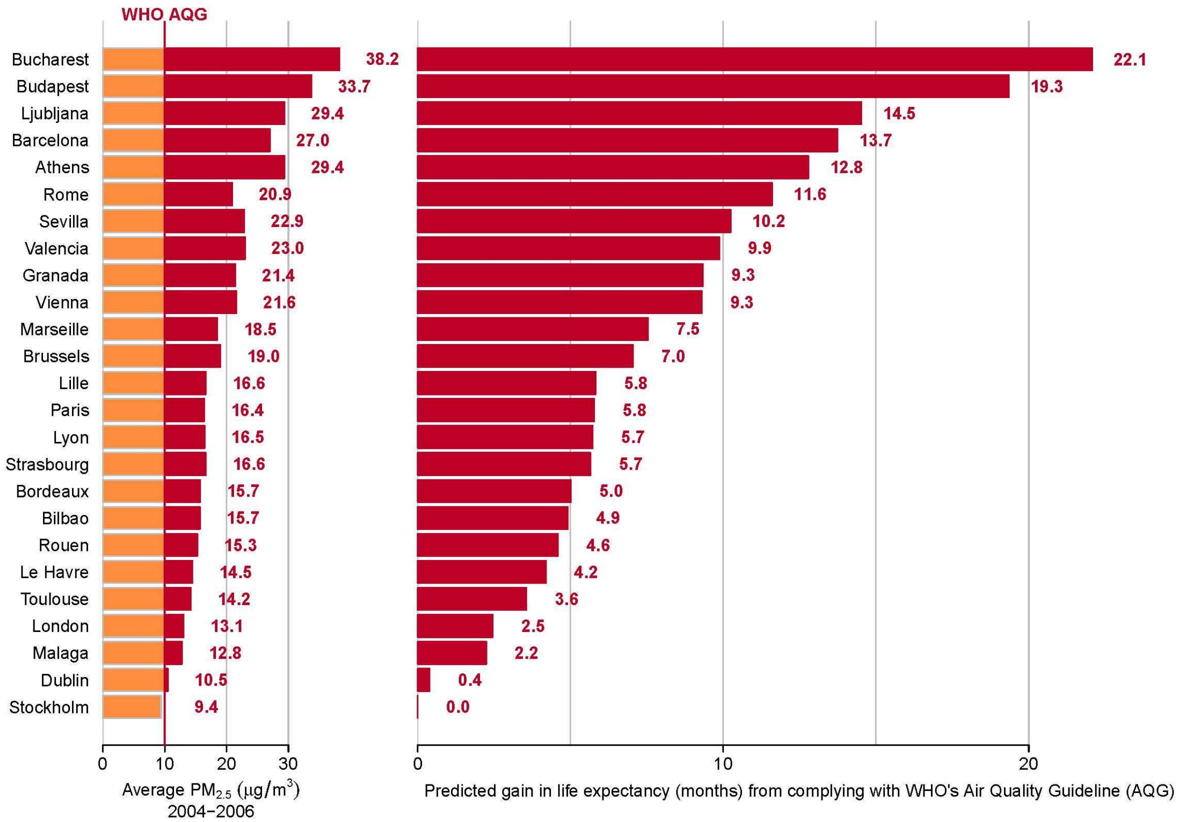
Summary

The Aphekom study was a multi-centre project funded by the European Commission (Grant Agreement: 2007105) with the aim of calculating, using standardised statistical techniques, the benefit to human health of reductions in air pollution. The project comprised investigators from 25 European cities including Valencia.

Data on mortality and hospital admissions in Valencia from 2004 to 2006 were used to assess potential benefits of reductions in PM_{10}, fine particles ($PM_{2.5}$) and ozone under a number of scenarios. A decrease in short-term average PM_{10} concentrations by 5µg/m^3, and to 20µg/m^3, has the potential to reduce the annual number of deaths attributable to PM_{10} by 2.3 /100,000 and 5.7/100,000 of the population. Relating to long-term benefits, a reduction in long-term average $PM_{2.5}$ concentrations by 5µg/m^3 and to 10µg/m^3 could reduce attributable mortality by 38/100,000 and 95/100,000 of the population over the age of 30 years under each scenario.

Across the 25 European cities the benefits of reducing levels of $PM_{2.5}$ fine particles (WHO's annual air-quality guideline) could add up to an additional 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. The results for $PM_{2.5}$ are summarised in the figure below:



Predicted average gain in life expectancy (months) for persons 30 years of age in 25 Aphekom cities for a decrease in average annual level of $PM_{2.5}$ to 10 µg/m3 (WHO's Air Quality Guideline)

Acronyms

APHEIS: Air Pollution and Heath, a European Information System (www.apheis.org)

Aphekom : Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe (aphekom.org)

ENHIS: Environment and Health Information System (http://www.euro.who.int/en/what-we-do/data-and-evidence/environment-and-health-information-system-enhis)

HIA: health impact assessment

O_3 : ozone

PM10 : particulate matter with an aerodynamic diameter <10 µm

PM2.5 : particulate matter with an aerodynamic diameter <2.5 µm

PM: Particulate Matter (generic term for particles irrespective of size)

VOLY: Value of Life Year

WHO: World Health Organisation

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 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.

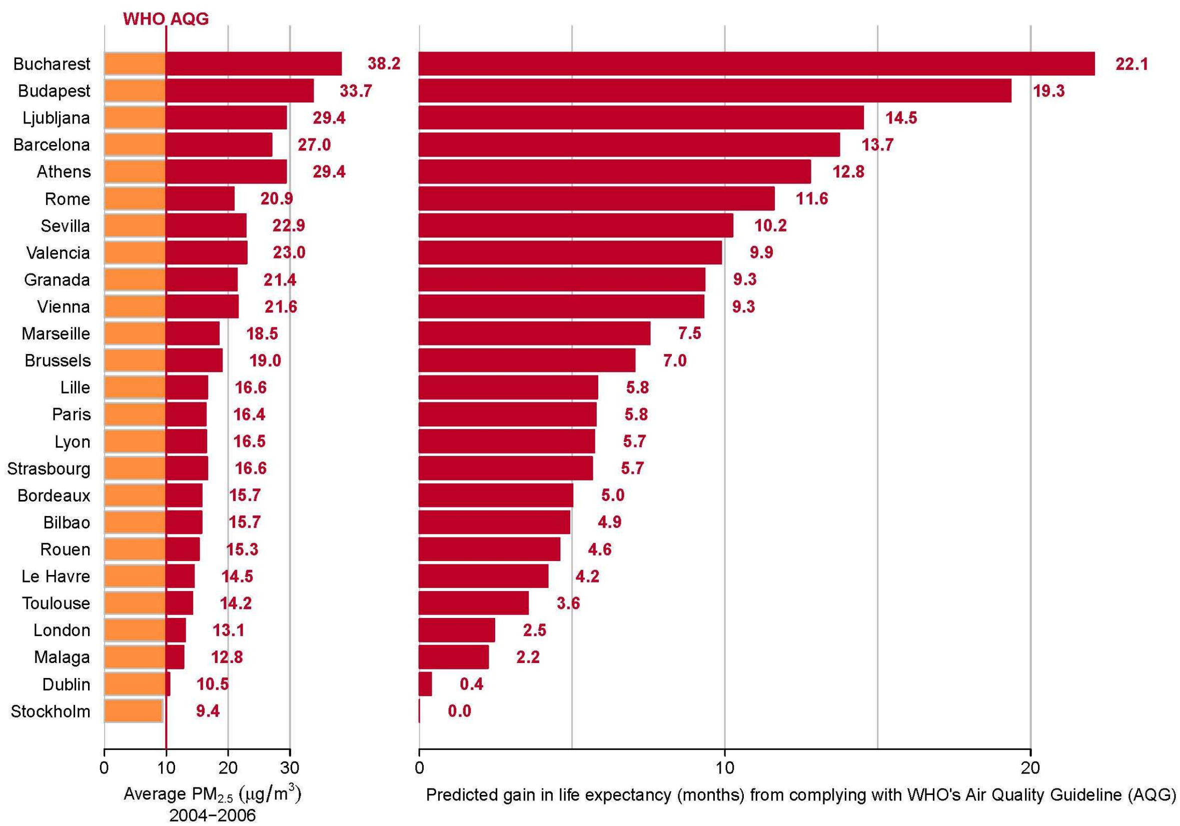
Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana, 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 micrograms/cubic metre 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. The results for $PM_{2.5}$ are summarised in the figure below:

Predicted average gain in life expectancy (months) for persons 30 years of age in 25 Aphekom cities for a decrease in average annual level of $PM_{2.5}$ to 10 µg/m^3 (WHO's Air Quality Guideline)

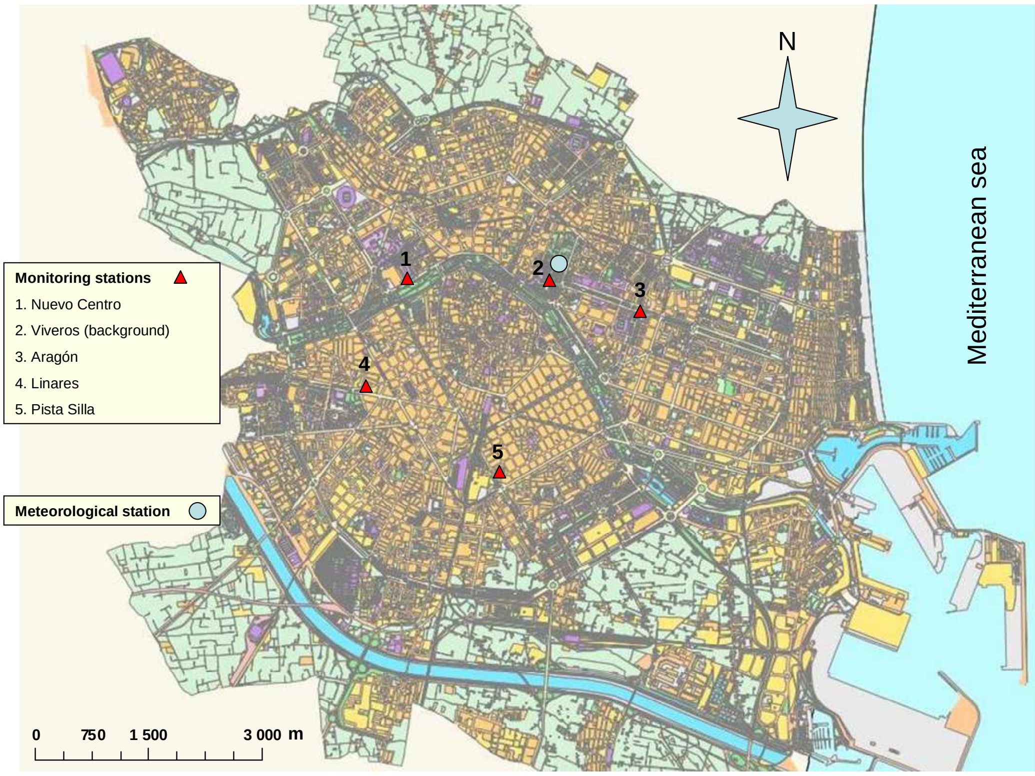


1.1. Description of the study area for Valencia

The study area comprises the urbanized part of the municipality of Valencia, an area of some 32km^2 in size (Figure 1). The municipality of Valencia has a network of air pollution monitoring stations from which the average exposure of the population in the study area can be estimated.

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 1 – Map of the study area



Climatology

The climate in Valencia, is a Mediterranean-type climate characterized by warm and dry summers and mild winters. Yearly average temperature hover around 18-degree Celsius and the average humidity around 70%. July and August are the peak summer months whence the average temperature is about 27-degree Celsius. In the winter months, from November to March, the average temperature is around 13-degree Celsius

Population in the study area

In January 2005 Valencia had an official population of 797,291. With this number of inhabitants, Valencia was the fourth most populous municipality in Spain. (source:http://www.ine.es/prodyser/pubweb/anuario06/anu06_02demog.pdf)

Commuting

: In addition to those living within the city, Valencia is surrounded by a metropolitan area with more than 600,000 inhabitants. Because daily activity of residents in the metropolitan area is closely related with the city of Valencia, this population should be also considered not anly as potentially exposed to air pollution in the city but also as contributing to the polllution

Previous HIA of air pollution in Valencia

Valencia city has been included in the previous HIA initiatives in Europe, including Apheis project(1) and also HIA in the Enhis programme (Environment and Health Information System (ENHIS). Two times in the Apheis project and once for the Enhis programme HIA estimates were obtained in Valencia, but because data on PM10 or PM2.5 was not available, HIA produced estimates only for short-term effects. (These city reports can be obtained at http://www.apheis.org/).
Briefly, black smoke data from three monitoring stations (named Viveros, Cementerio and Cruz Cubierta) was available for the Apheis2 and Apheis3 reports. For the last report we calculated the daily average of background levels in Valencia as the mean of the completed series from these three stations in year 2000. The annual average of daily mean levels (and standard deviation) of black smoke in Valencia in 2000 corresponding to these three background stations was 20.1 (11.4) µg/m^3.

In year 2000, 5,739 people died in Valencia for all causes except external ones. According to the HIA, if the 135 days with daily mean black smoke levels higher than 20 µg/m^3 were reduced to 20µg/m3, the consequent benefit for short-term effect would be roughly 14 deaths or (1.9 deaths per 100 000 inhabitants). The corresponding reduction in excess cases for hospital admissions for cardiac diseases would be around 17 people.

In the ENHIS1 HIA report ozone was included. In 2002 the ozone annual mean (and SD) of the maximum daily 1-hour concentration in the city of Valencia were 67.8 (25.3).5 µg/m3. For the summer period of the same year, the correspondent concentrations of the maximum daily 8-hour moving average concentration were 69.8 (17.3) µg/m3 of ozone (O_3) Only one day exceeded the limit value for health protection established in 2002/3/CE Directive (120 µg/m3 for daily 8-hour moving average).
As above mentioned PM10 data fulfilling the APHEIS criteria was not available for year 2002 and, consequently, estimates of its health impact were not calculated for Valencia. Regarding short-term effects of O3 in summer, all other things being equal, each reduction by 10 µg/m3 of the daily maximum 8-hour moving average concentrations would delay 8.16 deaths per year among the general population in the study area, 3.99 from cardiovascular diseases, and 3.31 from respiratory causes. In terms of hospital admissions, this would represent 0.70 respiratory admissions in the adult population and 8.01 in the population over 64 years old.

1.2. Sources of air pollution and exposure data

Sources

Air pollution in Valencia mainly derives from motor vehicle exhaust emissions, with industrial pollution playing a smaller part. Other potential emissions are combustion from agriculture or food activities (i.e. bakeries). Heating is not a major source in Valencia because of the mild climate during the winter. Relating ozone, the sea breeze, allowing for the re-circulation of pollutants during several days, joined to the high frequency of sunny days favor the increase of ozone concentrations.
Particulate matter and NO2 are the most problematic pollutants in the city of Valencia. Levels of NO2 sometimes exceed the annual limit values within the Directive of the European Union. The main sources have not changed since the last Apheis/Enhis1 findings.

Exposure data

In Valencia, air pollution levels are monitored by the Environmental Laboratory within the health division of the Valencia Council. The air pollution monitoring network consists of 14 manual and six automatic monitoring stations providing access to measured pollutant concentrations. For this study, daily average concentrations for the period 2004-2006 were collected from the only 1 background station (named Viveros station) monitoring PM_{10} (using TEOM monitors adjusted to gravimetric equivalence) and 5 (1 background and 4 oriented to traffic) monitoring ozone. Levels of $PM_{2.5}$ were calculated from PM_{10} concentrations using the European recommended 0.7 as conversion factor. This factor was validated with local results of empirical measures in Valencia using two stations in parallel for both PM_{10} and $PM_{2.5}$ in the same location that the station used here (i.e. Viveros garden). This results provided a coefficient of 0.69 for $PM_{2.5}$ from PM_{10} measurements. PM_{10} and ozone were measured using the gravimetric method and quimioluminiscence method, respectively.
All included monitoring stations, reported more than 75% of valid daily data for the study period. Summary statistics for daily concentrations (averaged across the 3 and 10 stations for PM_{10} and ozone respectively) are given below

Table 1 – 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)	59.0	24.3	18.0	95.8
PM10 (daily average)	32.8	12.1	15.0	58.0
PM2.5 (daily average)	22.3	10.9	10.8	44.5

Figure 2 – Ozone concentration in the study area

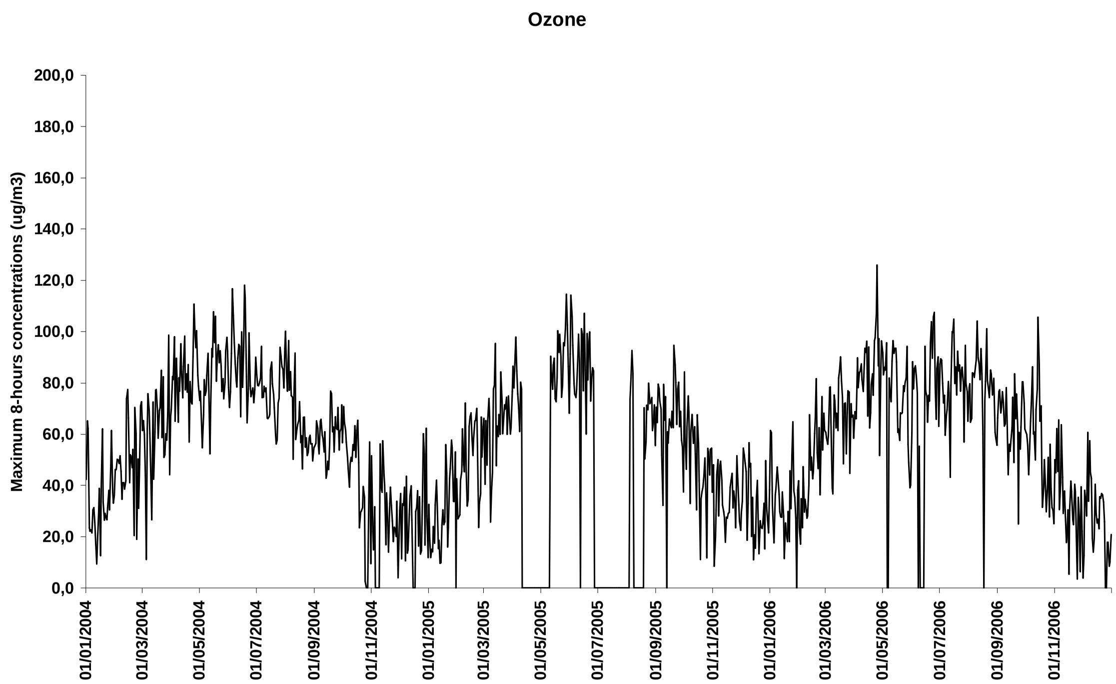


Figure 3 – PM10 concentration in the study area

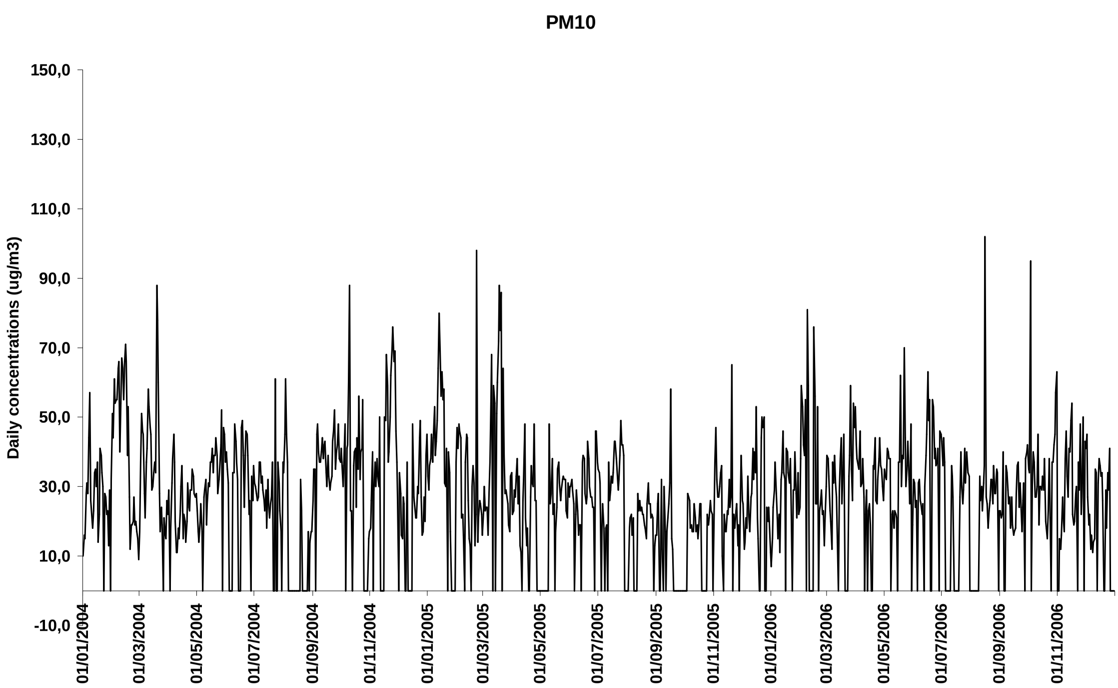
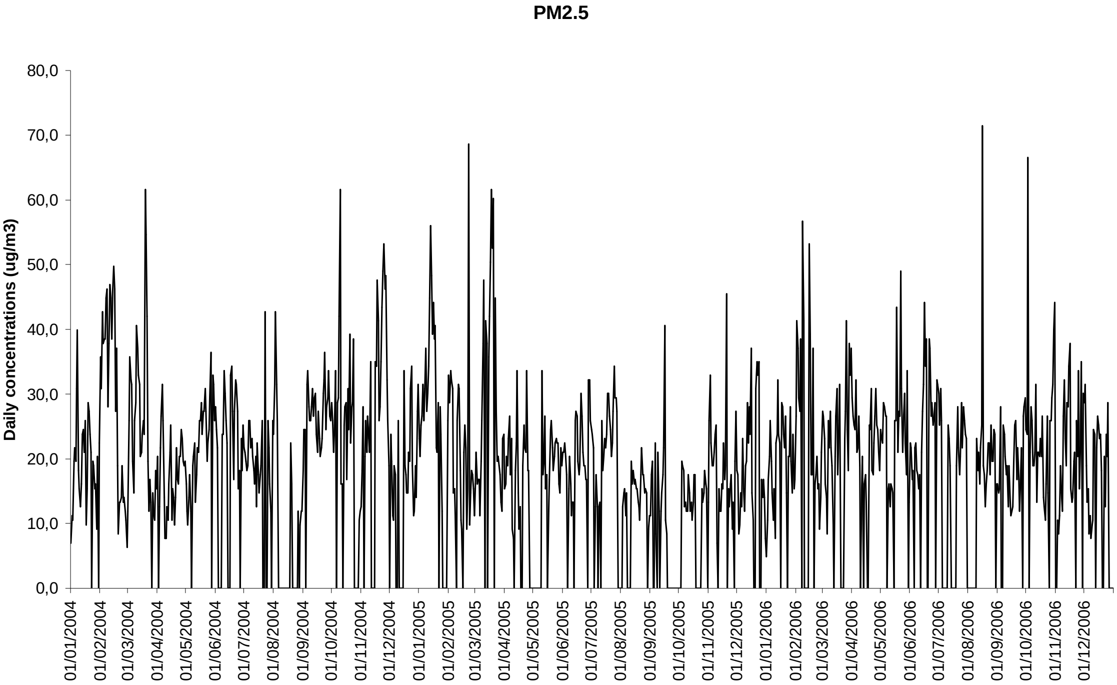


Figure 4 – PM2.5 concentration in the study area



1.3. Health data

The daily number of deaths in Valencia was obtained from the Valencian Community Mortality Register. The group to be studied was restricted to city residents only. Some Works have been published on the completeness of the register and the quality of patient diagnosis showing that the register is both complete and reliable.

The number of emergency daily admissions was obtained from the registry databases of the five hospitals of the public health system in the city. This system uses a standardised procedure to collect hospital admissions in Spain. In the Community of Valencia, roughly all the population is covered by the regional health system, although some people use some private health services. For the diagnoses used in Aphekom, it is thought that the coverage in year 2004 represented around 90% of the admissions in the city. Also, only admissions for residents of Valencia City were selected. The diagnosis used was the one that motivated the admission reflected in the discharge report. Table 2 shows the summary of the mortality and morbidity groups of causes included in this report.

Table 2 – 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	5573	755
Total mortality	< 1000	A00-Y98	> 30	6281	1308
Cardiovascular mortality	390-429	I00-I52	> 30	2111	440
Cardiac hospitalizations	390-429	I00-I52	All	4265	578
Respiratory hospitalizations	460-519	J00-J99	All	5427	735
Respiratory hospitalizations	460-519	J00-J99	15-64 yrs	1381	187
Respiratory hospitalizations	460-519	J00-J99	≥ 65 yrs	3312	449

* 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 PM10

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

Table 3 – Potential benefits of reducing annual PM10 levels on total non-external* mortality

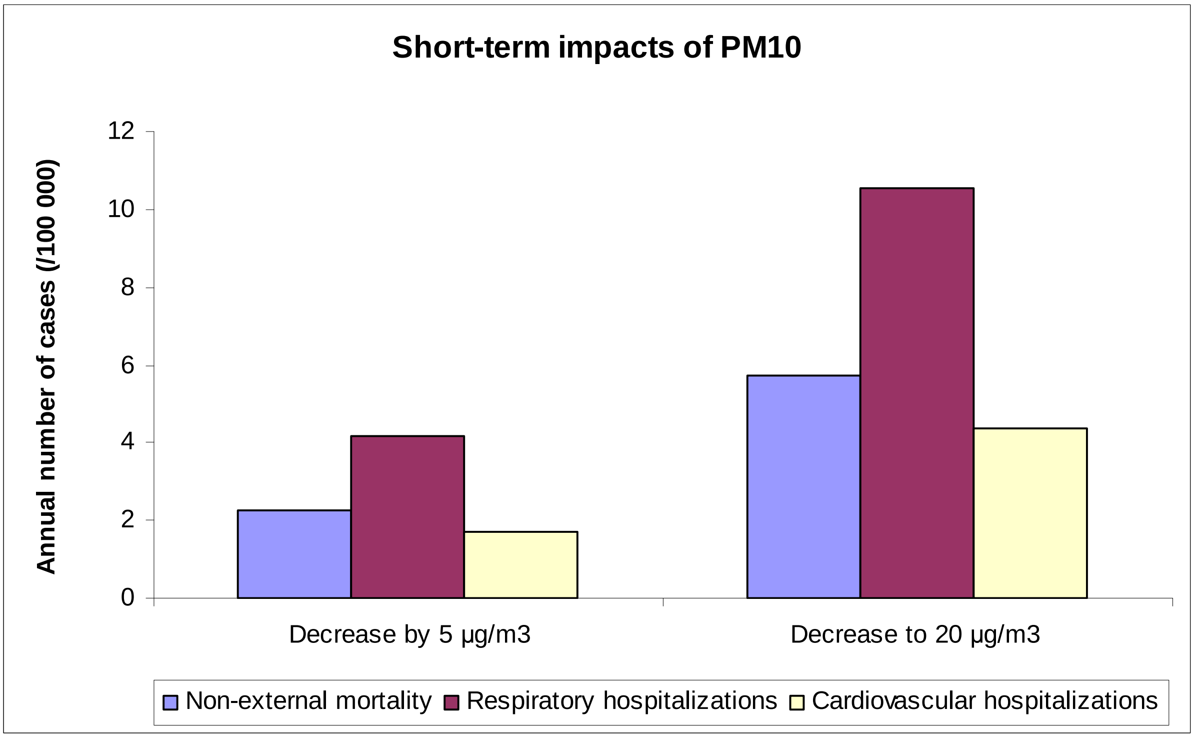
Scenarios	**Total annual number of deaths postponed**	**Annual number of deaths postponed per 100 000**
Decrease by 5 $\mu g/m^3$	49.9	2.3
Decrease to 20 $\mu g/m^3$	127.2	5.7

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

Table 4 – Potential benefits of reducing annual PM10 levels on hospitalisations

	Respiratory hospitalisations		**Cardiac hospitalisations**	
Scenarios	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**
Decrease by 5 $\mu g/m^3$	92.0	4.2	38.2	1.7
Decrease to 20 $\mu g/m^3$	233.9	10.6	97.3	4.4

Figure 5 – Potential benefits of reducing annual PM10 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.

Table 5 – Potential benefits of reducing daily ozone levels on total non-external* mortality

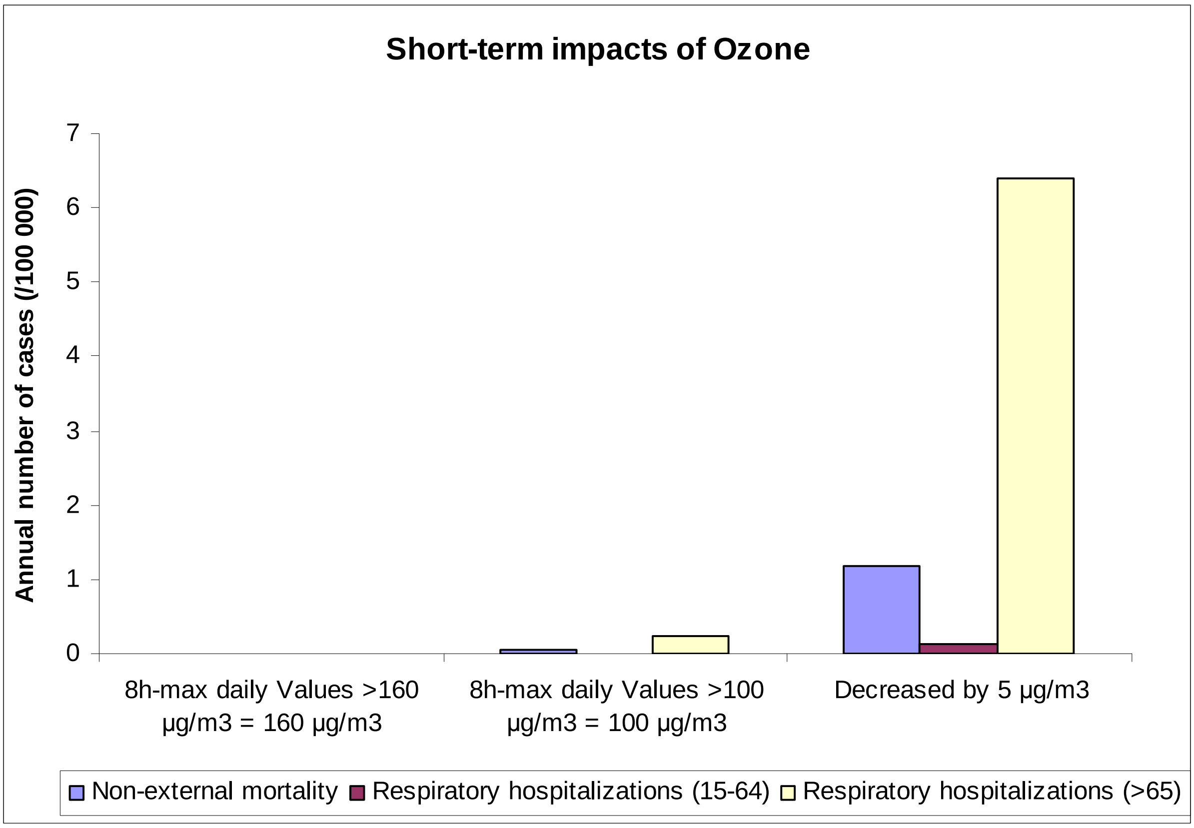
Scenarios	**Total annual number of deaths postponed**	**Annual number of deaths postponed per 100 000**
8h max daily values >160 µg/m^3 = 160 µg/m^3	0	0
8h max daily values >100 µg/m^3 = 100 µg/m^3	0	0
Decrease by 5 µg/m^3	9	1

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

Table 6 – Potential benefits of reducing daily ozone levels on hospitalizations

	Respiratory hospitalizations (15-64)		Cardiac hospitalizations (>64)	
Scenarios	**Total annual number of cases potsponed**	**Annual number of cases potsponed per 100 000**	**Total annual number of cases potsponed**	**Annual number of cases potsponed 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	8	6

Figure 6 – Potential benefits of reducing daily ozone levels on mortality and on hospitalisations



1.4.3. Long-term impacts of 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 AQG).

Table 7 – Potential benefits of reducing annual PM2.5 levels on total non-external* mortality and on life expectancy

Scenarios	Total annual number of deaths postponed	Annual number of deaths postponed per 100 000	Gain in life expectancy
Decrease by 5 µg/m^3	180	38	0,3
Decrease to 10 µg/m^3	456	95	0,8

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

Table 8 – Potential benefits of reducing annual PM2.5 levels on total cardiovascular mortality

Scenarios	Total annual number of deaths posponed	Annual number of deaths postponed per 100 000
Decrease by 5 µg/m^3	116	24
Decrease to 10 µg/m^3	288	60

Figure 7 – Potential benefits of reducing annual PM2.5 levels on mortality

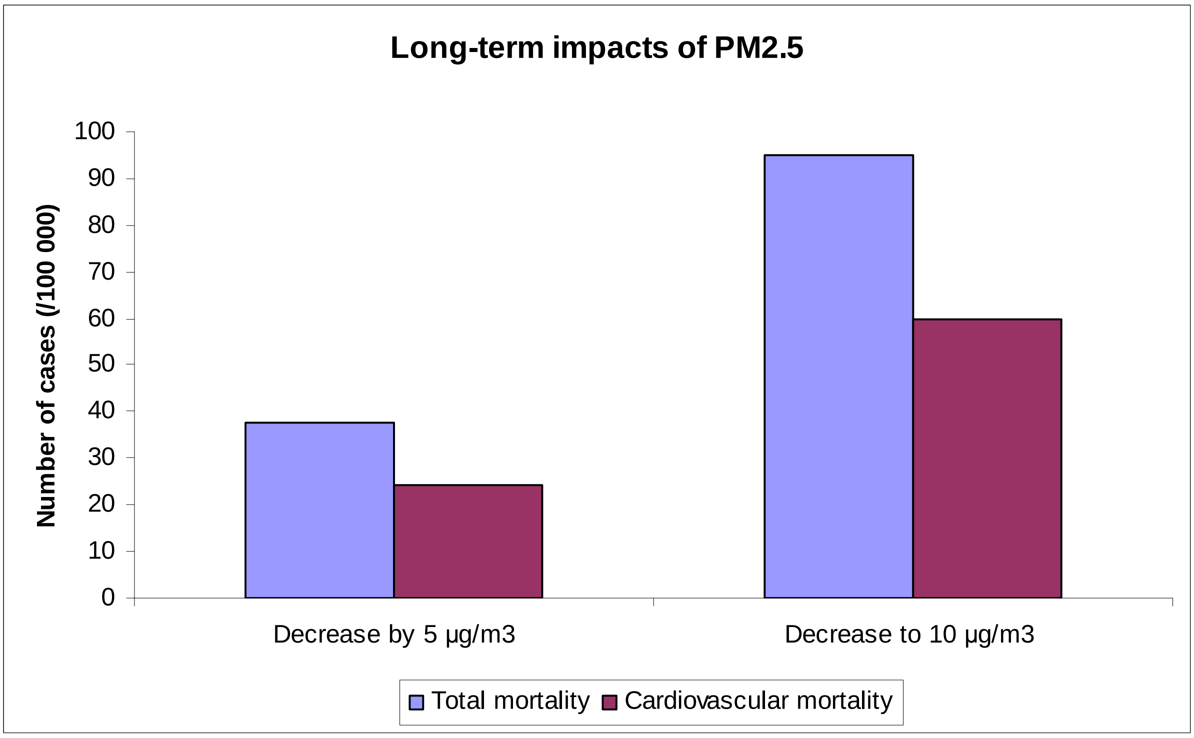
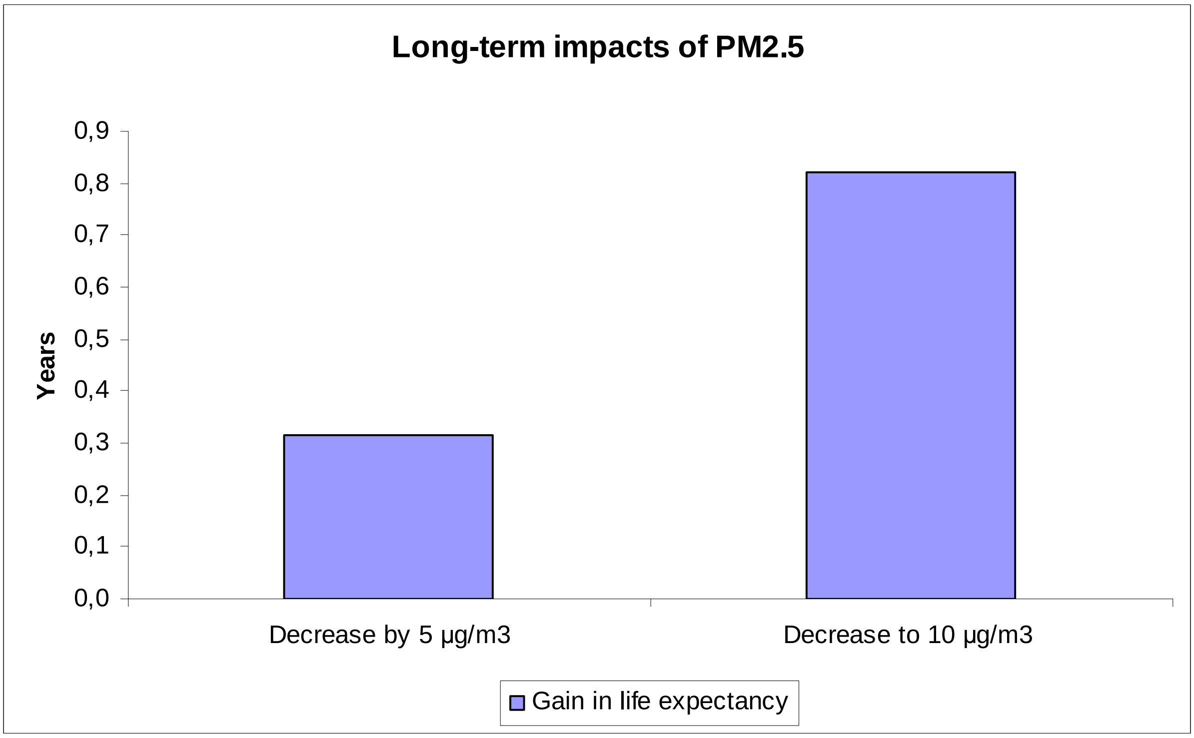


Figure 8 – Potential benefits of reducing annual PM2.5 levels on life expectancy



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 pollution the monetary cost was estimated at €86,600. Hence for a reduction of 5µg/m^3 in average PM_{10} levels in Valencia the estimates saving is €4.3m. Savings arising from long term exposure were estimated at € 1,655,000 per death. Hence for a reduction of 5µg/m^3 in average $PM_{2.5}$ levels in Valencia the estimates saving is €298M

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). For Spanish cities the economic cost of a hospitalization was estimated at €3664 and €3189, for cardiovascular and respiratory causes respectively. Hence the economic benefits of a reduction of 5µg/m^3 in average PM_{10} levels in Valencia is estimated as €140,000 for cardiac causes hospitalizations and €293,000 for respiratory causes hospitalizations.

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 considerable uncertainty in the health h impact assessment and in the quantification these results illustrate the magnitude of the potential benefits associated with reductions in air pollution in London 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.

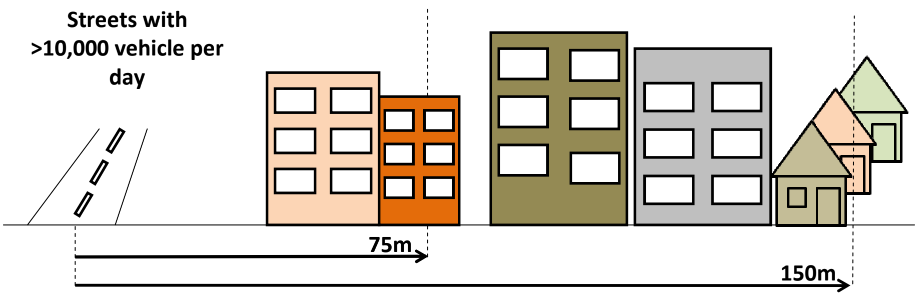
Chapter 2. Health Impacts and Policy: Novel Approaches

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.

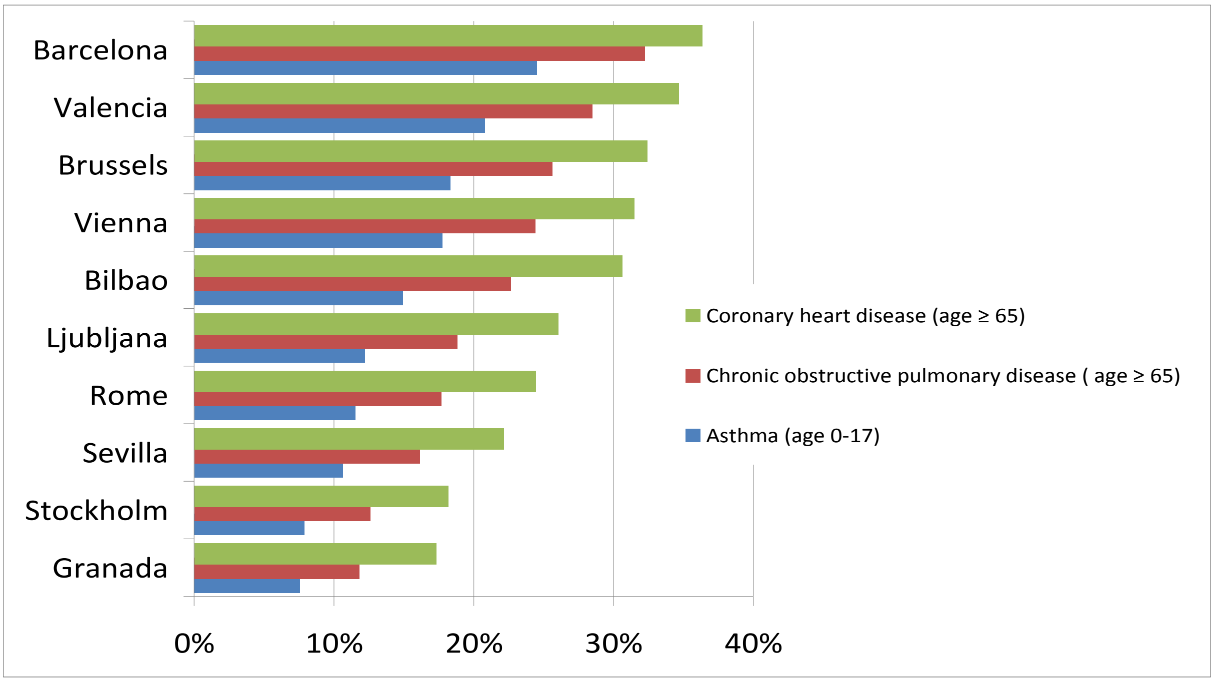
Figure 9 – Estimated percentage of people leaving near busy roads



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%

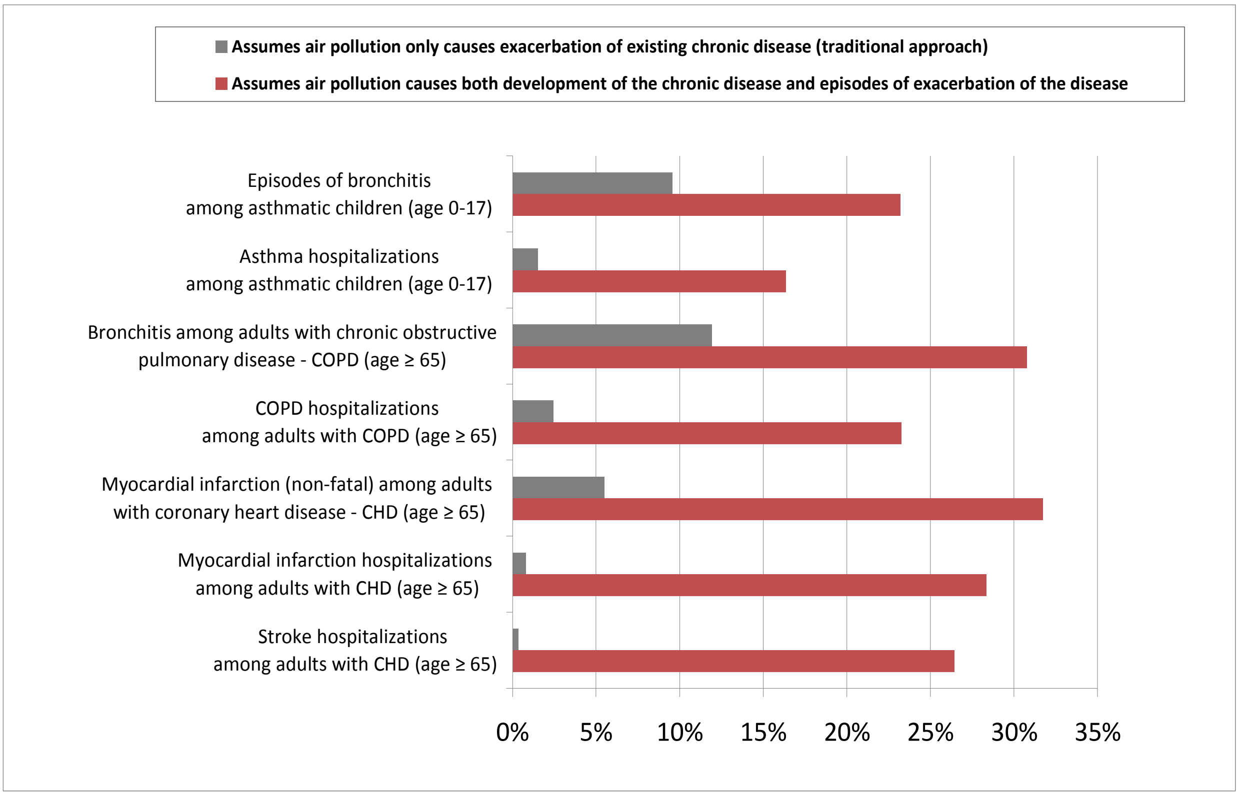
In the cities studied, our HIA showed that living near these roads could be responsible for some 15-30 percent of all new cases of: asthma in children; and of COPD (chronic obstructive pulmonary disease) and CHD (coronary heart disease) in adults 65 years of age and older.

Figure 10 – 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 11 – 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.

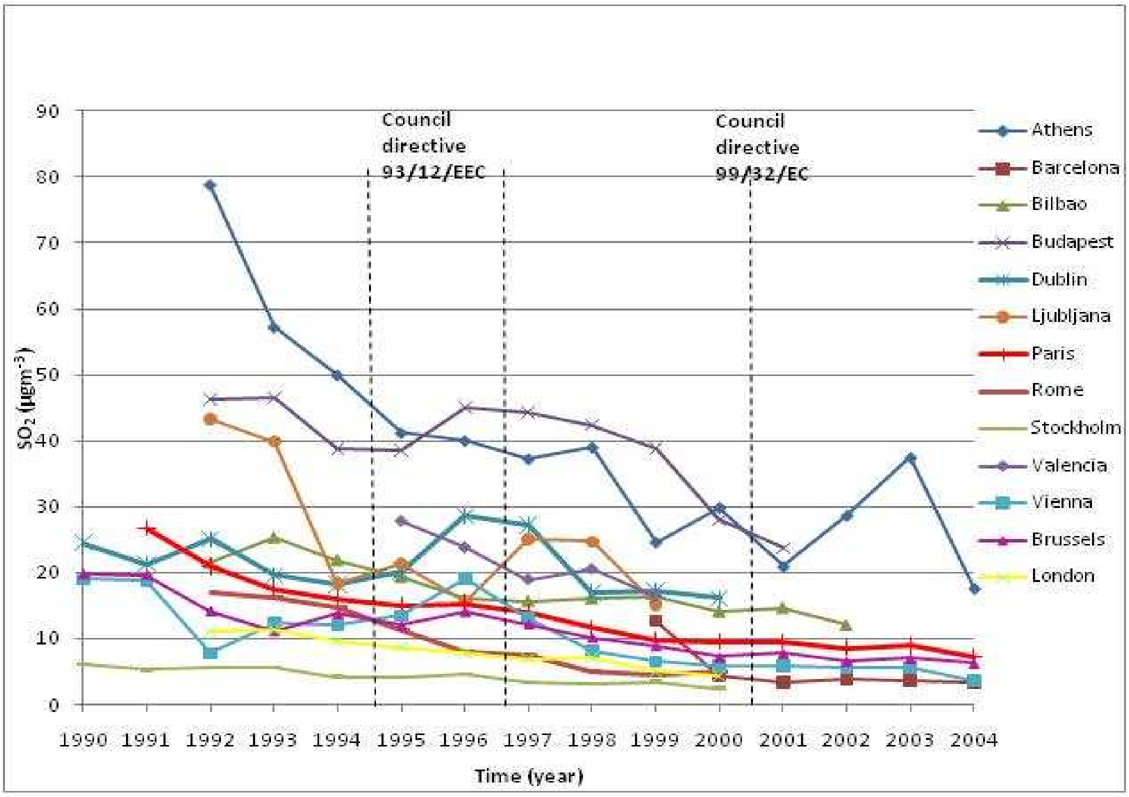
The economic valuation is not sufficiently robust at the city level from a HIA as well as an economic perspective to allow for local computations.

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



Figures 13 and Figure 14 show preliminary work done using hourly SO2 data from Vienna, Austria showing seasonal plots for winter (Fig.13) and summer (Fig 14) for a central urban station for the years 1990 to 2000. For example: In Figure 13 SO2 levels are showing a general decreasing trend over time. The two peaks observed consistently throughout all years between 6am and noon and as well between 4pm and 11pm for the winter plots (Fig. 13) 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. 14) shows a clear reduction in peak SO2 levels for the afore mentioned time periods. This might indicate the proportion of SO2 that resulted from emissions due to heating during the winter months especially as high SO2 levels are observed for a few consecutive hours from ~5pm up to midnight coinciding with inversion. The smaller peaks are still observed again coinciding with the morning and evening rush hours and also reflecting climatic effects.

In Fig. 13 the observed winter SO2 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 SO2 levels do not necessarily have to be caused by traffic! It is not clear, if these high SO2 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 13 – Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000

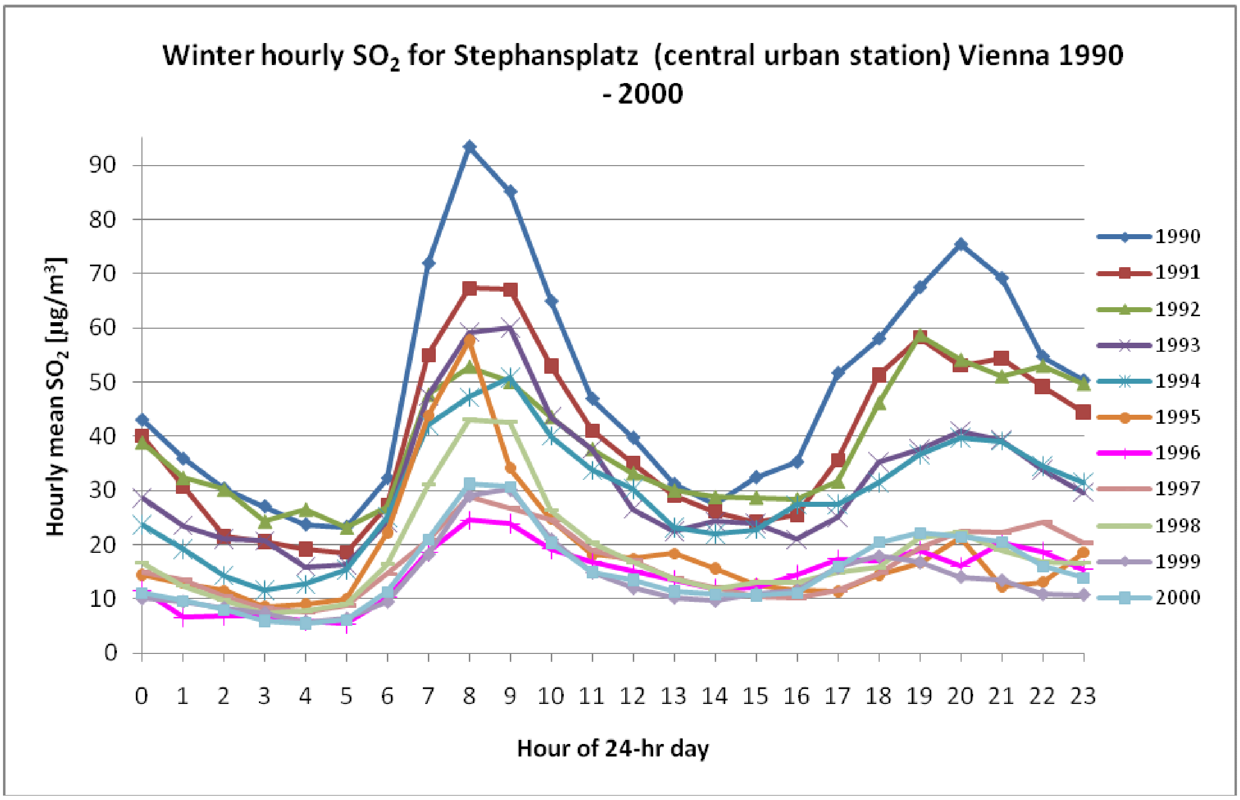


Figure 14 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

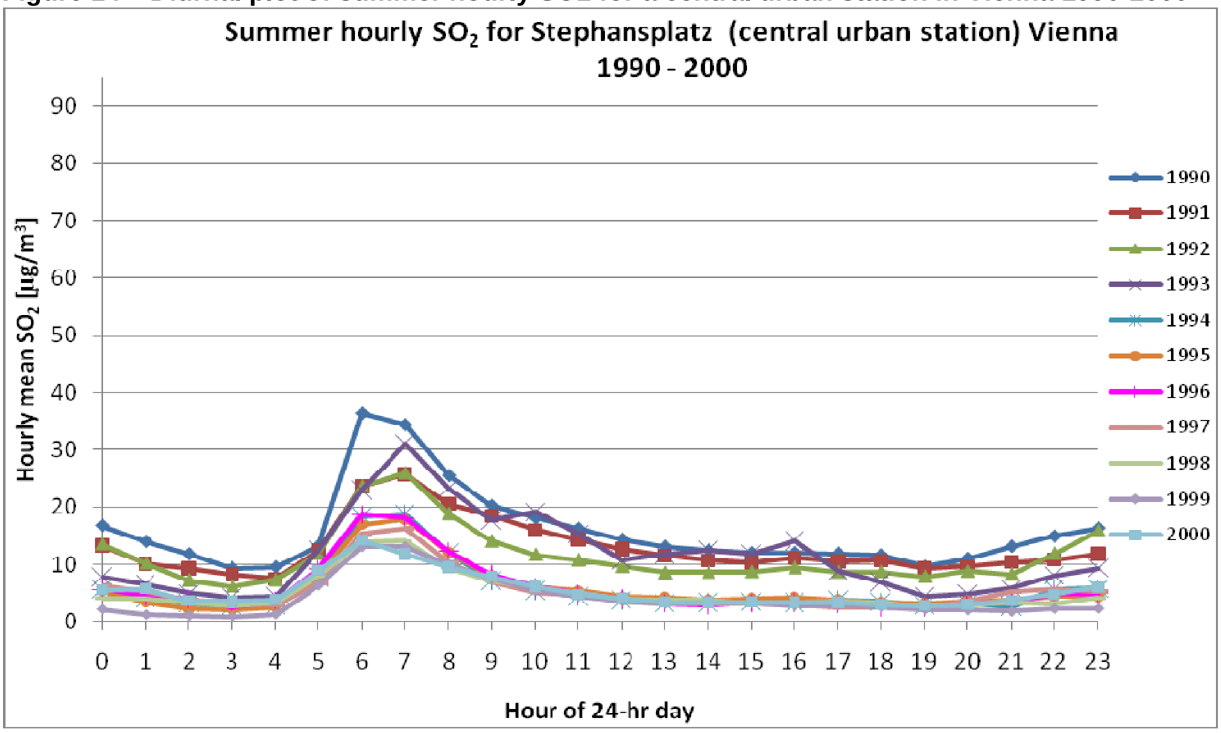
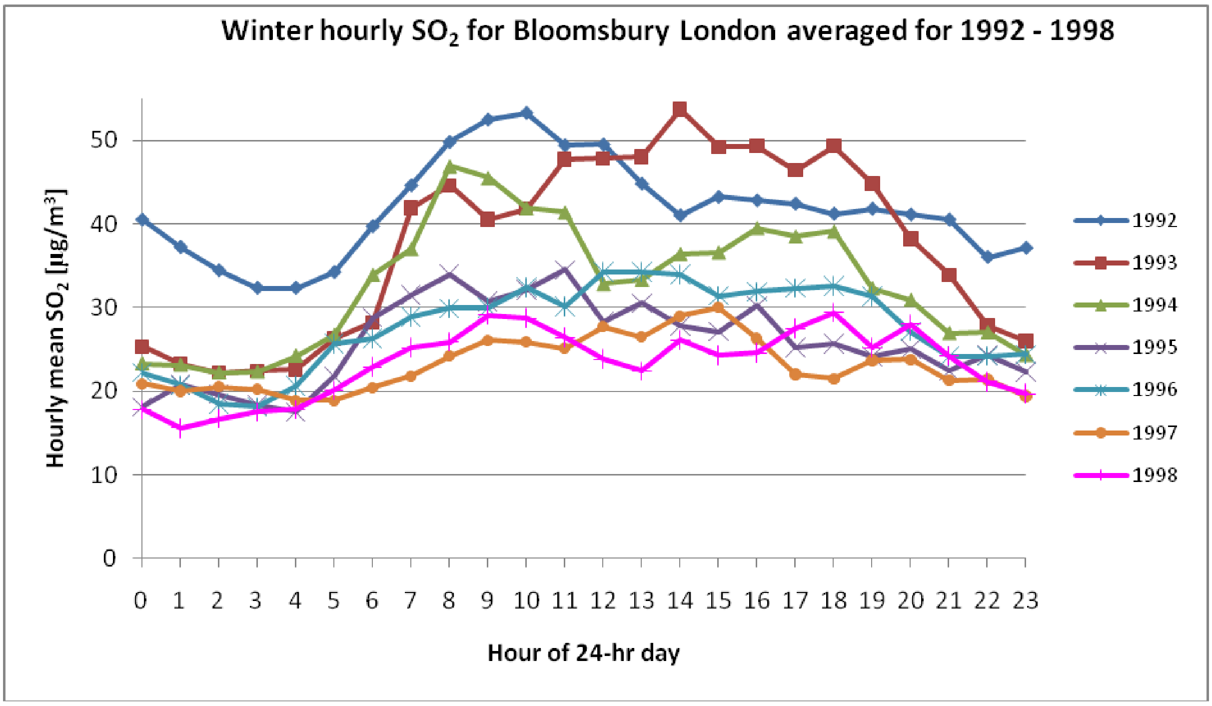


Figure 15 shows a 24hr-plot of hourly SO_2 data from an urban background station in London averaged for the winter months. In comparison to the pattern observed in Fig. 13 for Vienna, where 2 distinct peaks throughout the day for the winter months were observed, here in Fig.15 levels tend to rise markedly 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 15 – 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 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

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 stakeholders 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.

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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 9 – 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	Non-external 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, Δx = 5 µg/m^3
- Scenario 2, Δx =($[PM10]_{mean}$ – 20 µg/m^3).
  Δx = 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 $[O_3]_i \geq 160$ μg/m^3, $Oi=([O_3]_i-160)$
  if $[O_3]_i < 160$ μg/m^3, $Oi=0$

- Scenario 2, if $[O_3]_i \geq 100$ μg/m^3, $Oi=([O_3]_i-100)$
  if $[O_3]_i < 100$ μg/m^3, $Oi=0$
- Scenario 3, where the ozone yearly mean is decreased by 5 μg/m^3. Δx = 5 μg/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, Δx = 5 μg/m^3
- Scenario 2, $\Delta x = ([PM2.5]_{mean} - 10$ μg/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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