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

Aphekom

Local city report

Vienna

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Summary

There is no threshold level for health effects of air pollution. On the contrary the number of deaths and hospital admissions rise linearly and persistently with increasing pollution levels. Measures to reduce air pollution have been consistently shown to improve population health.
Estimates of the health impact of air pollution serve as a tool for policy makers and the general public to better understand the impact of their decisions. Vienna participated in the European Public Health project "Aphekom" and contributed data to all scientific work packages.

Classical health impact assessment methodologies showed the lasting impact of air pollution on the health of the population in Vienna. A reduction of PM2.5 by 5µg/m³ only (annual mean) could postpone 449 deaths annually or increase the average life expectancy by 0.3 months.

Thirty-six percent of the population in Vienna lives closer than 75 m to a busy road. This causes chronic diseases of the cardiovascular and respiratory system and thus accounts for approximately 30% of all cases of coronary heart disease in the elderly.

European and national legislation to reduce the sulphur content in fuels were successful. SO_2 levels dropped convincingly in many urban areas in Europe including Vienna. Time series analyses showed the overall benefit of this measure.

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

HIA: health impact assessment

O3 : ozone

PM_{10} : particulate matter with an aerodynamic diameter <10 µm

$PM_{2.5}$: 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.

Vienna participated in the 2005 program of Apheis that focussed on the one hand on health effects in children, on the other hand on ozone. Then health and air pollution data from 2002 were used:
In 2002 the PM10 annual mean (SD) was 30 (17.3) µg/m³, above the 1999/30/EC Directive limit value for 2010 (20 µg/m³), and below that established for 2005 (40 µg/m³). For the summer period of the same year, the mean (SD), P5 (5th percentile) and P95 of the maximum daily 8-hour moving average concentration of ozone (O3) were 89.9 (22.1), 43.2 and 120.8 µg/m³.
Regarding children, infant mortality in Europe is quite low and consequently, the expected attributable number of deaths related to air pollution is also very low. All other things being equal, the reduction of the annual average levels of PM10 to 20 µg/m³ would prevent 4.8 total postneonatal deaths. Reducing PM10 daily mean values to 20 µg/m³ would further prevent 106 hospital respiratory admissions.
As far as short-term effects of O3 in summer are concerned, all other things being equal, each reduction by 10 µg/m³ of the daily maximum 8-hour moving average concentrations would delay 24.3 deaths per year in the general population in the study area, 19 from cardiovascular diseases, and 4.1 from respiratory causes. In terms of hospital admissions, this would represent 7 respiratory admissions in the adult population (between 15 and 64 years of age) and 22.7 in the population over 65 years.

Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana, London, Lyon, Malaga, Marseille, Paris, Rome, Rouen, Seville, Stockholm, Strasbourg, Toulouse, Valencia and Vienna. In each participating centre, the project analysed the short-term impacts of ozone and PM10 on mortality and morbidity, as well as the long-term impacts of PM2.5 on mortality and life expectancy in populations 30 years of age and older.

This work shows that a decrease to 10 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.

1.1. Description of the study area for *Vienna*

Vienna is the capital of Austria. With its population of approx. 1.5 Mio it lies at the eastern end of the Alps. In the west it is surrounded by the hills of the Vienna Woods but in the east the land opens to the Pannonian Basin. This enables a good mixing of air on most days. Air pollution episodes with high particulate matter are mostly observed in winter with inversion or with masses of air transport from industrial centers in South-Eastern Europe. Ozone peaks on hot summer days in the outskirts of Vienna.

Some heavy industry and power plants are situated within the city area but more plants are located especially to the east and south of the city boarders. Nevertheless the most important local source of ground level air pollution in the city is road traffic including traffic within the city and commuting to and from the outside.

Air masses in the area are quite uniform with background monitoring stations reporting comparable pollution levels all over the city and showing good correlation over time. While the local air mass also extends far outside of the city boarder health data are only available according to administrative boundaries and therefore the HIA focuses on the city alone.
PM10 daily mean values exceed the limit value of the European Union (50 µg/m³) at most monitoring sites for at least some days. On the other hand the annual mean value at all sites is below the limit value (40 µg/m³). There is no clear trend in PM air pollution in Vienna.
High pollution days are linked to certain weather scenarios that cannot be influenced by local measures. Therefore the city cannot sufficiently reduce short term high pollution peaks while a moderate reduction of the everyday local emission of PM seems feasible.
The Viennese EPA (MA 22, 2005) estimates that on high pollution days 60% of the PM pollution at background stations is derived from foreign sources and only 25% originate in Vienna. But on top of these background exposure a considerable local impact is seen at curbside stations and at the stations located in the vicinity of industries (e.g. Liesing, see figure 1).

Air pollution data were taken from the monitoring stations indicated in figure 1. For PM10 daily averages for the years 2004 to 2006 were averaged over the stations "Lobau", "Schafbergbad", "Stadlau", "Laaer Berg", "Belgradplatz", "Gaudenzdorf", "Kendlerstraße", "Liesing", and "Rinnböckstraße". When data were missing from one stations the values were estimated based on linear regression from the station with the highest temporal correlation coefficient (usually >0.9).
PM2.5 is monitored only at two stations where one (Taborstraße) is a curbside station. "Währinger Gürtel" is also not perfectly background but not located directly near a busy road. Because of many data gaps in 2004 for PM2.5 the years 2005 to 2007 were used instead.
For ozone the years 2004 to 2006 were used and the data of the stations "Hohe Warte", "Lobau", "Stephansplatz", "Hermannskogel" and "Laaer Berg" were averaged.
Health data and population data were for the years 2004 to 2006 and were retrieved from official sources at "Statistics Austria".

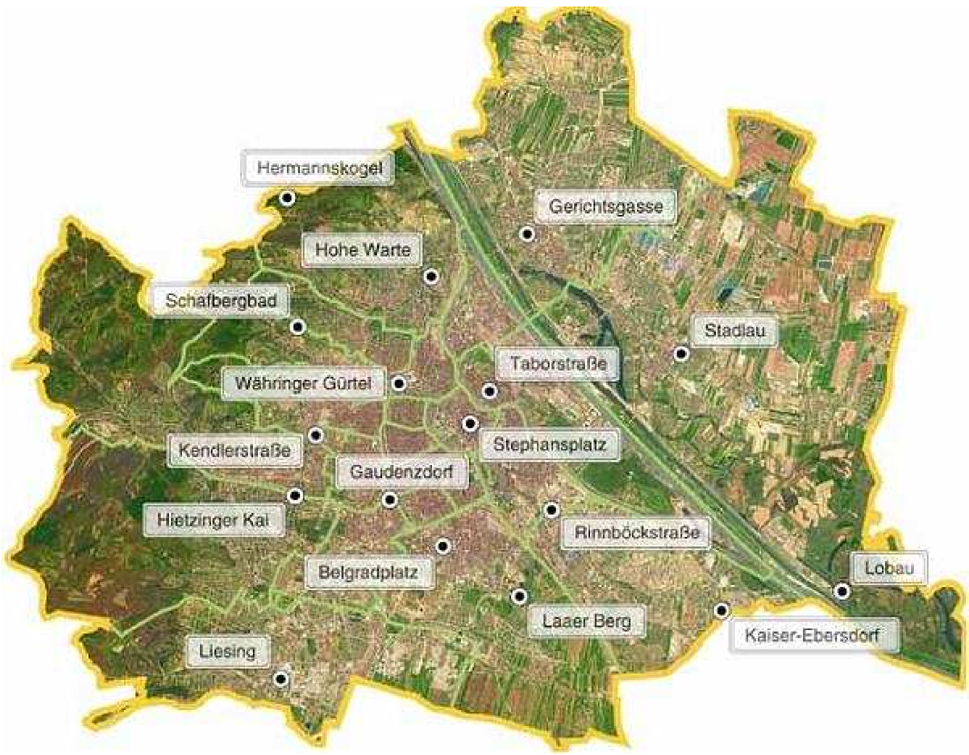


Figure 1 – Map of the study area

Population in the study area and other characteristics

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.
Vienna has a temperate climate with an average temperature of approx. 12℃. In 2007 the highest daily mean temperature was 29.1℃ and the highest (daytime maximum) temperature was 36.8℃. The minimal daily average temperature in winter was -4.9℃ and the minimal temperature (night time minimum in winter) was -7.7℃. Relative humidity (d aily man) varied between 45 and 97% (average: approximately 70%) and the pressure between 964.6 and 1013.1 hPa (average: 991.7). Daily precipitation varied between 0 and 58.4 mm/day with an average of 2.4 mm/day.

Within the administrative boundaries of Vienna (414 km²) in 2006 in total 1.66 million people were registered with an age distribution that is typical for the aging populations of the area (only 240,000 less than 15 years old, while 266,000 are 65 years and older).

1.2. Sources of air pollution and exposure data

Sources

Table 1 – Main sources of air pollution *(expressed as tons/year) (emission data for Vienna, 2006)*

Pollutant	Road	Heating	Industry	Energy
SO_2	28	391	162	549
NO_X	21610	1312	1550	1888
PM_{10}	839	292	502	58
$PM_{2.5}$	1442	277	184	49

Exposure data

Both Ozone and PM2.5 show the typical annual variation with higher ozone levels in summer and higher PM2.5 and PM10 levels in winter. On average PM2.5 makes up 75% of the total PM10 which is a reasonable ratio in the local situation.

Table 2 – Daily mean levels, standard deviation and 5th and 95th percentiles for air pollutants *(2004-2006 apart from PM2.5, see above!)*

Pollutant	Daily mean ($\mu g/m^3$)	Standard deviation ($\mu g/m^3$)	*5th percentile* ($\mu g/m^3$)	*95th percentile* ($\mu g/m^3$)
Ozone (daily 8h max)	73	29	23	121
PM10 (daily average)	29	18	10	64
PM2.5 (daily average)	22	16	6	52

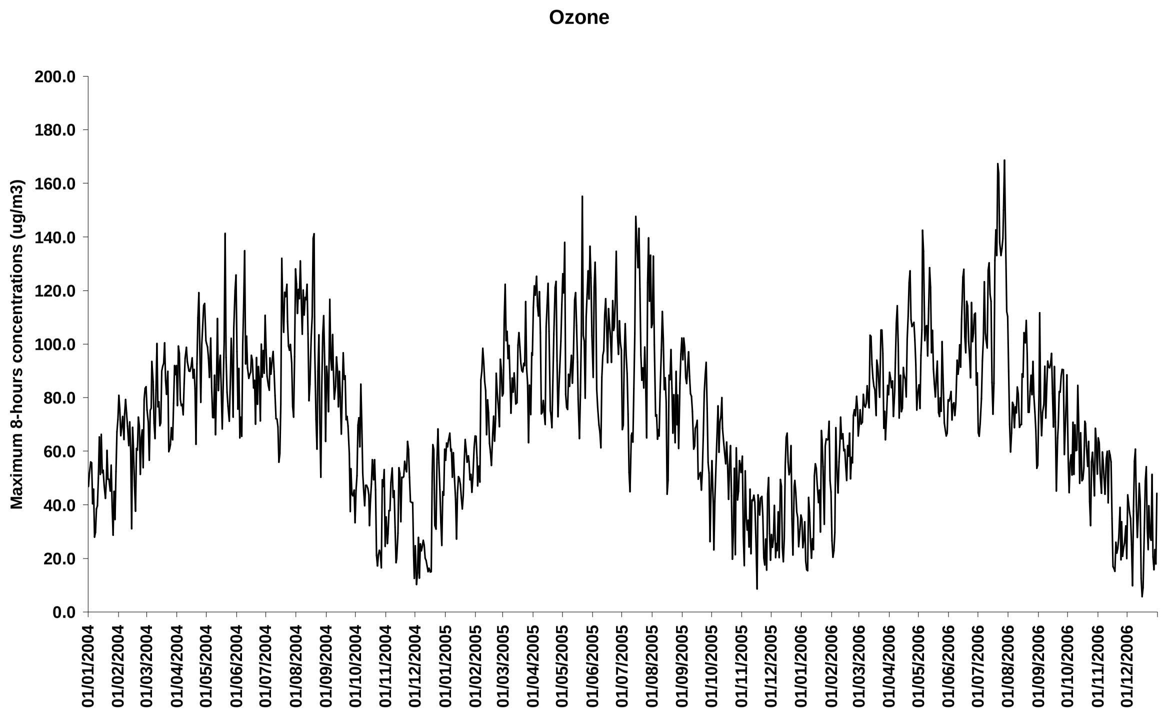


Figure 2 – Ozone concentration in the study area

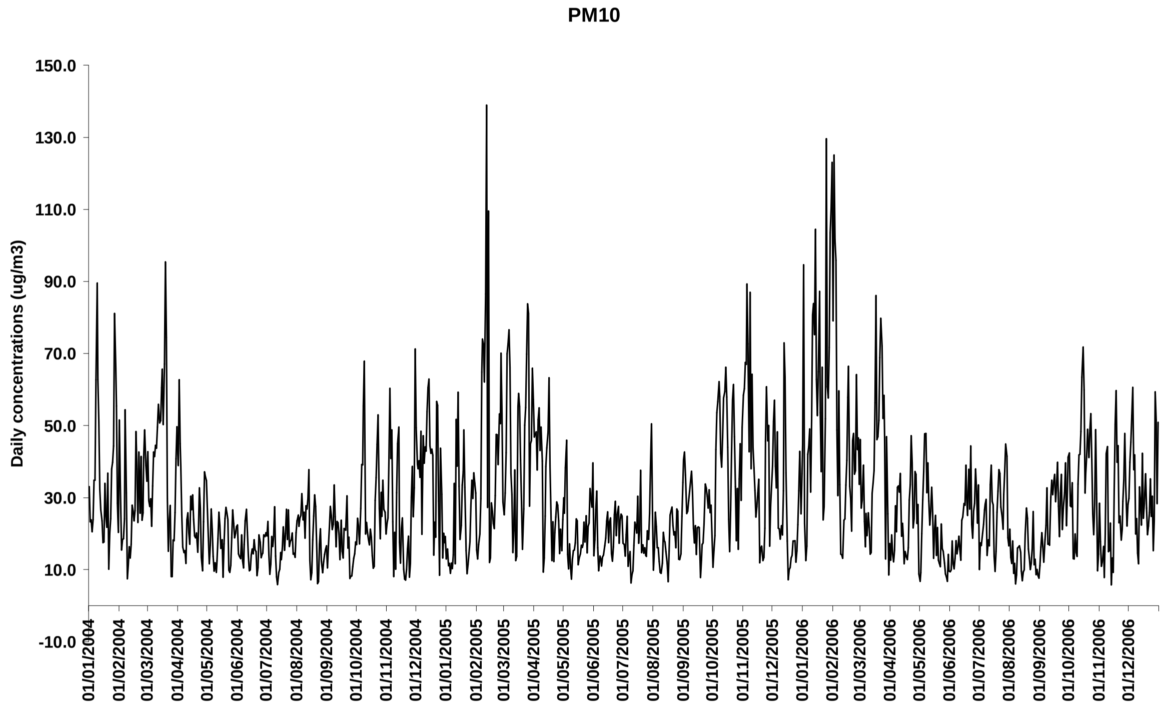


Figure 3 – PM10 concentration in the study area (2004-2006)

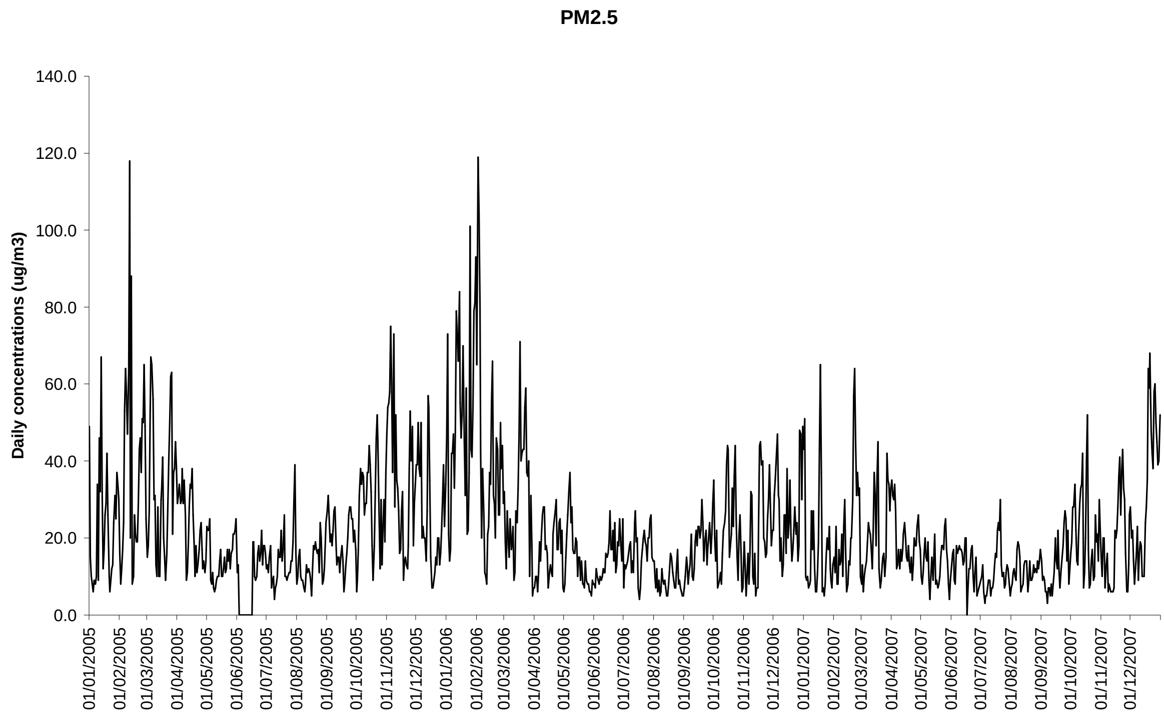


Figure 4 – PM2.5 concentration in the study area (2005-2007)

1.3. Health data

Health data are primarily based on the "Jahrbuch der Gesundheitsstatistik" (Yearbook on Health Statistics) edited by *Statistics Austria*.

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	15,150	914
Total mortality	< 1000	A00-Y98	> 30	15,646	1,422
Cardiovascular mortality	390-429	I00-I52	> 30	7,332	666
Cardiac hospitalizations	390-429	I00-I52	All	37,303	2,250
Respiratory hospitalizations	460-519	J00-J99	All	30,796	1,858
Respiratory hospitalizations	460-519	J00-J99	15-64 yrs	13,153	1,143
Respiratory hospitalizations	460-519	J00-J99	≥ 65 yrs	9,295	3,492

* 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 µg/m^3, and then a scenario where the PM10 annual mean is decreased to 20 µg/m^3, the WHO annual air quality guideline (WHO-AQG).

Time series analyses have shown also for Vienna that there is not threshold level for health effects of daily mean PM10. So even with already low levels every additional reduction in the pollutants (e.g. by 5 µg/m^3) would have a health benefit. Reduction of PM10 annual mean to the WHO guideline value of 20 µg/m^3 would even have a more pronounced effect.

Table 4 – 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 µg/m^3	25	1
Decrease to 20 µg/m^3	45	3

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

Table 5 – 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 µg/m^3	56	3	39	2
Decrease to 20 µg/m^3	101	6	71	4

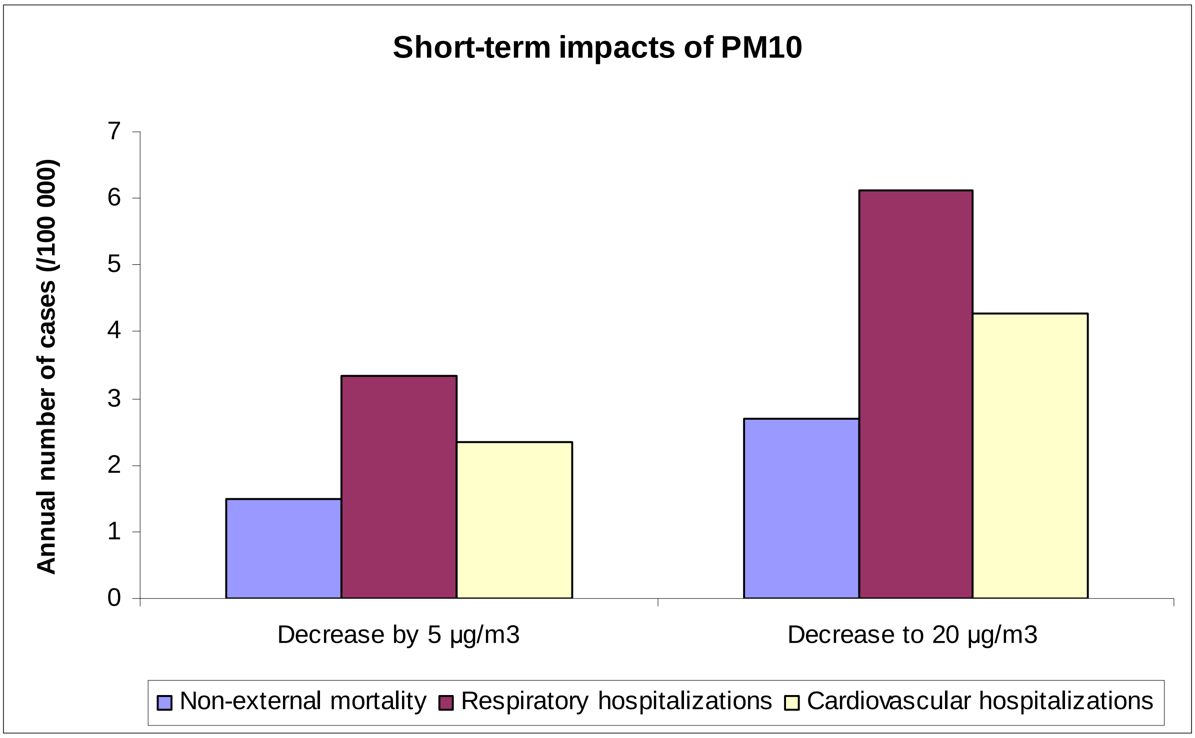


Figure 5 – Potential benefits of reducing annual PM10 levels on mortality and on hospitalisations

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.

Ozone levels in the city itself are most often not very high. To be sufficiently stable in the atmosphere ozone requires a relatively “clean” air. So to a certain extend ozone is negatively correlated with the primary pollutants and thus is a poor proxy of inner city air quality. Thus health effects of ozone in the city of Vienna are less pronounced than those of fine dust.

Table 6 – 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	7	0
Decrease by 5 µg/m^3	13	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)		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	1	0	5	2
Decrease by 5 µg/m^3	2	0	9	3

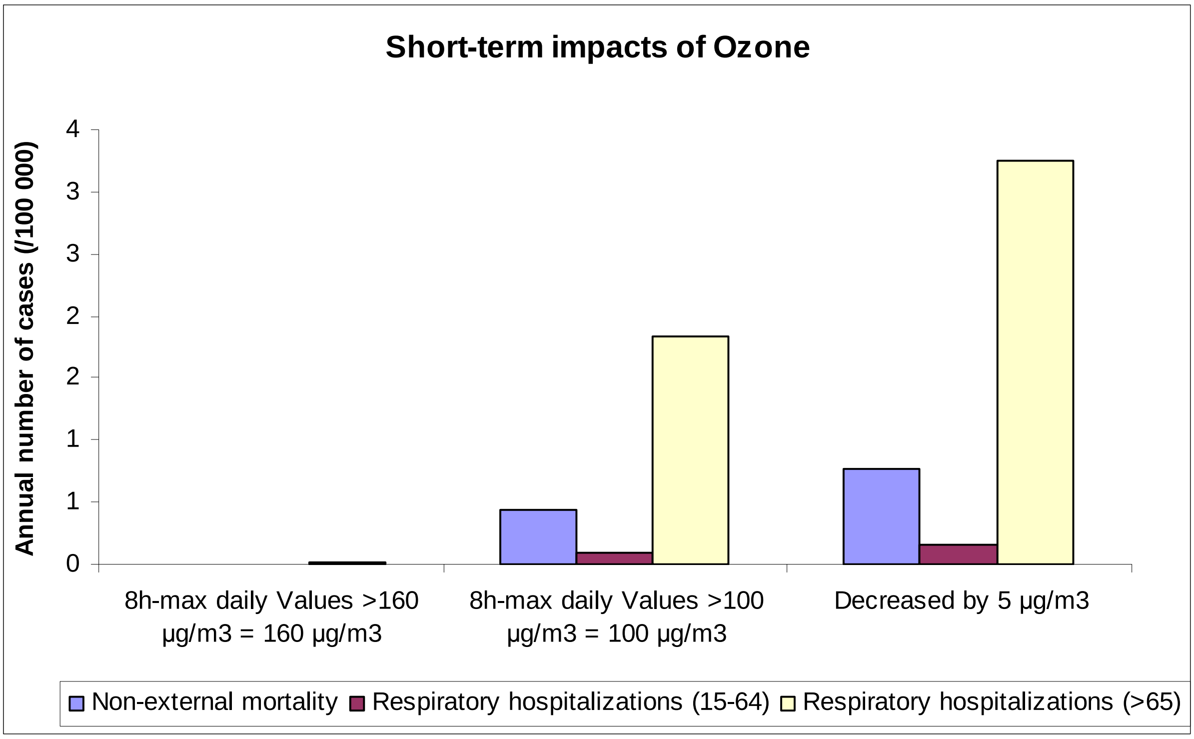


Figure 6 – Potential benefits of reducing daily ozone levels on mortality and on hospitalisations

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).

The “per mass concentration” impact of PM2.5 is considered stronger than that of PM10. And several cohort studies have proven that the long-term impacts of air pollution are more severe than daily pollution levels. So it is no surprise that long-term impacts of PM2.5 outweigh the impact of short term effects of PM10.

Table 8 – 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 (years)
Decrease by 5 µg/m^3	449	41	0.3
Decrease to 10 µg/m^3	1,192	108	0.9

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

Table 9 – 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	404	37
Decrease to 10 µg/m^3	1047	95

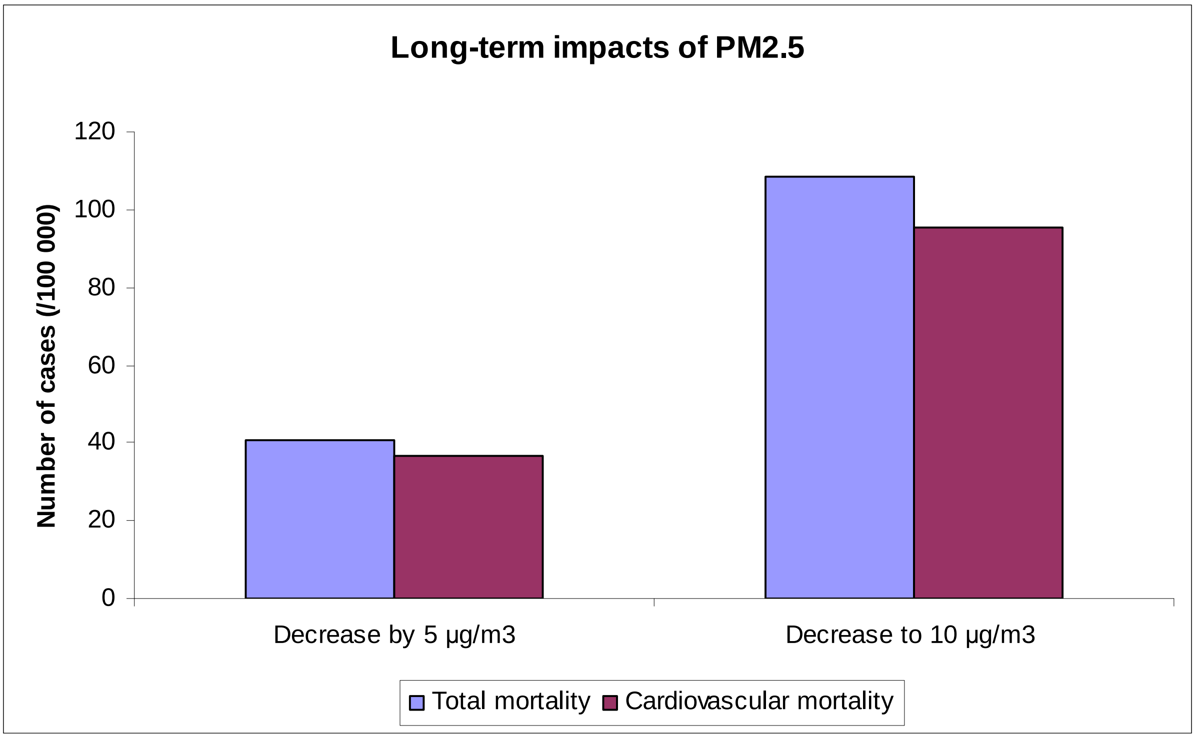


Figure 7 – Potential benefits of reducing annual PM2.5 levels on mortality

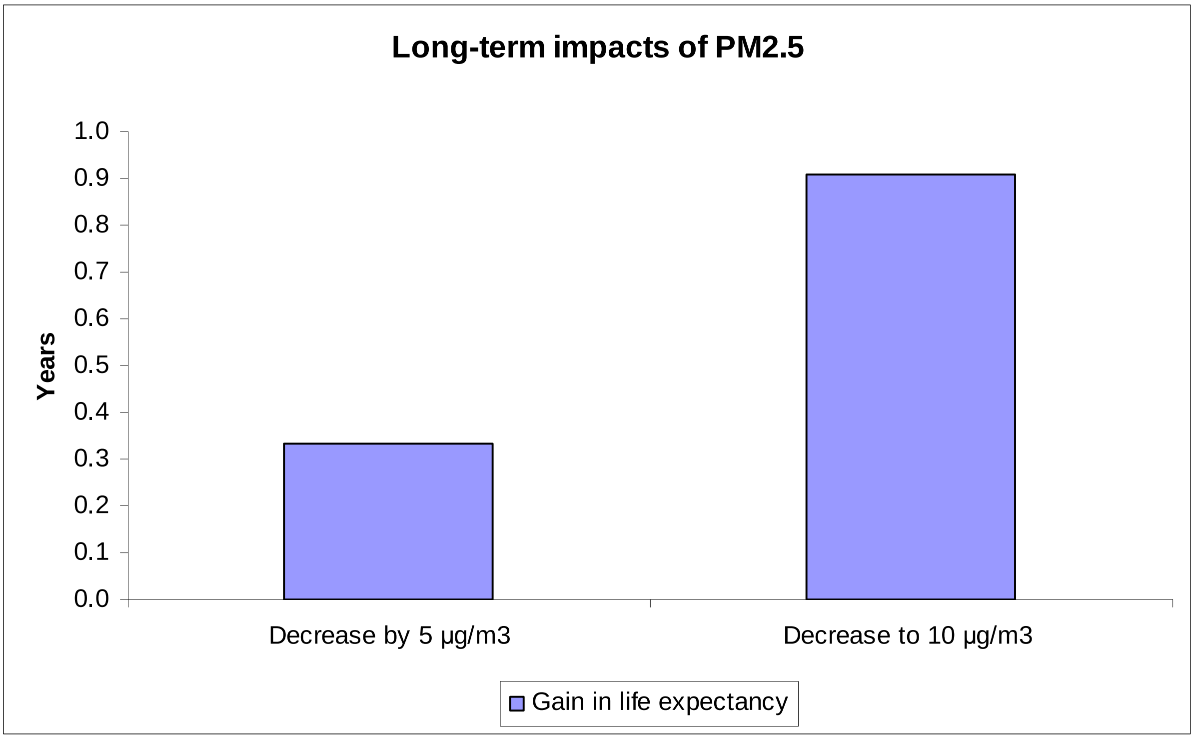


Figure 8 – Potential benefits of reducing annual PM2.5 levels on life expectancy

The HIAs were performed in 25 European cities in a comparative way allowing for the visualisation in figure 9. In spite of a unified methodology still city specific aspects like the choice of monitoring sites must be kept in mind.

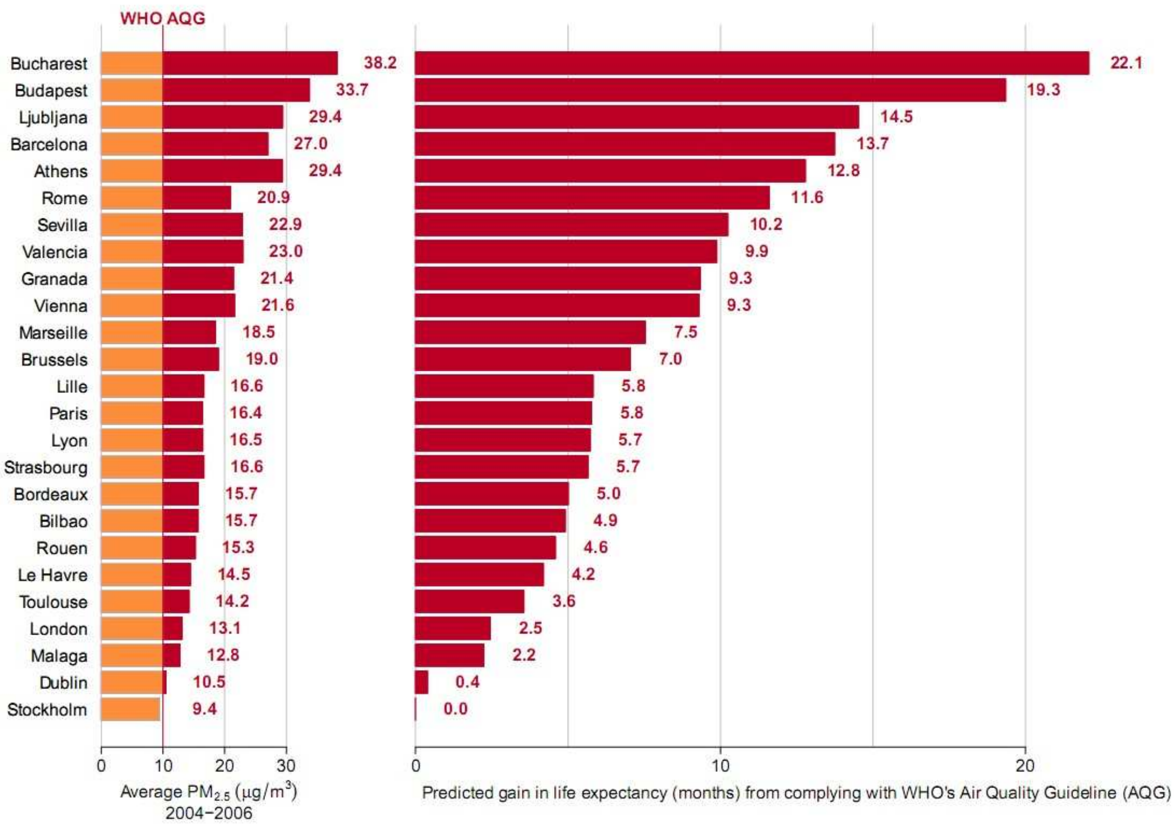


Figure 9 – Long-term HIA for annual PM2.5 levels, comparison between cities

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 are going to differ depending on the short- or long-term nature of the exposure to air pollution (see Appendix 2).

For short-term impacts, the monetary value of €86,600 should be applied to the total annual number of deaths postponed in your city.
This would translate into annual prevented costs of € 2,165,000.00 if PM10 levels were reduced by 5 µg/m³ and even **€ 3,897,000.00** were the WHO guideline value of 20 µg/m³ reached.

For long-term impacts, the monetary value of € 1,655,000 should be applied to the total annual number of deaths postponed in your city.
Not surprisingly seen this way a reduction of PM2.5 by 5 µg/m³ could even save € 668,620,000.00 per year and even more (**€1,732,785,000.00**) could be saved were the guideline value of 10 µg/m³ be reached.

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.
Therefore, if PM10 (annual mean) were reduced to 20 µg/m² (WHO guideline value) annual hospitalisations costs (due to respiratory and cardiac causes) of **€ 605,668.00** could be saved.

1.4.5. Interpretation of findings

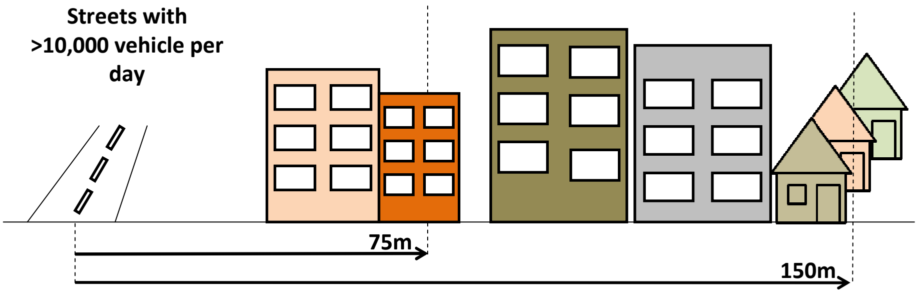
As has been shown repeatedly in economic terms mortality costs by far outweigh the costs of hospitalisation. Nevertheless both outcomes need to be considered and balanced with the costs of implementing stricter rules for air quality improvement.

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)	PM10 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 10 – 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.

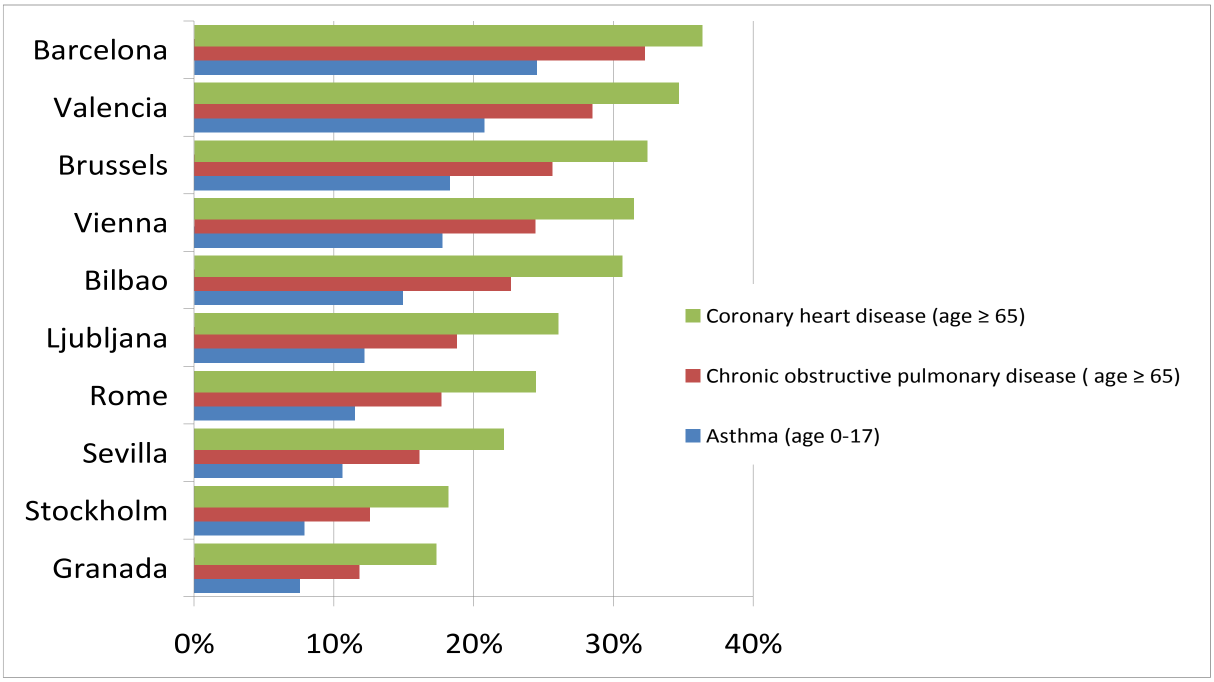


Figure 11 – Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

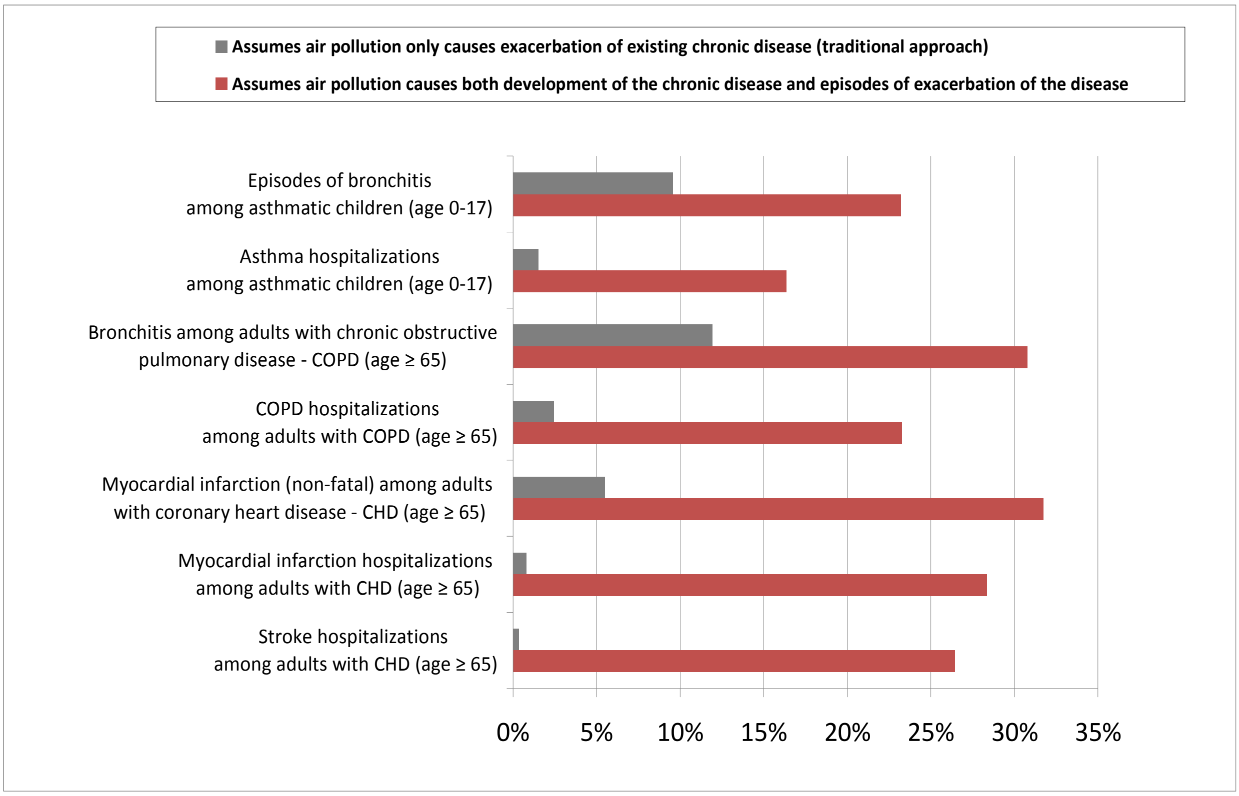


Figure 12 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

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.

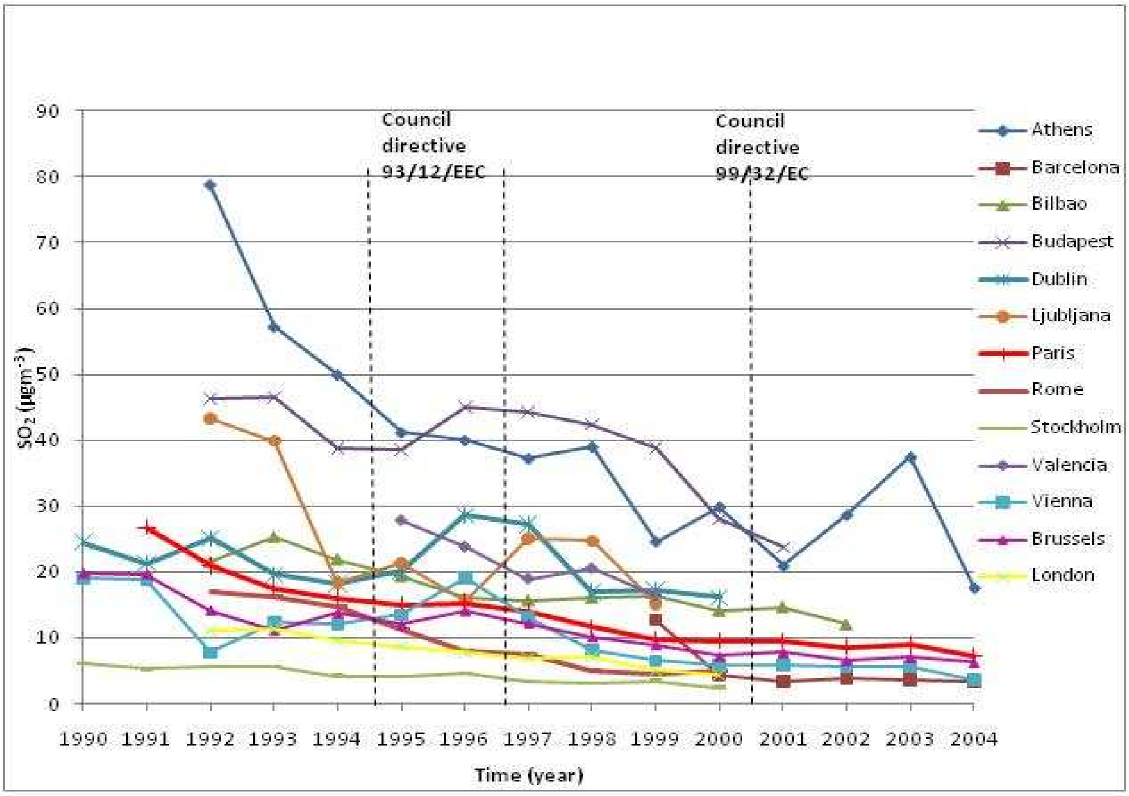


Figure 13 – Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

Also Vienna albeit starting at low levels already displayed a clear reduction in annual SO_2 concentrations. In the earlier years the daily pattern still showed a peak in the morning and in the evening indicating road traffic as a main local contributing source. With improvements in fuel composition these peaks diminished. In comparison in London the levels stay higher throughout the day in winter indicating (coal) heating as a main source. In summer SO_2 levels in Vienna are negligible.

Figures 14 and Figure 15 show preliminary work done using hourly SO_2 data from Vienna, Austria showing seasonal plots for winter (Fig.14) and summer (Fig 15) for a central urban station for the years 1990 to 2000. For example: In Figure 13 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. 14) 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. 15) shows a clear reduction in peak SO_2 levels for the afore 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. 14 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.

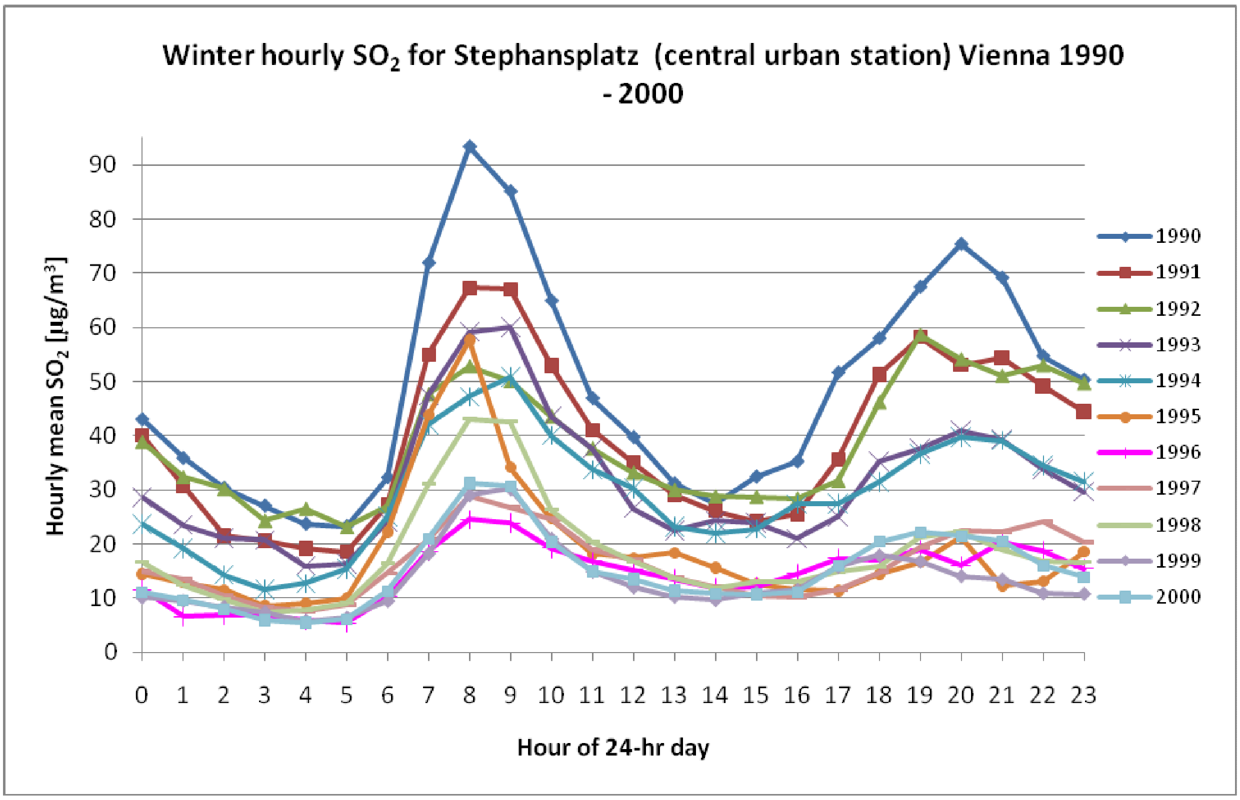


Figure 14 – Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000

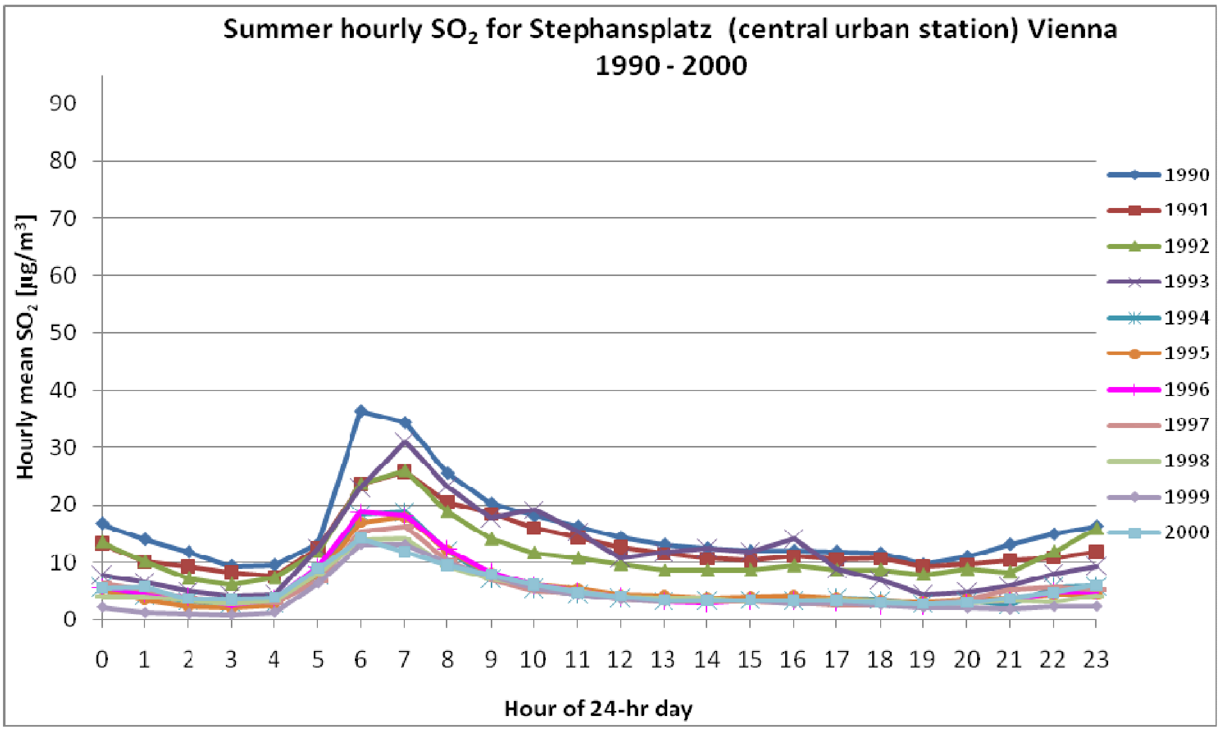


Figure 15 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

Figure 16 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.

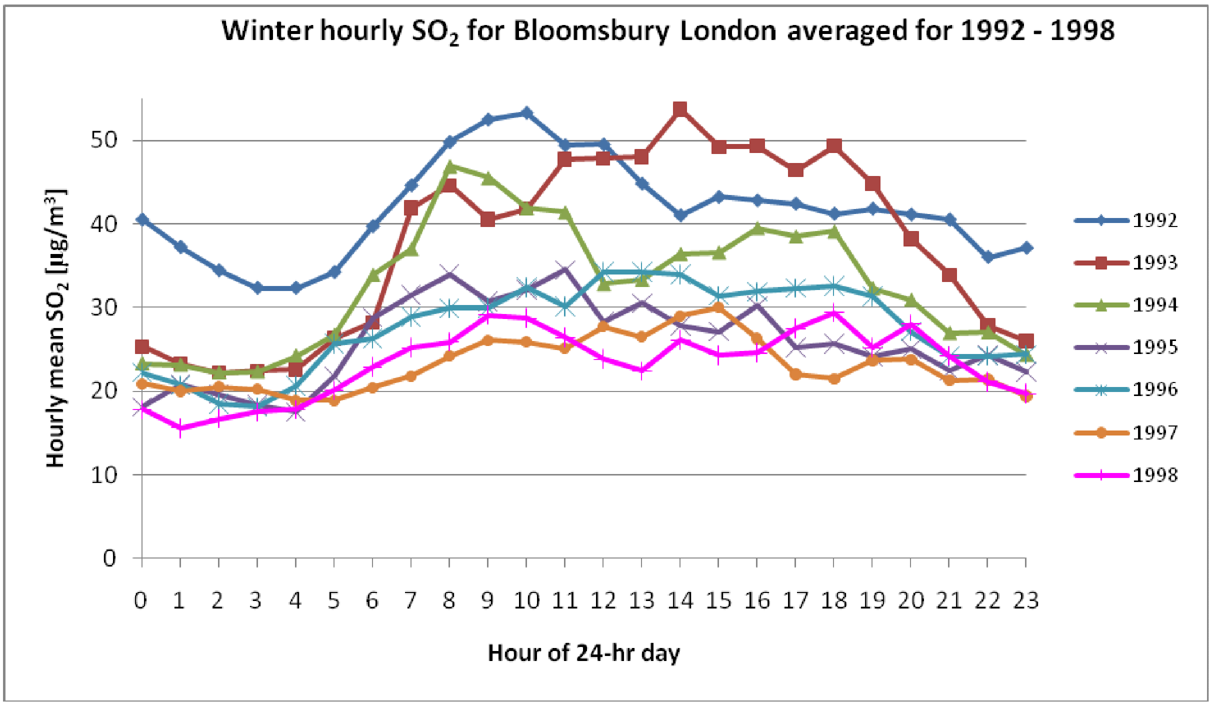


Figure 16 – Diurnal plot of winter hourly SO_2 for an urban background station in London 1992-1998

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

Vienna has participated and provided data to all scientific work packages of Aphekom. The collection of the various data was in itself a very interesting experience. Although air quality in Vienna is generally not bad it became evident that there is still room for improvements. The high percentage of people living close to busy roads was unexpected and deserves closer attention because health effects of the very fresh aerosol near the curb has a very severe impact on long term health.

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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	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, Δx = ($[PM2.5]_{mean}$ – 10 µg/m^3)
  Δx = 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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