Aphekom *

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

City report

Stockholm

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Summary

There is a downward trend of 60% in the annual mean of the NO_2 concentrations in urban background air over the last 25 years. The downward trend is slower in traffic hotspots, and the Swedish environmental quality standard for NO_2 to protect human health is still exceeded, in 2009 at the monitoring stations at street level in the city centre: Hornsgatan, Sveavägen och Norrlandsgatan, and in other places in the city as well according to model calculations. Less studied and more toxic compounds may not have developed in the same way. Pollutants such as ultrafine particles occur in high concentrations along streets and roads carrying heavy traffic. Evidence is rapidly growing that living near a lot of traffic may have serious health effects, particularly on the development of chronic diseases.

Until now, health impact calculations have not explicitly incorporated this local effect. 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. Recent studies of asthma in children as well as chronic obstructive lung disease (COPD) and coronary heart disease in elderly have shown the increase in risk of having 10 000 or more vehicles per day with 75, 100 and 150 meters, respectively.

14% of Stockholm children 0–17 years opf age have 10 000 or more vehicles per day within 75 m, associated with 64% higher risk of having asthma. This means that of the prevalent cases in this age group we estimate that 8 % are caused by high traffic pollution exposure. 20% of persons 65 years or older in Stockholm have 10 000 or more vehicles per day within 100 m, associated with 79% higher risk of having COPD, meaning that 13% of the COPD cases in Stockholm are caused by traffic pollution.

The effect of long-term exposure to particles on mortality is estimated from the annual mean urban background level. The Aphekom scenario where the $PM_{2.5}$ annual mean in the Greater Stockholm area is decreased by 5 $\mu g/m^3$, would result more than 300 less preterm deaths per year.

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 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.

Health impact assessments have been used before to estimate the health impacts especially from the regional and urban background levels of particles in Greater Stockholm. In the Apheis Study it was calculated that a reduction of the yearly urban background mean level of PM_{10} in Stockholm by 5 µg/m^3, would as a long term effect decrease the number of preterm deaths with up to 230 persons per year. The short-term effect on mortality only, would over one year accumulate to approximately 60 deaths fewer, if the PM_{10} level was 5 µg/m^3 lower.

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.

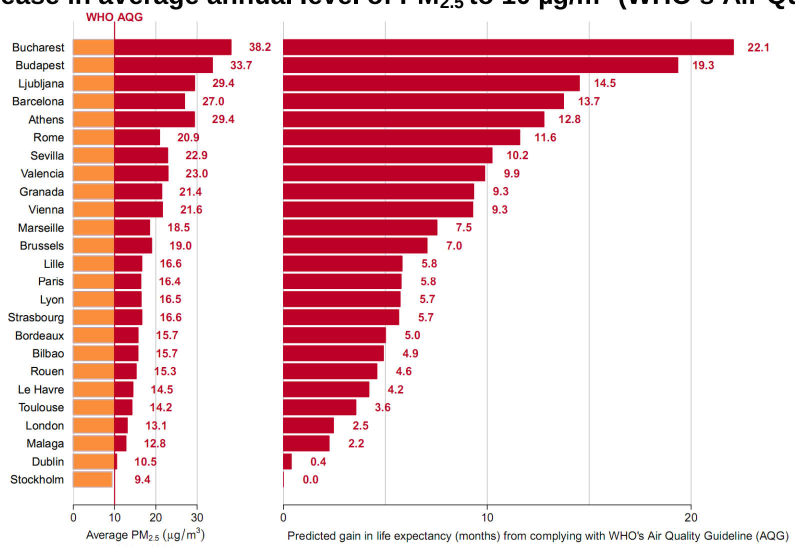
Since the regional background concentration of particles around Stockholm is low, also the urban background concentration of particles in general does not exceed the WHO air quality guidelines. However, along major streets there are violations also of the limit value for PM_{10}. A reduction of urban background concentrations of $PM_{2.5}$ to the WHO air quality guideline is thus not a relevant scenario for Stockholm.

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.

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 Stockholm

The Greater Stockholm area has been used as a study area before in the epidemiological Aphea-2 Study, as well as for the health impact calculations in Apheis. This area originally included 41 parishes, but some changes of administrative borders have occurred over the years. The population has also been increasing, there were approximately 1 021 000 inhabitants in this Greater Stockholm area in 1988 (Aphea-2) and now close to 1.3 million. The municipality Stockholm City in itself has close to 0.8 million inhabitants.

The annual mean urban background PM_{10} levels are relatively uniformly distributed over the city. This is due to the importance of long range transport, which contributes with 60% to 70% to the annual mean value. Even close to roads, local vehicle exhaust emissions contribute to less than 10% of PM_{10}.This is why one major background stations for PM_{10} have been used in epidemiological health studies as well as for health impact calculations concerning the urban background exposure. Also in this report we use such exposure information to estimate effects of the urban background exposure of particles.

A new aspect in this Aphekom Study is to also estimate the health impacts of very local traffic pollution exposure, with results coming from another type of epidemiological studies. This is why study we now also study the Stockholm population in terms of proximity to traffic.

In 1996 an environmental zone was created around the city centre. This means that trucks and busses that do not fulfil predetermined demands on age (max 8 years) and emissions, are not allowed to pass through the city centre. The result has been lowered emissions of particles and nitrogen dioxide. Later a congestion tax has further reduced the growth of traffic.

There is a downward trend of 60% in the annual mean NO_2 concentrations over the last 25 years in the urban background. The downward trend is slower in hotspots, and the Swedish environmental quality standard for NO_2 to protect human health is exceeded, in 2009 at the monitoring stations at street level in the city centre: Hornsgatan, Sveavägen och Norrlandsgatan, and in other places in the city as well, according to calculations. Less studied and more toxic compounds may not have developed in the same way.

Climatology

Stockholm has a sub-continental climate as it is situated next to the Baltic Sea. The mean temperature during winter half year, October-March, is approximately 2° C and the mean temperature during summer is 13°C. The yearly average temperature is 7,2 °C and the average precipitation 539 mm.

Population in the study area

The Greater Stockholm area had a population of 1.26 million in 2005, approximately 0.8 million were 30 years old or more and included in the calculations of long-term impacts on mortality of reductions in particle levels. The population had been growing to 1.29 million in 2007, the year for which the population living close to high traffic flows in Stockholm was calculated.

1.2. Sources of air pollution and exposure data

Sources

30-40 % of PM_{10} in Stockholm comes from local sources, wear particles from traffic being to major local source due to the use of studded tyres in winter (Table 1, Figure 1). Road traffic is the most important local source also for nitrogen oxides, NO_x. The calculated contribution from residential heating, stoves and boilers, is built on poor data.

Table 1 – Main sources of air pollution *(%)*

Pollutant	Road	Residential Heating	Industry Power plants	Other sources (Off road vehicles, sea traffic)
SO_2				
NOx	51	4	18	27
PM_{10}	68	17	11	4
Primary $PM_{2.5}$	12	47	24	17

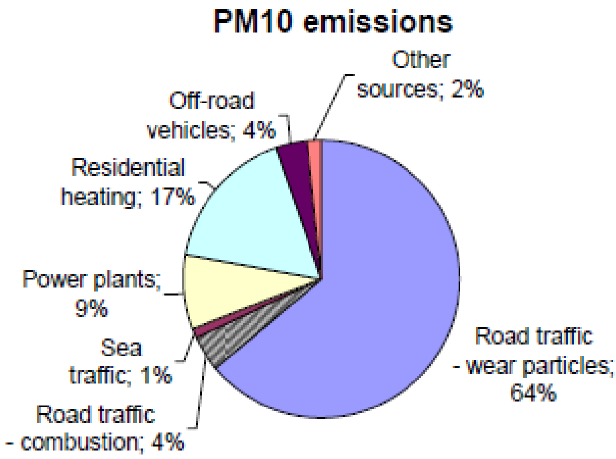


Figure 1. Local sources of PM10 in Greater Stockholm (35*35 km) (From: Tess part 1, Stockholm och Uppsala Läns Luftvårdsförbund, 2007:2).

In Stockholm urban background the levels of PM_{10} were almost unchanged 1994–2006, but since 2006 the concentrations seems to be a little bit lower. In traffic hotspots a downward trend of 20-30% (annual mean) has been monitored the last decade.

Exposure data

In this study as in Aphea-2 and in Apheis we have used the major urban background station at Södermalm to describe the annual mean concentration and daily mean values of particulates and ozone. The station was used in several of the epidemiological studies providing exposure-response functions for short-term effects on mortality and hospitalisations applied in our impact assessment. This is a roof station that is not influenced by emissions from the local streets.

PM_{10} and $PM_{2.5}$ are both measured using a TEOM instrument, with a local correction factor.

Ozone is monitored using a UV monitor.

During the study period (2004–2006) the daily mean of ozone (O_3), particulate matter (PM_{10}) and fine particles ($PM_{2.5}$) were 65±20, 16±10 and 9±6 µg/m^3, respectively (Table 2). The majority of the ozone concentrations (5th–95th percentile) stayed between 36 and 101 µg/m^3. For PM_{10} and $PM_{2.5}$ similar percentiles were 6–36 µg/m^3 and 4–22 µg/m^3. This indicates that majority of the levels are rather low, however, with high pollution level episodes. For ozone, these happen summertime, when the daily 8h max levels may increase up to 143 µg/m^3 (Figure 2). For PM_{10} the higher levels appeared usually spring time after snow had melted, but the levels have been high at autumn and winter as well (Figure 3). For fine particles ($PM_{2.5}$) the highest levels appeared at winter, but also at spring and during other periods of the year (Figure 4).

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)	65	20	36	101
PM_{10} (daily average)	16	10	6	36
$PM_{2.5}$ (daily average)	9	6	4	22

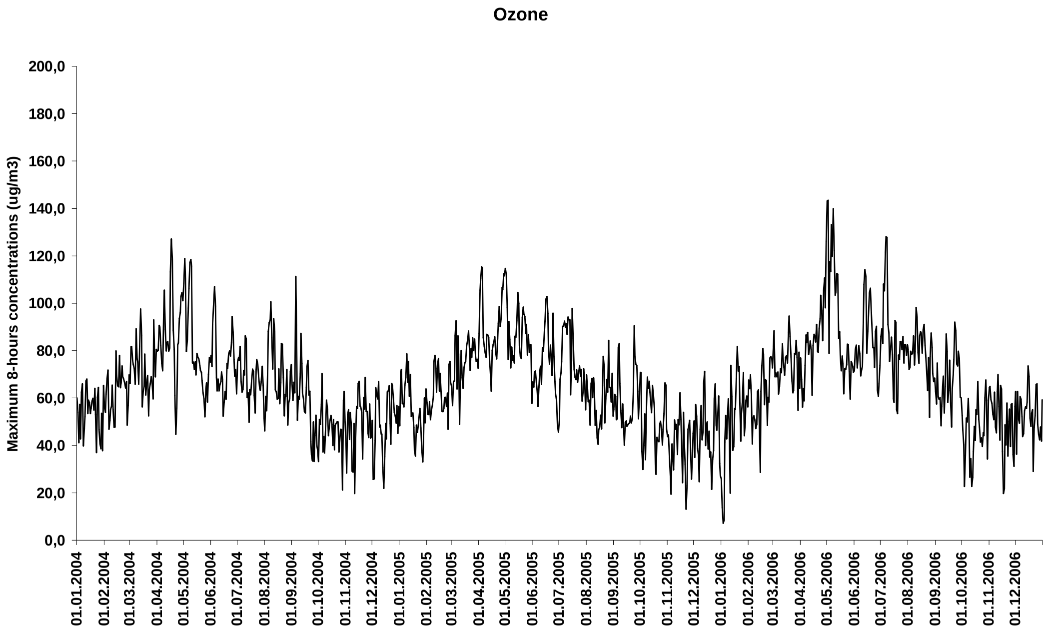


Figure 1 – Ozone concentration in the study area

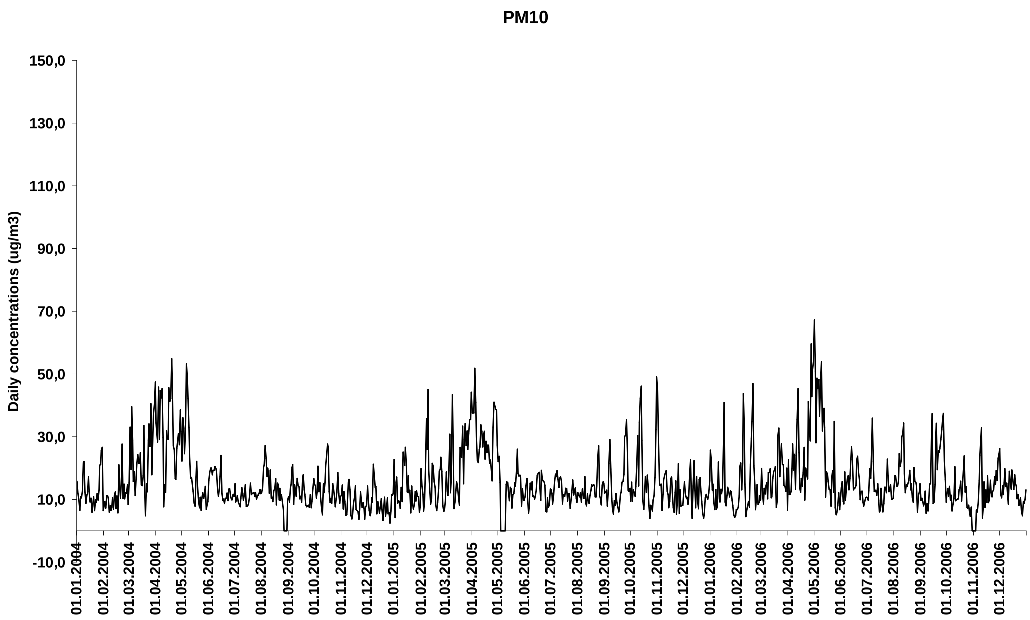


Figure 2 – PM_{10} concentration in the study area

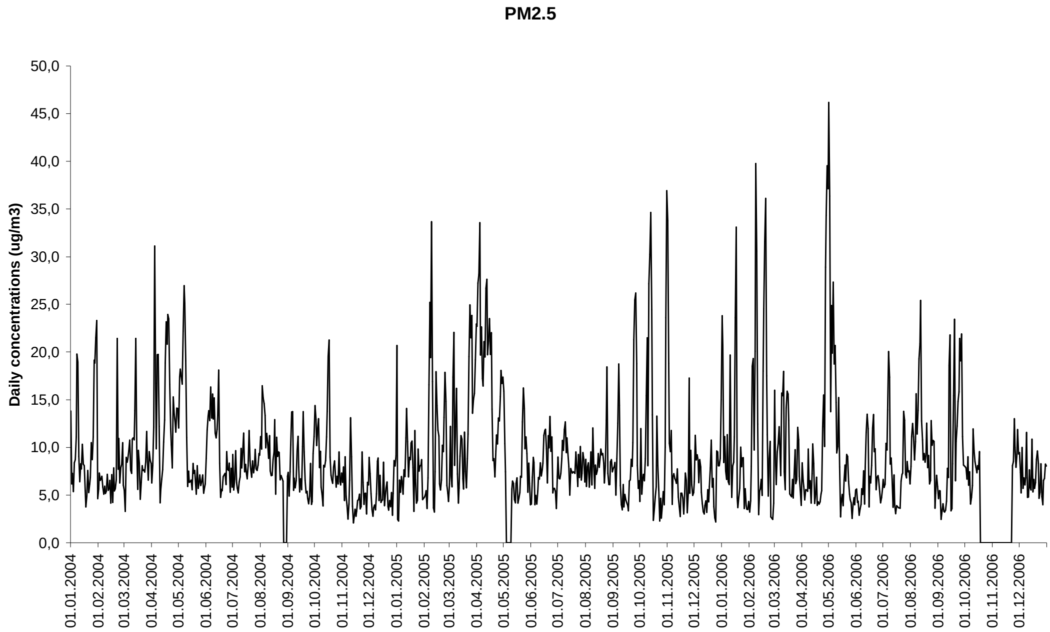


Figure 3 – $PM_{2.5}$ concentration in the study area

1.3. Health data

The health data was provided by the National Board of Health and Welfare and the data was of good quality. As it indicates, about 40% of the total mortality in the age group >30 years is induced by cardiovascular causes (Table 3). Moreover, also the rate of cardiovascular hospitalizations is higher compared to respiratory hospitalizations. Among the respiratory hospitalizations, most of the cases happen in older age group (≥ 65) (Table 3).

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	10 523	837.0
Total mortality	000-999	A00-Y98	> 30	11 048	1 380.4
Cardiovascular mortality	390-429	I00-I52	> 30	4 362	545.0
Cardiac hospitalizations	390-429	I00-I52	All	13 994	1 113.0
Respiratory hospitalizations	460-519	J00-J99	All	8 778	698.1
Respiratory hospitalizations	460-519	J00-J99	15-64 yrs	2 281	265.6
Respiratory hospitalizations	460-519	J00-J99	≥ 65 yrs	4 758	2 613.1

- **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 considered a scenario, where the annual mean of PM_{10} is decreased by 5 µg/m^3. In Stockholm a scenario where the PM_{10} annual mean is decreased to 20 µg/m^3, was not included, as the WHO annual air quality guideline (WHO-AQG) for PM_{10} in urban background area is already fulfilled.

Decreasing the PM_{10} levels by 5 µg/m^3 would have a significant effect on public health already from the short-term effect on daily number of deaths. The annual number of death postponed would decrease by 31.4 cases annually that makes 2.5 cases per 100 000 persons (Table 4). This reduction would also affect the number of hospitalizations. The number of respiratory hospitalization would decrease by 49.6 annually and the size of the effect would be the same magnitude with cardiac hospitalizations (41.8 cases per year) (Table 5). The decrease in hospitalization rate would be somewhat higher for respiratory hospitalizations compared to cardiac hospitalizations (Figure 5).

This indicates that even the WHO-AQG is fulfilled in urban background levels, improving the air quality to even higher level, would have essential public health beneficiary.

Table 4 – Potential benefits of reducing annual PM_{10} 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	31.4	2.5

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

Table 5 – Potential benefits of reducing annual PM_{10} levels on hospitalisations

	Respiratory hospitalisations		Cardiac hospitalisations	
Scenarios	**Total annual number 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	49.6	3.9	41.8	3.3

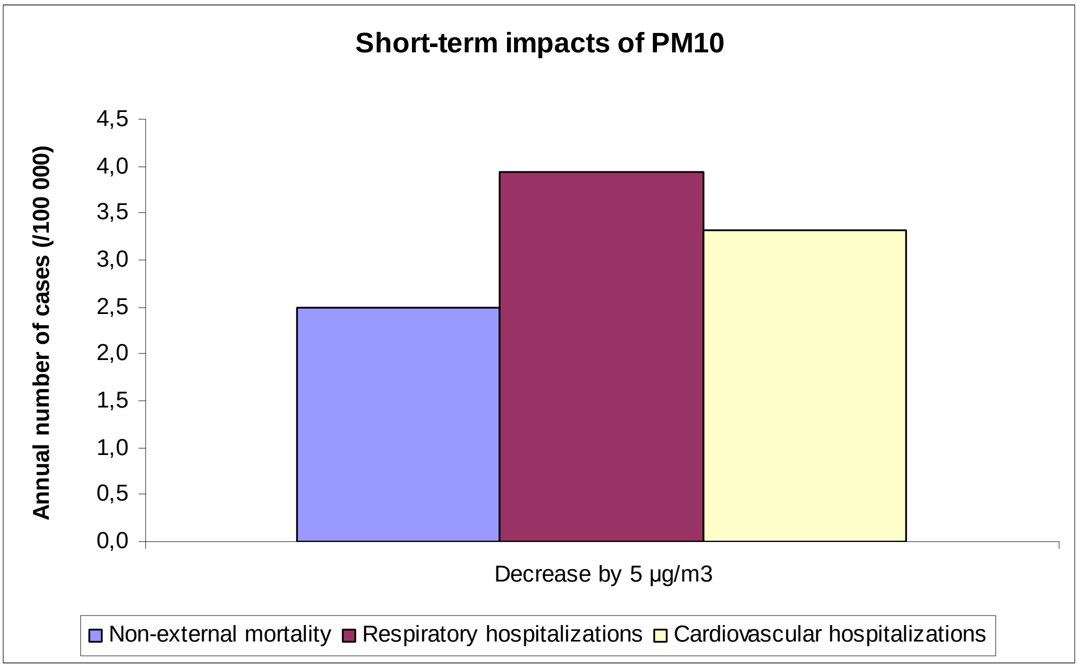


Figure 4 ─ Potential benefits of reducing annual PM10 levels on mortality and on hospitalisations

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.

As the first considered scenario (all daily values above 160 µg/m^3 are reduced to WHO-IT), is fulfilled in urban background area in Greater Stockholm, it was not included in further analysis. The calculations were made with scenarios, where all daily values above 100 µg/m^3 were reduced to WHO-AQG (100 µg/m^3), and a scenario when the daily 8h max mean was decreased by 5 µg/m^3.

As the ozone levels in urban background in 2004–2006 were very close to WHO-AQG, the effects according to the scenario 'reducing the 8h max daily values to 100 µg/m^3 are small. The annual number on deaths would increase by 2.2, that makes 0.2 cases per 100 000 people. The number of respiratory hospitalizations among younger persons (15–64 years) would decrease annually by 0.2 and in older age-group (>64) by 1.6. In hospitalizations rates, this would make 0.02 and 0.9 cases per year.

The effects of the scenario, when the daily 8h max mean is decreased by 5 µg/m^3, are much bigger (Figure 6). Decreasing the ozone levels would results in 16.3 postponed death annually that makes 1.3 cases per 100 000 people (Table 6). Also the gain in reduction of hospitalizations would be much larger. The effects would be again bigger in older age group (>64), where 11.8 respiratory hospitalizations could be avoided, compared to 1.1 cases among younger people (15–64) (Table 7).

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 >100 µg/m^3 = 100 µg/m^3	2.2	0.2
Decrease by 5 µg/m^3	16.3	1.3

*** 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 cases postponed**	**Annual number of cases postponed per 100 000**	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**
8h max daily values >100 μg/m^3 = 100 μg/m^3	0.2	0.02	1.6	0.9
Decrease by 5 μg/m^3	1.1	0.1	11.8	6.5

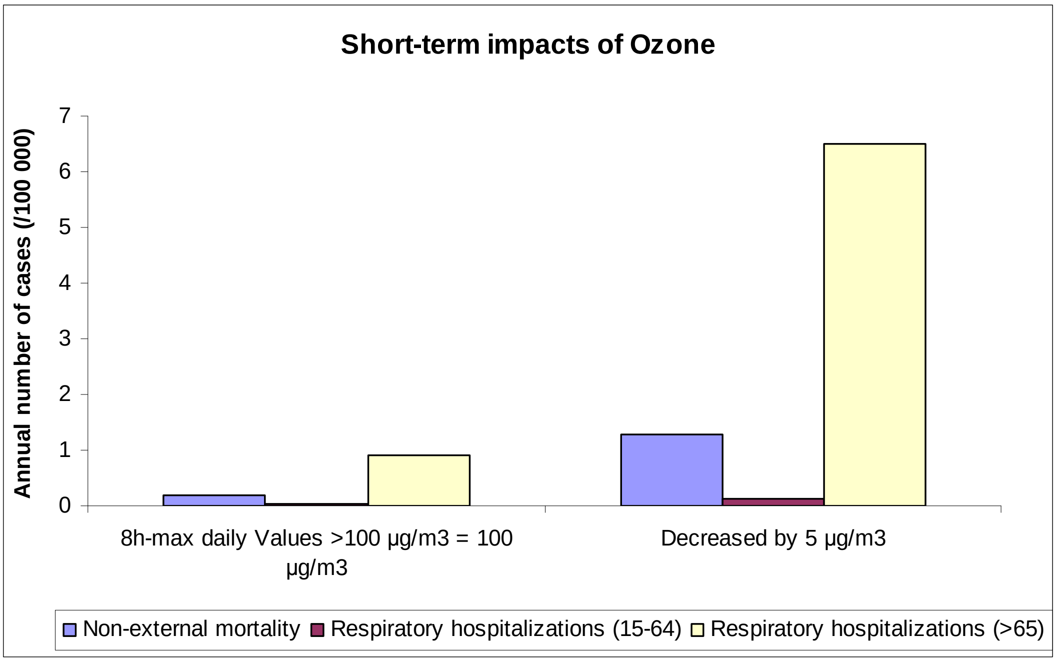


Figure 5 ─ Potential benefits of reducing daily ozone levels on mortality and on hospitalisations

1.4.3. Long-term impacts of $PM_{2.5}$

For Stockholm we only considered a scenario, where the $PM_{2.5}$ annual mean is decreased by 5 μg/m^3, as the WHO AQG to decrease the $PM_{2.5}$ annual mean to 10 μg/m^3 is already fulfilled in urban background air in Stockholm.

However, decreasing the levels of fine particles by 5 μg/m^3 would have substantial effect on public health. The number of postponed death would be 317 annually (Table 8) and the majority of the reduction would be due to decrease of cardiovascular mortality (Figure 7). The decrease in mortality rates would be 39.6 and 30.0 death per 100 000 people because of total and cardiovascular mortality, respectively (Table 8, 9). This would increase the life expectancy on average by 0.31 years (Figure 8). However, for Stockholm this large reduction would be difficult, due to the already low levels.

Table 8 – Potential benefits of reducing annual $PM_{2.5}$ levels on total 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	317.2	39.6	0.31

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

Scenarios	Total annual number of deaths postponed	Annual number of deaths postponed per 100 000
Decrease by 5 µg/m^3	240.3	30.0

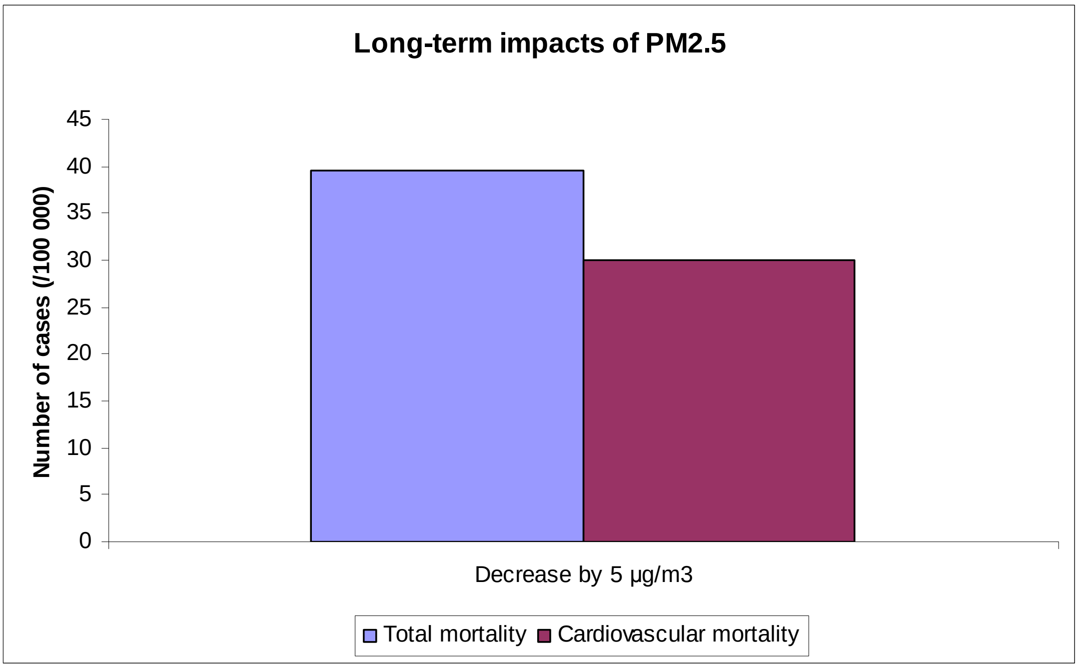


Figure 6 — Potential benefits of reducing annual PM2.5 levels on mortality

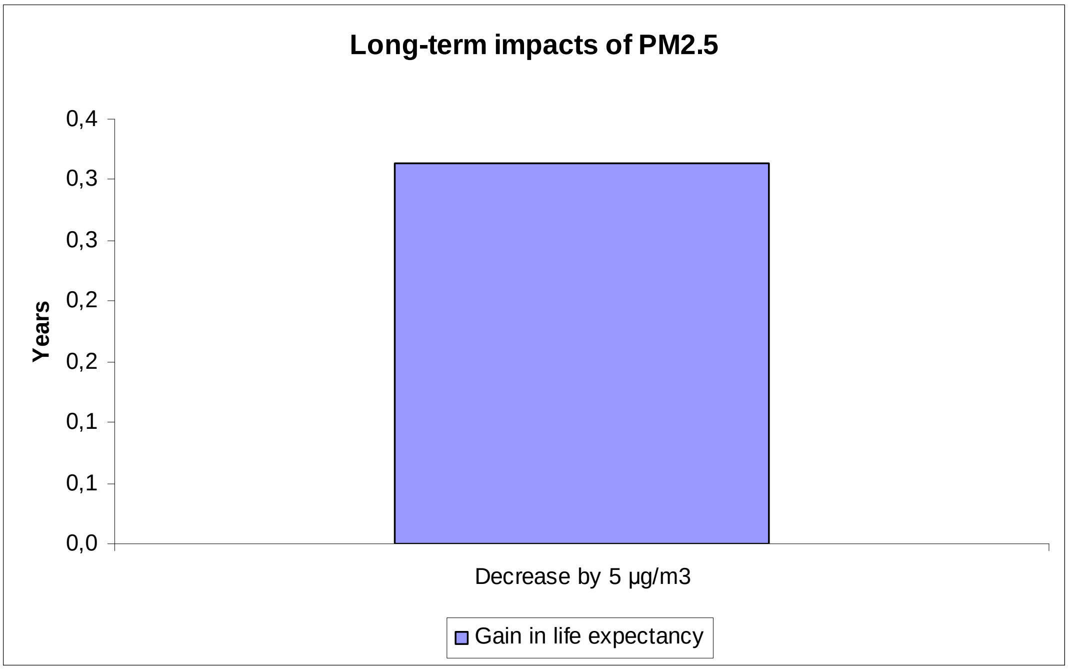


Figure 7 — Potential benefits of reducing annual PM2.5 levels on life expectancy

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 reduction of hospitalisations.

Mortality

The long-term effects as preterm mortality have a substantial effect on public health that will results in large amount of external costs. However, if the number of postpones death could be reduced, the money would be saved with-in the society.

If the described different scenarios would be put in monetary value, the largest effect would have the scenario, where the annual level on $PM_{2.5}$ is reduced by 5 µg/m^3. This would mean saving 525 million Euros annually in Greater Stockholm area, that is € 1,655,000 on average per preterm mortality case. The benefits (in terms of life expectancy) that 30 year-old people would gain over their lifetime if exposed to the described reduced fine particles concentration instead of the current existing air pollution level in the Greater Stockholm area, is expected around 600 million Euros.

Also the short-term mortality has substantial external costs, however, somewhat lower. Decreasing the PM_{10} annual daily average levels by 5 µg/m^3 would help to save three million Euros and decreasing the O_3 daily 8h max mean by 5 µg/m^3 would result in saved one and a half million Euros. As the scenario of keeping the O_3 8h max daily values below 100 µg/m^3 had minor health effects, also the monetary cost are low. The average value of short-term mortality case has been expected around €86,600.

Hospitalisations

The other costs related to short-term effects are due to direct and indirect expenses of hospitalisations. Decreasing the PM_{10} annual daily average levels by 5 µg/m^3 would save 0.16 million Euros due to respiratory (€ 3,177 per case) and 0.15 million due to cardio-vascular (€ 3,666 per case) hospitalizations. The effects of reducing O_3 daily 8h max mean by 5 µg/m^3 would result in saved 0.04 million Euros, where majority of the effects appears in older age group (>64). Again the scenario of keeping the O_3 8h max daily values below 100 µg/m^3 had minor effect, as currently the O_3 levels are very close to 100 µg/m^3.

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

The current analysis has been indicating that improving the air quality to even higher level would have extensive effect on public health. Among the scenarios, decreasing the long-term $PM_{2.5}$ exposure would have the largest effect, resulting in more than 300 avoided preterm deaths in a year. The monetary value of that is huge – more that 500 million Euros. The effects of the other scenarios had much smaller, however, considerable. In the large difference between the scenarios was also driven by selection of cases and methodological aspects, especially between the cost of long-tern and short-term effects. The data in Stockholm was good quality and available.

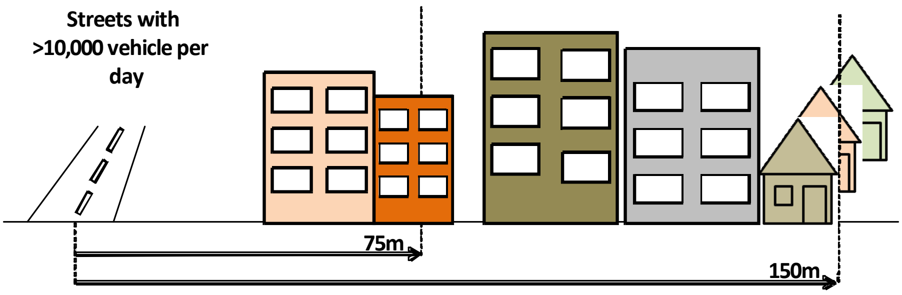
In interpretation and policy making, both long-tern and short-term effects should be reduced. As the reduction scenarios had large difference in size, the current analysis has shown reduction of $PM_{2.5}$ more important; however, reducing PM_{10} and O_3 is vital as well.

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 9 ─ 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.

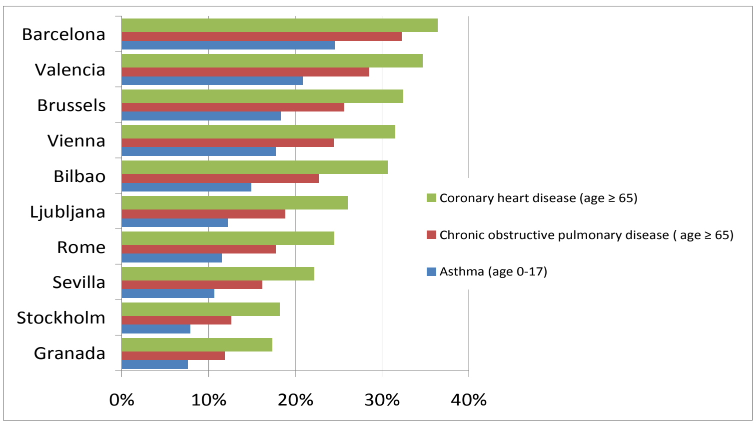


Figure 10 ─ Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

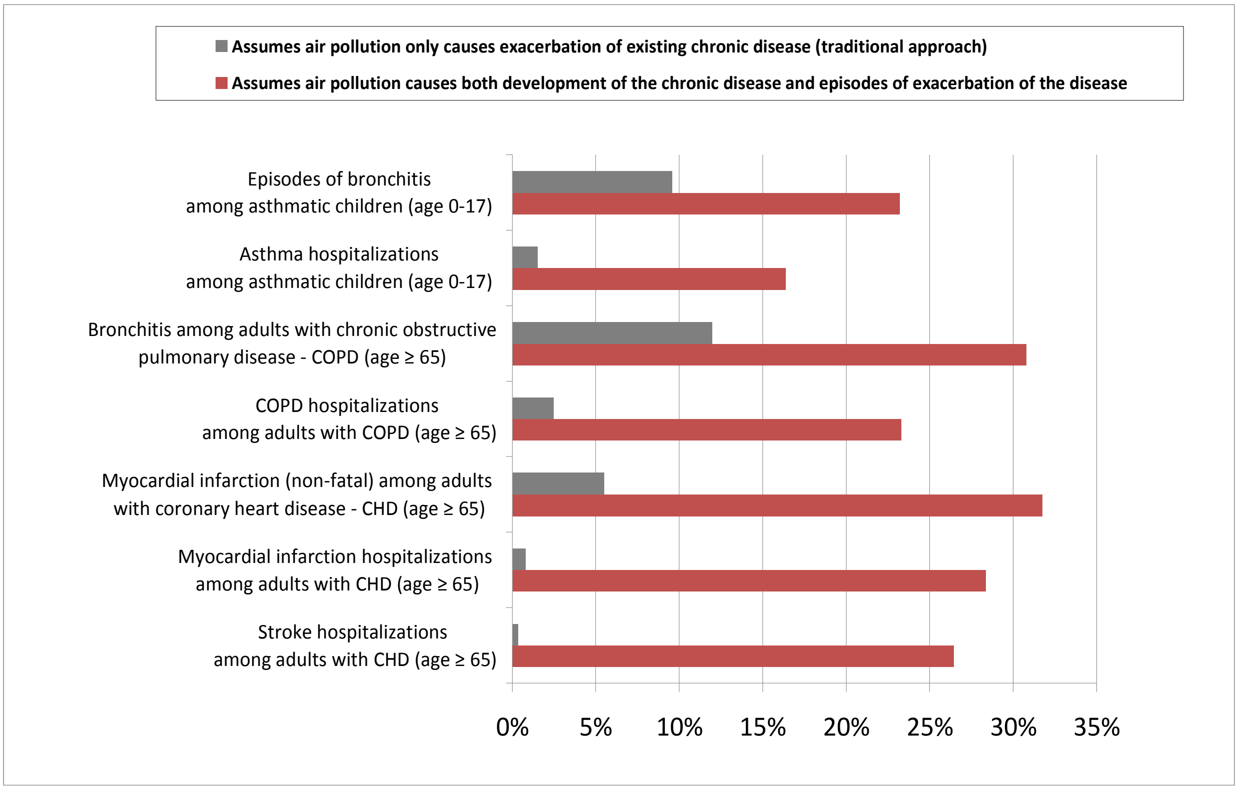


Figure 11 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

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. However, in Sweden and Stockholm most of the reduction in sulphur levels was in place already before 1990 (Figure 12).

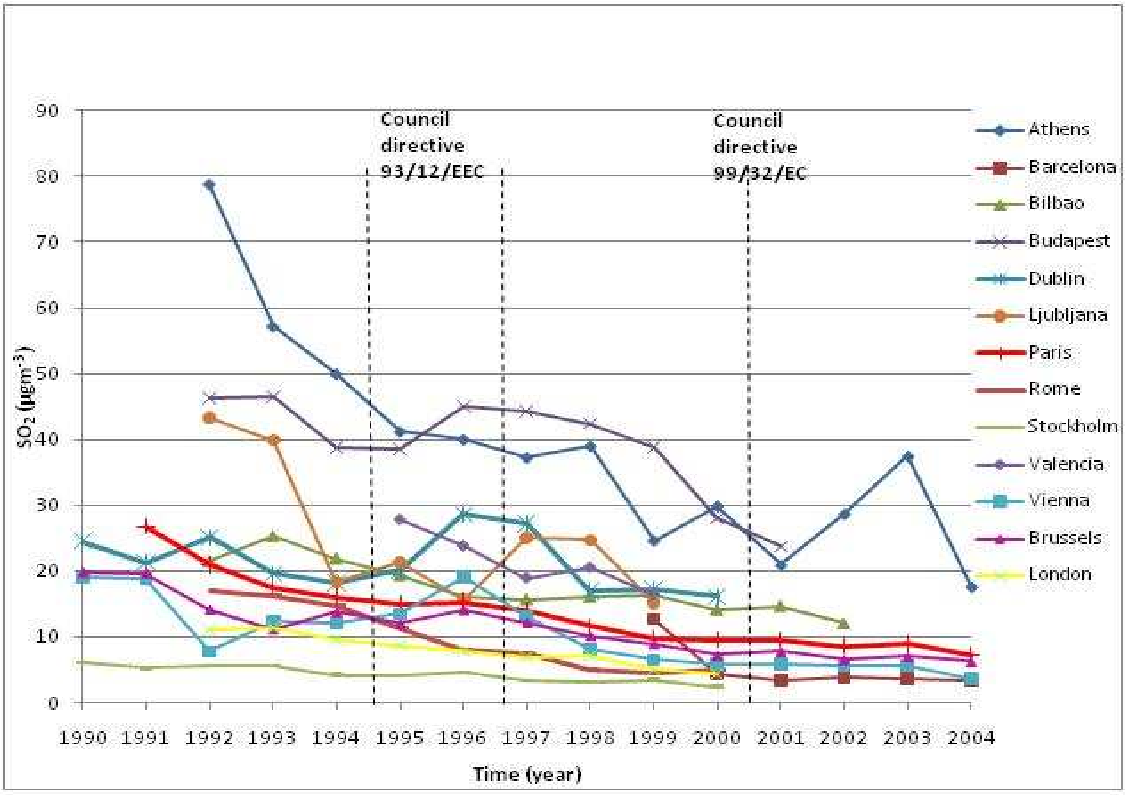


Figure 12 – Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

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.

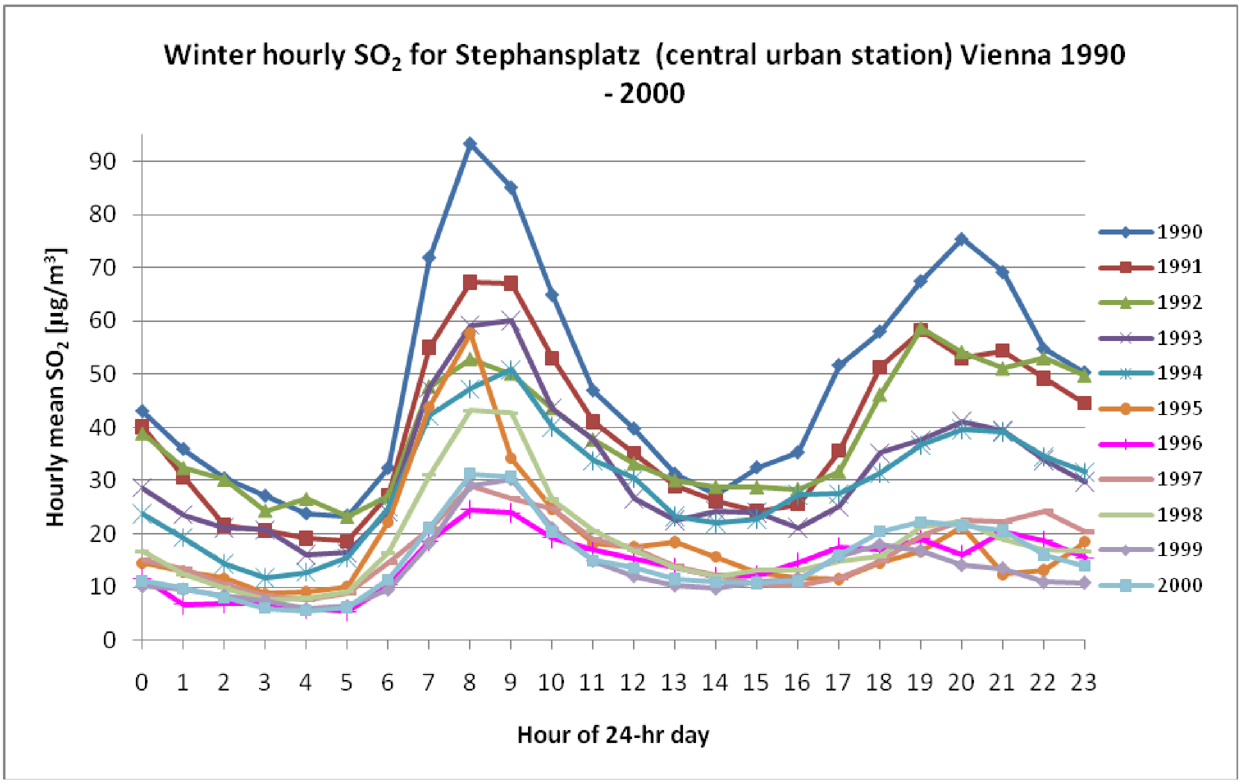


Figure 13 – Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000

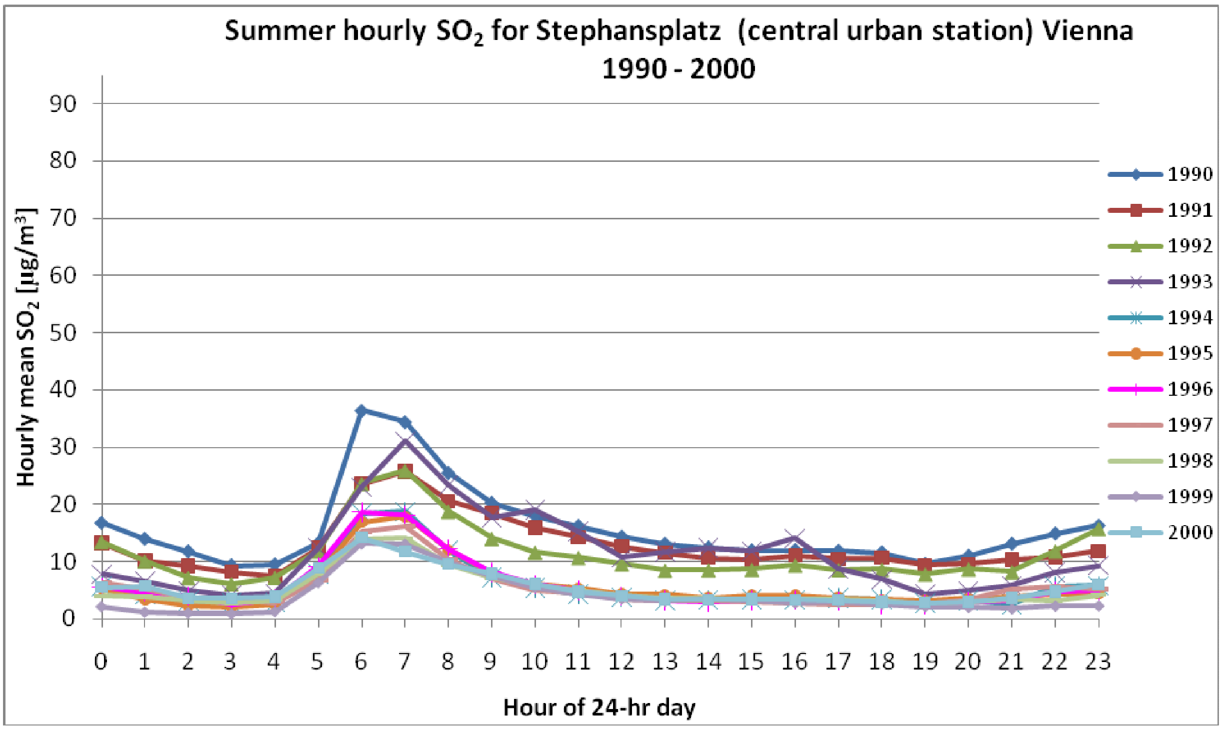


Figure 14 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

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.

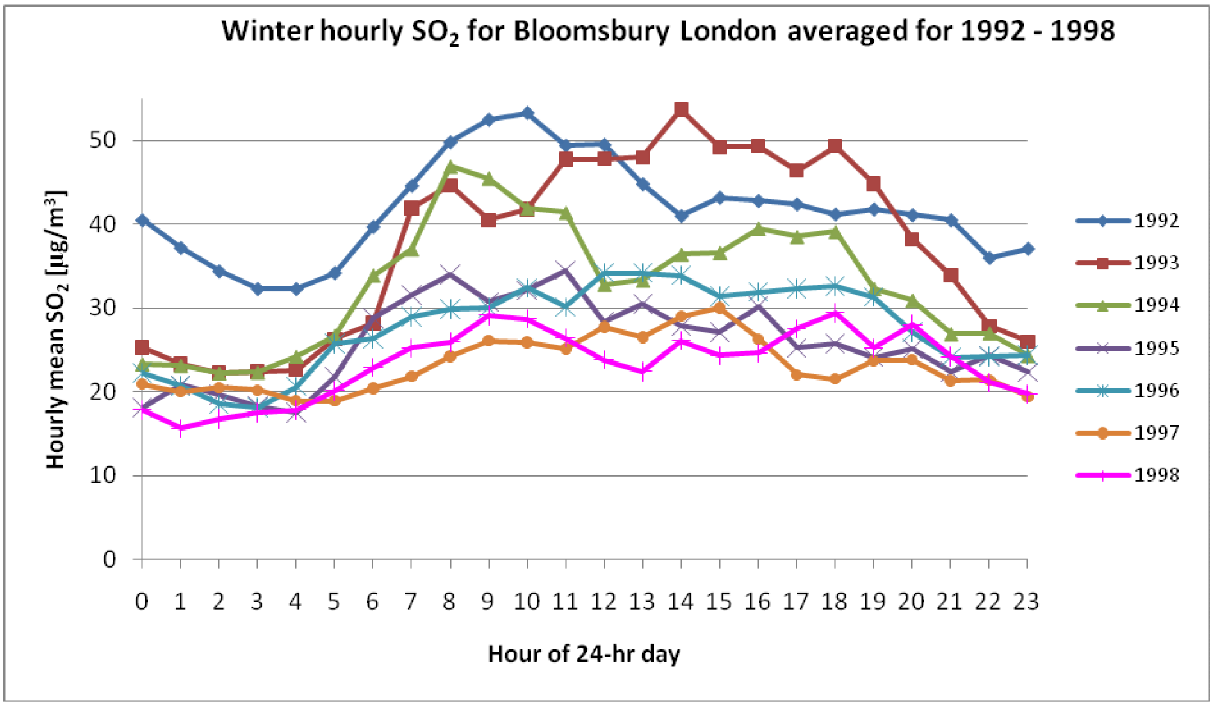


Figure 15 – Diurnal plot of winter hourly SO_2 for an urban background station in London 1992-1998

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 in the Aphekom Project.

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, in the cities where the calculation is done a VOLY of €86,600 has been applied to each premature death to compute the benefits for short-term mortality of the EU legislation to reduce the sulphur content of fuels at the city level. The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation. For Stockholm the reduction in sulphur levels were in place before the study period, so it would be misleading to estimate the benefits from 1990.

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

The Aphekom project has shown that despite reductions in the concentration of some pollutants such as sulphur dioxide and nitrogen dioxide over the last decades, especially air pollutants from traffic are causing large health impacts in particular among those living close to busy streets. For example, we estimate approximately 8 % of asthma in children living in the City of Stockholm to be attributed to local traffic exposure, and an even larger fraction of COPD cases among elderly in the city.

Stockholm is lucky to have low levels of fine particles ($PM_{2.5}$) in the incoming air masses, which means that the urban background concentrations just meet the guidelines by WHO. Close to large streets however, the PM_{10} limits are exceeded especially due to many days with high levels of road dust during winter and spring.

Since traffic pollution pose mainly a local problem in Stockholm, there are good possibilities to work for a reduction in the urban and street contribution to peoples exposure. The congestion tax has a good effect on traffic reduction in the city, but must be followed by further stimulation of alternative mode of transportation. Restrictions regarding the use of studded tyres are also expected to improve air quality in the future.

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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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