Aphekom

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

Local city report

Budapest

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Summary

The PM10 pollution increased in the years of 2004-2006 in Budapest, compared to the values of the years 1999-2000. The per cent of days when PM10 concentration exceeded short-term vs. long-term limit values was 36% resp. 54%. The daily ozone concentration was far below the limit value (120 $\mu g/m^3$ max of 8h moving average), and the160 $\mu g/m^3$, the information threshold value was never reached

The Health Impact Assessment showed a relatively small benefit due to the short term reduction the daily average PM10 concentration reduction by 5 $\mu g/m^3$: 65 avoidable death cases, while the reduction to 20 $\mu g/m^3$ could prevent 365 death cases due to non-external total mortality in a year.

The analysis estimated that the reduction of the long-term PM2.5 pollution levels to 10 $\mu g/m^3$ would reduce mortality in Budapest by 2952 deaths in one year, which means a gain of 1.6 life years for the total 30 years old population of Budapest.
The potential economical value of the reduction of PM2.5 producing gain in life expectancy was assessed in two different scenarios. The results of the two scenarios reflect a 5 times difference of the annual economic benefits (1 vs. 4.9 billion €) for the sake of a decrease to 10 $\mu g/m^3$ for the entire population of Budapest older than 30 years.

The major source of air pollution in Budapest is traffic, especially heavy trucks and also private cars. Public transportation is very well developed, but only approximately 80% of the buses are environmental friendly (catalysers and no diesel engines). There was no significant improvement in the electronically driven public vehicles, and no new metro lines were built joining the outskirts to the city centre. In the last years the emission from heating with wood and cool also contributed to the increase of the level of PM concentration.

The results of the HIA proved evidence for the health benefits of the amendment of outdoor air quality. These results should help in planning effective environmental policy on city level in order to meet the requirements of EU policy concerning air quality and reduce health risks for the population.

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.

The previous Apheis analysis based on the pollution data of 2000, estimated that reduction of the long-term PM pollution to the levels of PM2.5 of 15 $\mu g/m^3$ would reduce mortality in Budapest by 1702.7 deaths in one year, which would save 421 years of expected life for starting year of simulation. If the daily means of PM10 would be kept under 20 $\mu g/m^3$, 146,2 deaths and 292,4 cardiac hospital admissions could have been avoided in the year 2000.

The ENHIS1 study showed that the reduction of PM10 concentration had a benefit in reduction of postneonatal mortality, however this effect was very small, because of the small number of postneonatal death cases. The impact of O3 on the health state of the general population could be improved by reducing the O3 8 hour maximum concentration. A reduction by 10$\mu g/m^3$ would save the lives of 253 persons dying from all causes, 194 – dying from cardiovascular causes and 27 – dying from respiratory causes. The reduction of the concentration to 120$\mu g/m^3$ would save the lives of only 3 persons.

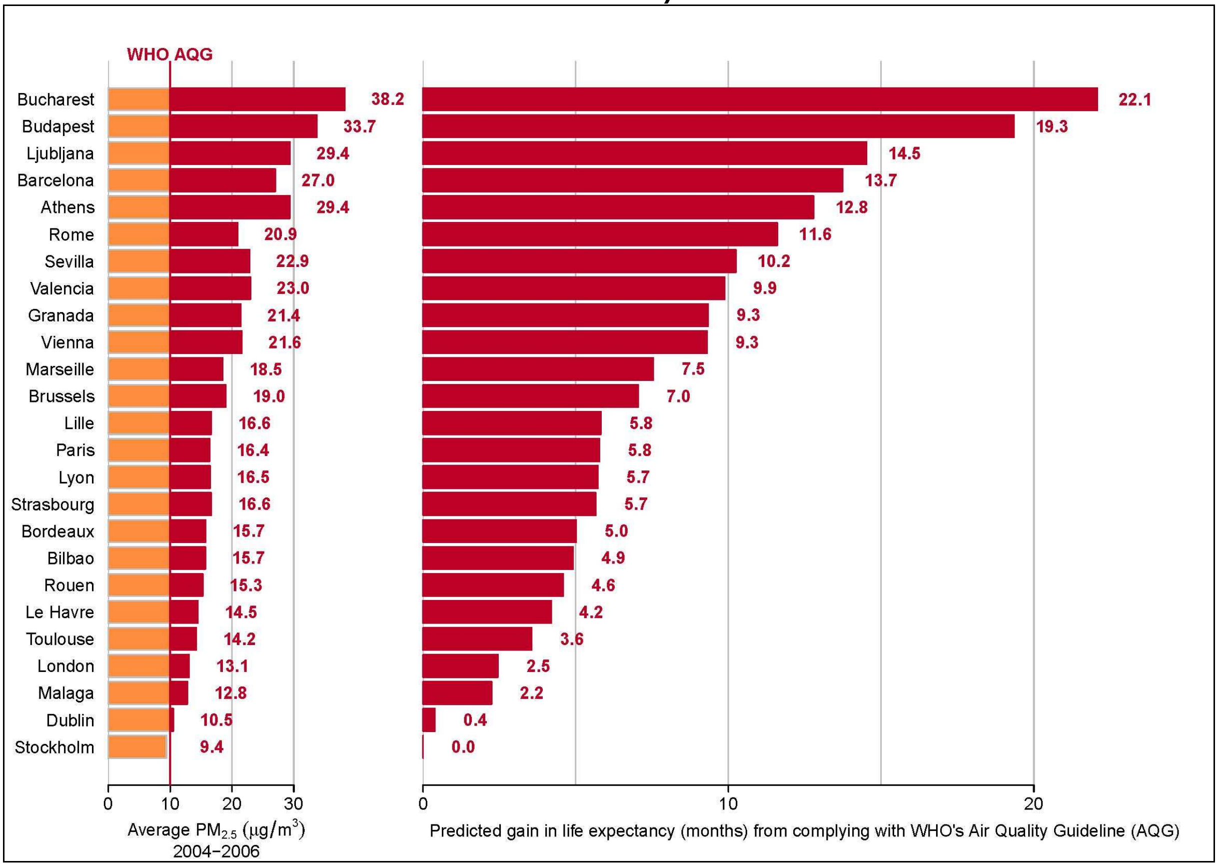
Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana, 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.

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



1.1. Description of the study area for Budapest

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.

Population in the study area

Budapest has 23 districts (I.-XXIII.), its area is 525 km^2 the number of population varies between 21765 and 129847. In 5 districts the number of inhabitants is over 100 000, the mean population density is 3218 persons/km^2 .The total population in 2005 was 1 690 109 persons, out of it 18% were older than 65 years.

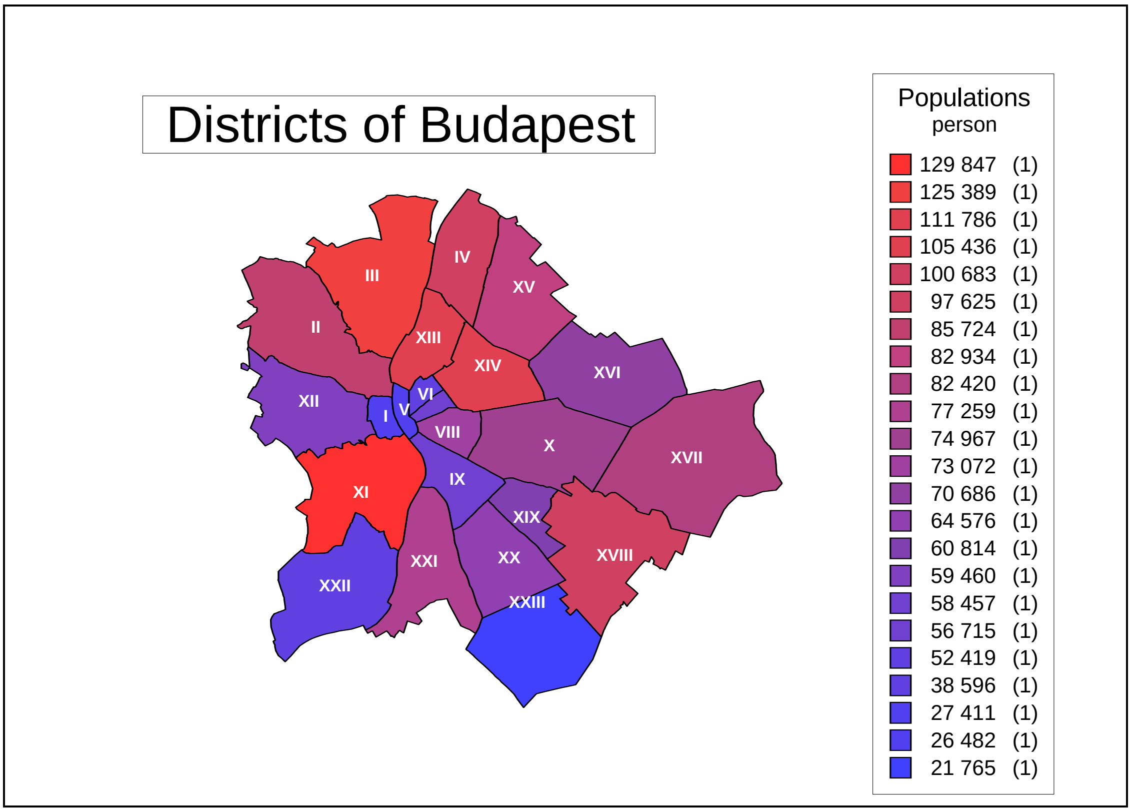


Figure 1 – Map of the study area

Climatology

Hungary has a continental climate, with a great variability among the four seasons. The coldest month is January and the warmest one is July. The weather in Budapest is transitional influenced by the wet and mild weather of the Transdanubian Region and the changeable weather of the Great Plain.
The variation of the daily temperature is considerable. The yearly mean temperature of the country is 9.7 ℃, this value is 11.2 ℃.in Budapest. The mon thly mean temperature is 24.8 ℃ in the hottest month, in July, respectively 0.2 ℃ in the coldest one, in January. The daily maximum can reach 33-38 ℃ on a hot day, while in winter the daily mi nimum temperature can be -20.0 ℃.
The spring starts at the beginning of April in Budapest with a lot of rain, the summer is dry and hot. Autumn is cool, foggy and rainy. The winter is relatively short, not too cold and dry in general. The yearly amount of precipitation is 617 mm. The sum of sunny days is 1853 in Budapest. The prevailing wind direction is North-West during the year, there are calm days as well, therefore foggy and smoggy days are quite frequent during winter.The yearly mean windspeed is 2.4 m/sec.

1.2. Sources of air pollution and exposure data

Sources

The major source of air pollution in Budapest is traffic, especially heavy trucks and also private cars. Public transportation is very well developed, but only approximately 80% of the buses are environmental friendly (catalysers and no diesel engines). There was no significant improvement in the electronically driven public vehicles, and no new metro lines were built joining the outskirts to the city centre during the study period.

Table 1 – Main sources of air pollution in Budapest, 2003 (expressed in tons/year)

Pollutant	Road	Heating	Industry	Other sources
SO_2	275	625	1647	60
NOx	98227	2608	3344	1529
Primary PM_{10}	1854	379	320	5

Exposure data

The classical air pollutants are monitored by the National Air Quality Network run by the Environmental Inspectorate of the Ministry of Environment. The network of online monitoring system was established in 1992 and first run by the National Public Health Service. In the year of 2003 the system was assigned to the Ministry of Environment. The Air Quality Monitoring Network of Budapest has 11 stations, 4 out of them measure traffic related type pollution, 3 measure suburban type of pollution.

PM10 is monitored by 11 on-line automatic stations (the method of measurement is TEOM). NO2, CO are measured by 11 automatic stations, SO2 and O3 are measured by 9 automatic stations. The methods of measurement are UV fluorescence (SO2), chemiluminescence (NO2), infrared rays spectrometry (CO) and O3 UV absorption. When calculating the health impact of particulate matters a correlation factor of 0.70 was used for PM2.5.

Each station measures PM10, the average of the concentration of three background stations was used for PM10 health impact assessment, and the average concentration of six stations was used for ozone in this analysis.

Air pollution network and the monitoring stations used in the study are shown in the map below.

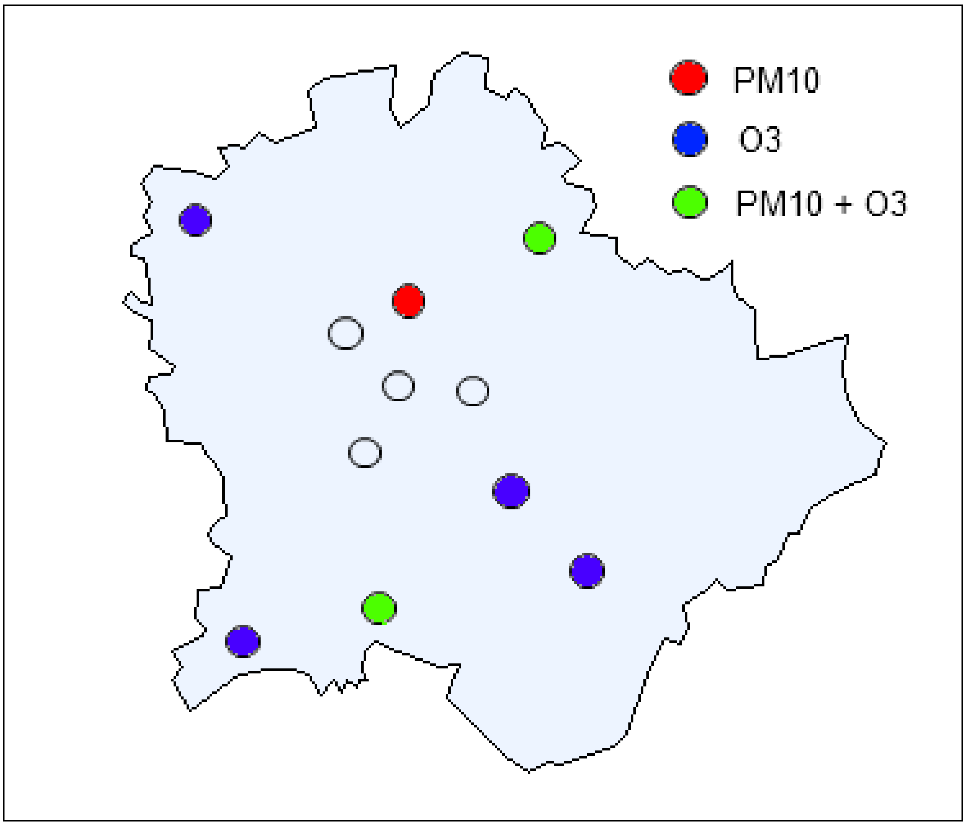


Figure 2 – Map of the monitoring stations

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	29	16	111
PM10 (daily average)	48	27	18	101

The daily mean concentration of both pollutants is under the limit value, although the mean PM10 concentration is only by 4% less than the limit value. It must be mentioned that the 95th percentile is above 100 μg/m^3 , which is the threshold value of smog alert when the air pollution situation lasts for more than two days according to the Hungarian legislation (306/2010 (XII.23.) Governmental Order).

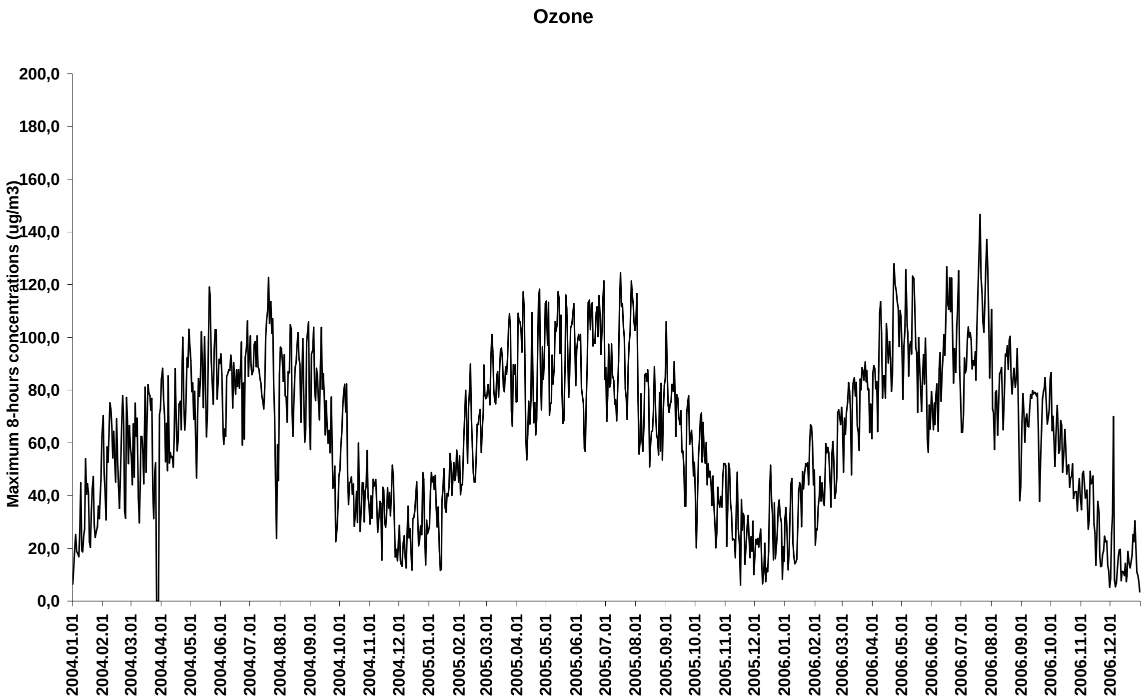


Figure 3 – Ozone concentration in the study area

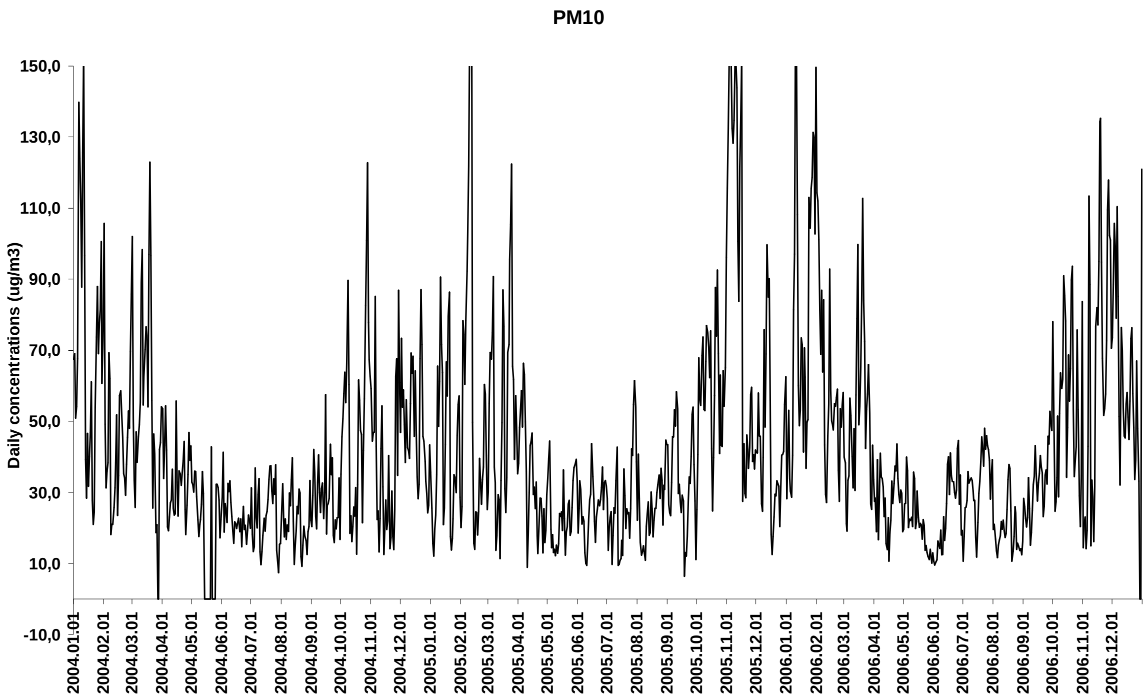


Figure 4 – PM10 concentration in the study area

1.3. Health data

Mortality data were gained from the Central Statistical Office concerning the years 2004-2006.
The mortality data are routinely collected, a quality control is carried out by the Central Statistical Office. The ICD-10 codes are applied. Mortality data are manually recorded.

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	22 093	1307
Non-external mortality	< 800	A00-R99	> 30	21876	1294
Cardiovascular mortality	390-429	I00-I52	> 30	11504	681

*** 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).

As the daily mean PM10 concentration was 48 µg/m^3, the reduction to 20 µg/m^3 could prevent 365 death cases due to non-external total mortality. Even a reduction by 5 µg/m^3 of all the 24-hour values of PM10 would prevent 65 death cases due to the same causes in Budapest.

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	65	4
Decrease to 20 µg/m^3	365	22

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

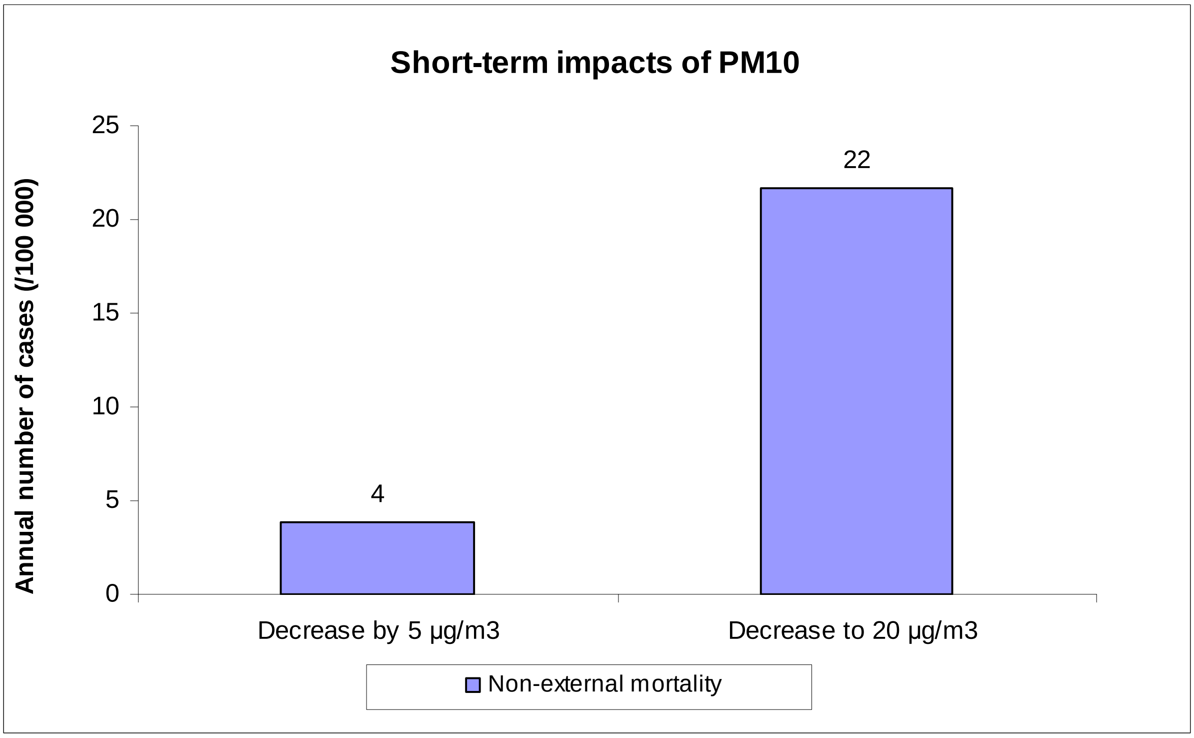


Figure 5 – Potential benefits of reducing annual PM10 levels on mortality

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.

The 8h maximum daily ozone concentration was less than 160 µg/m^3 so the first scenario is not relevant for Budapest. In the second case where all daily values above 100 µg/m^3 were reduced to 100 µg/m^3 , the benefit would be 9 cases of non-external deaths. The reduction of the daily mean by by 5 µg/m^3 could avoid the death of 34 persons.

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	9	1
Decrease by 5 µg/m^3	34	2

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

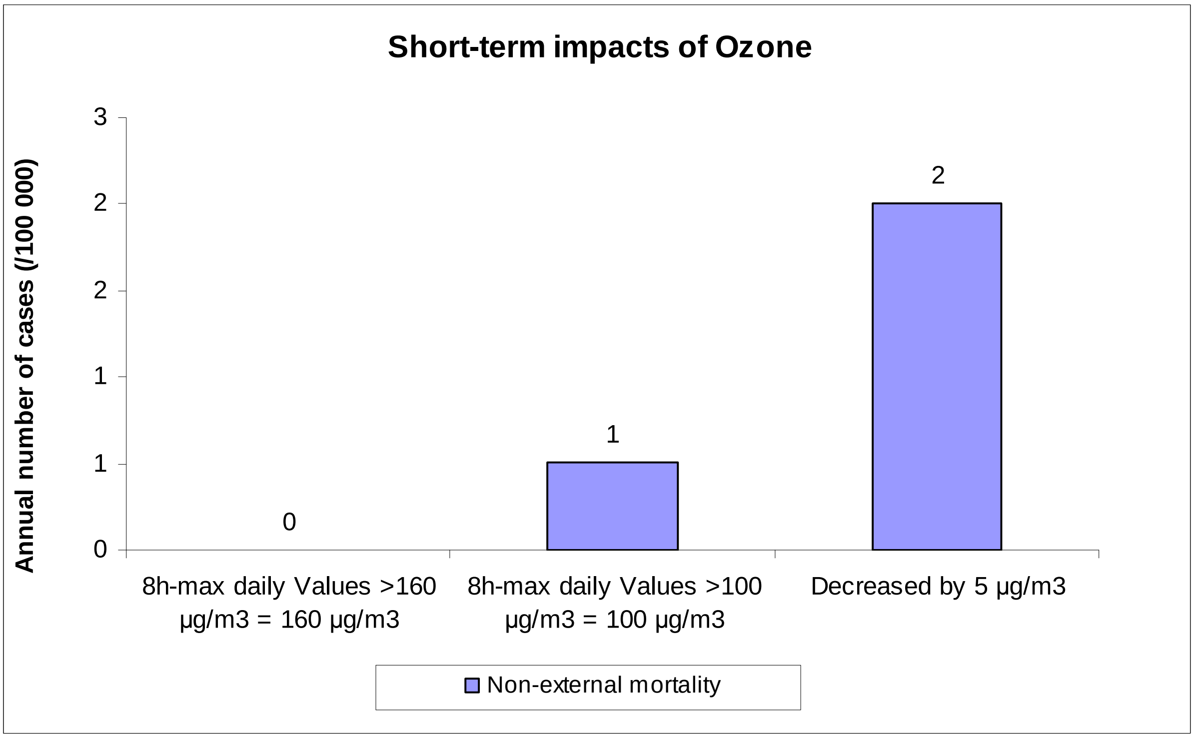


Figure 6 – Potential benefits of reducing daily ozone levels on mortality

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 long term reduction of PM2.5 concentration by 5 µg/m^3 would prevent a considerable number of deaths of 657 cases of all causes mortality, more reduction of PM2.5 (to 10 µg/m^3), would prevent almost five times more (2952) death cases (Table 6). Similar benefits could be gained concerning cardiovascular mortality (Table 7). The benefits can also be expressed in the gains of life expectancy for a person of 30 years old due to reduced risk of death from all causes in the city of Budapest This indicator shows the weight of the scenario of reducing the annual mean concentration to 10 µg/m^3.

Table 6 – Potential benefits of reducing annual PM2.5 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	657	57	0,3
Decrease to 10 µg/m^3	2952	255	1,6

Table 7 – Potential benefits of reducing annual PM2.5 levels on total cardiovascular mortality

Scenarios	Total annual number of deaths postponed	Annual number of deaths postponed per 100 000
Decrease by 5 µg/m^3	634	55
Decrease to 10 µg/m^3	2711	234

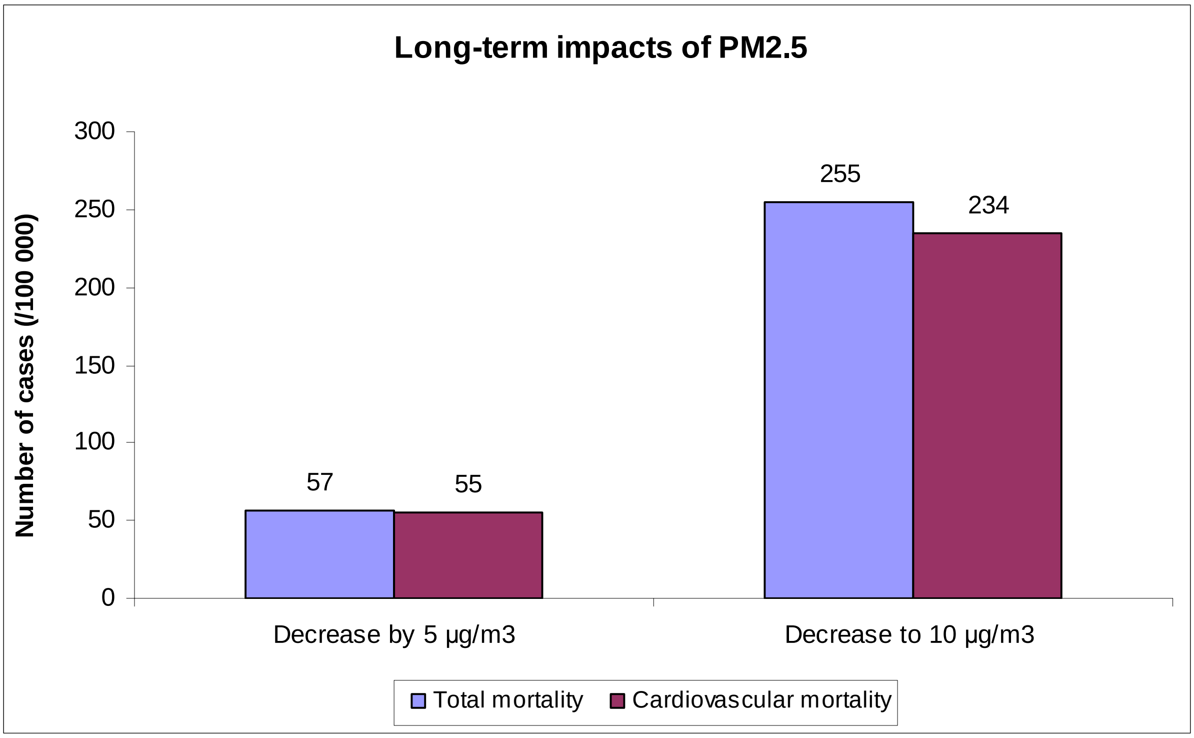


Figure 7 – Potential benefits of reducing annual PM2.5 levels on mortality

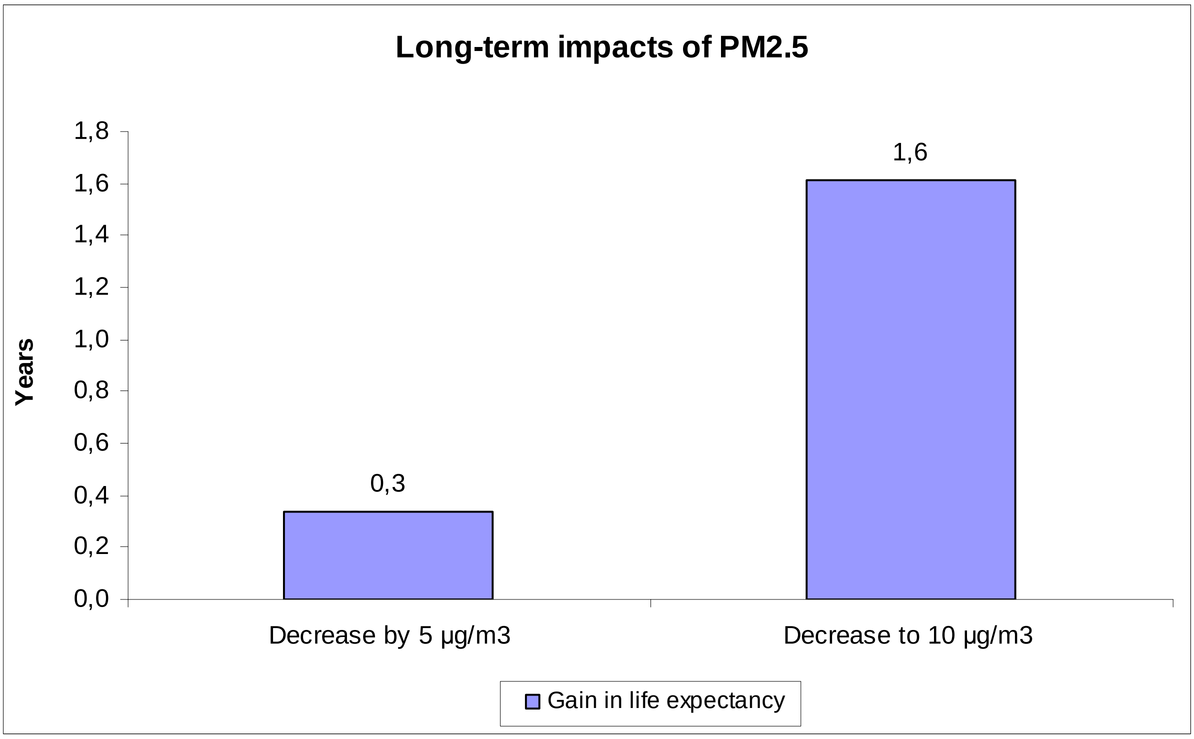


Figure 8 – Potential benefits of reducing annual PM2.5 levels on life expectancy

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

The economic valuation of short term impact of air pollution on the inhabitance of Budapest revealed a benefit of more than 5.5 million Euros by avoiding 65 death cases in the scenario of reducing PM10 concentration levels by 5 μg/m^3 . The potential reduction of PM10 to 20 μg/m^3, by saving the lives of 365 people would produce an approximately five times higher benefit than the previous scenario (31 million €). However it should be kept in mind that the short term scenarios consider avoided deaths within the given year, therefore the smaller amount of VOLY was applied (Table 8).

Table 8 – Potential economic benefits of reducing daily PM10 levels on total non-external mortality

Scenarios	Annual number of attributable deaths avoided	VOLY (€)	Annual economic benefit (€)
Decrease by 5 μg/m^3	65	86 600	5 658 023
Decrease to 20 μg/m^3	365	86 600	31 649 732

Table 9 – Potential economic benefits of reducing annual PM2.5 levels on total non-external mortality

Scenarios	Annual number of attributable deaths avoided	VSL (€)	Annual economic benefit (€)
Decrease by 5 μg/m^3	657	1 655 000	1 086 873 325
Decrease to 10 μg/m^3	2952	1 655 000	4 885 028 138

In case of long term effects of air pollution the numbers of avoided deaths are greater compared to short term effects. Long term effects may cause lost of life years more than one year, therefore the value of statistical life is considered. Table 9 represents the potential economical value of the reduction of PM2.5 producing gain in life expectancy in two different scenarios. The results represent the long term gain for the entire population of Budapest older than 30 years. The two scenarios reflect a 5 times difference of the annual economic benefits (1 vs. 4.9 billion €) for the sake of a decrease to 10 μg/m^3.

Table 10 – Potential economic benefits of reducing annual PM2.5 levels on life expectancy

Scenarios	Gain in life expectancy	VOLY (€)	Economic benefit (€)
Decrease by 5 μg/m^3	0,3	86 600	855 654 706
Decrease to 10 μg/m^3	1,6	86 600	4 108 434 726

Table 10 represents the potential economic value of the gain of life expectancy of the 30 years old population of Budapest over their lifetime if they were exposed to the 10 μg/m^3 or by 5 μg/m^3average annual level of PM2.5 instead of the current existing air pollution level in the city. The reduction of air pollution to the annual mean of 10 μg/m^3 would produce a 4.1 billion € lifetime economic gain for the cohors of present 30-year old population, similarly to the economic gain of 4.9 billion € for the total population older than 30 yeras for one year in Budapest.

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.

1.4.5. Interpretation of findings

Exposure assessment

The 3-year average of daily PM10 concentration was slightly more than the limit value (40 μg/m^3) 10% of the short term PM10 exposure was under 20 μg/m^3 respectively 37% was above the present daily limit value of 50 μg/m^3.
During the 3 years the daily O3 concentration was higher than the daily limit value (120 μg/m^3 maximum of 8 hours moving average) on 2% of the days. There were no days over 160 μg/m^3 ozone concentration.

Health outcomes

As the daily average PM10 concentration was 48 μg/m^3, the reduction to 20 μg/m^3 could prevent relatively high number of deaths. Much less effect could be gained by reducing the daily PM10 concentration by 5 μg/m^3. This finding gives evidence for the planning of policies aiming at reducing the short term peak concentration with a considerable gain in health.

The daily O3 concentration was in a lower range, compared to particulate matter. So the reduction of short term peak concentration would have less benefit for the health of the population of Budapest. From public health point of view much more important would be the reduction of the long term concentration of small size particulate matter. The highest benefit could be gained by the reduction of the yearly mean PM2.5 concentration to 10 μg/m^3, by this reduction nearly 3000 deaths due to non external causes could be avoided, resulting a considerable gain in life expectancy of 1.6 years for the population over 30 years. The potential economical benefit of this scenario is around 4.9 billion € for one year for the related population group. It must be kept in mind that the health impact assessment is valid only for the circumstances of the chosen year. The same methodology of the HIA can produce considerably different results if the baseline conditions change.

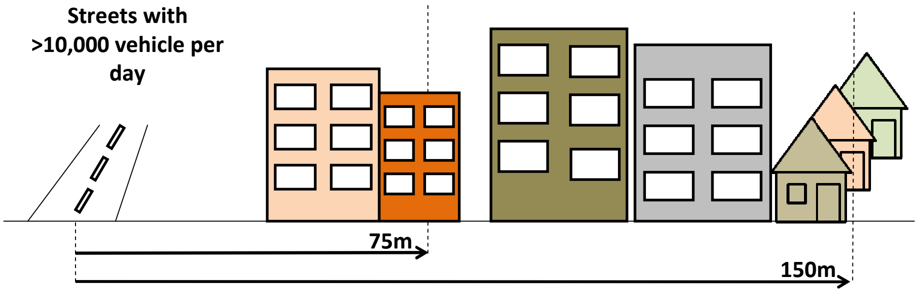
In the present years the air quality, especially the concentration of PM showed an increasing tendency in Budapest compared to the years of 1999-2000 – partly due to the increase of traffic related emissions and partly to turning back to heating with wood and coal instead of natural gas. On the other hand it should be mentioned that the overall mortality is relatively high, life expectancy for both sexes is in the lower range among the EU cities. The results of the health impact assessment clearly proved the benefits of cleaner air. These results should be used in planning of medium – and long term environmental health policy of the capital, aiming at the reduction of traffic and household related pollution emission.

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.

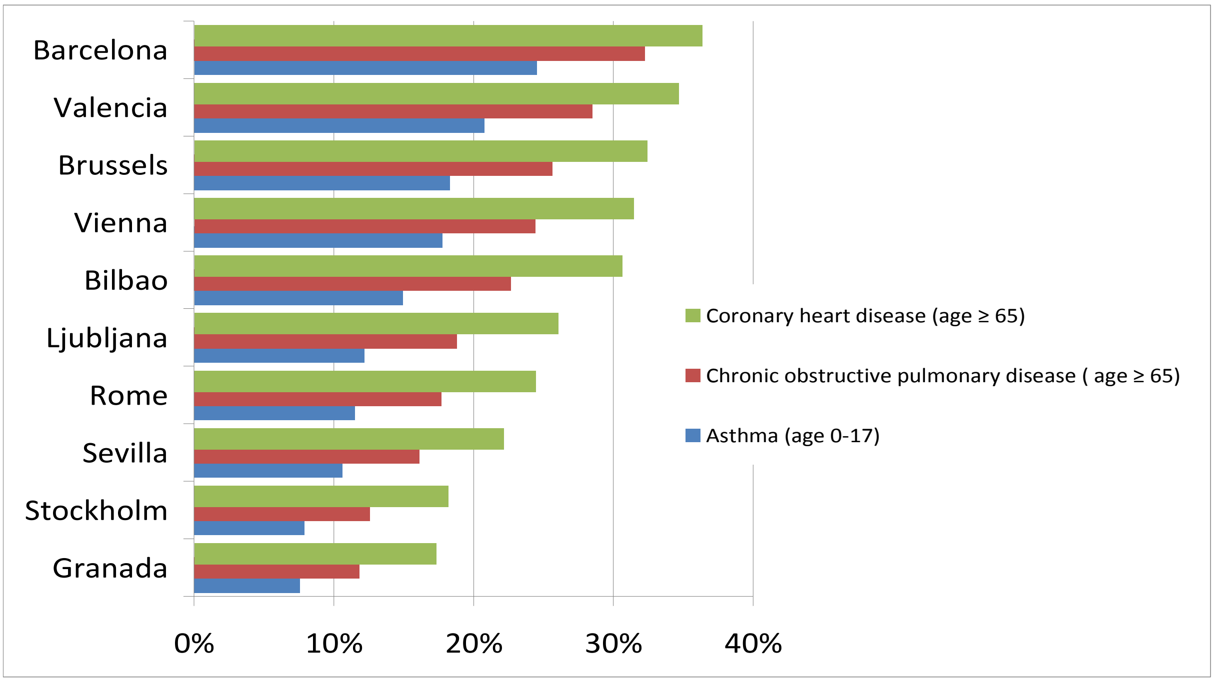


Figure 10 – Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

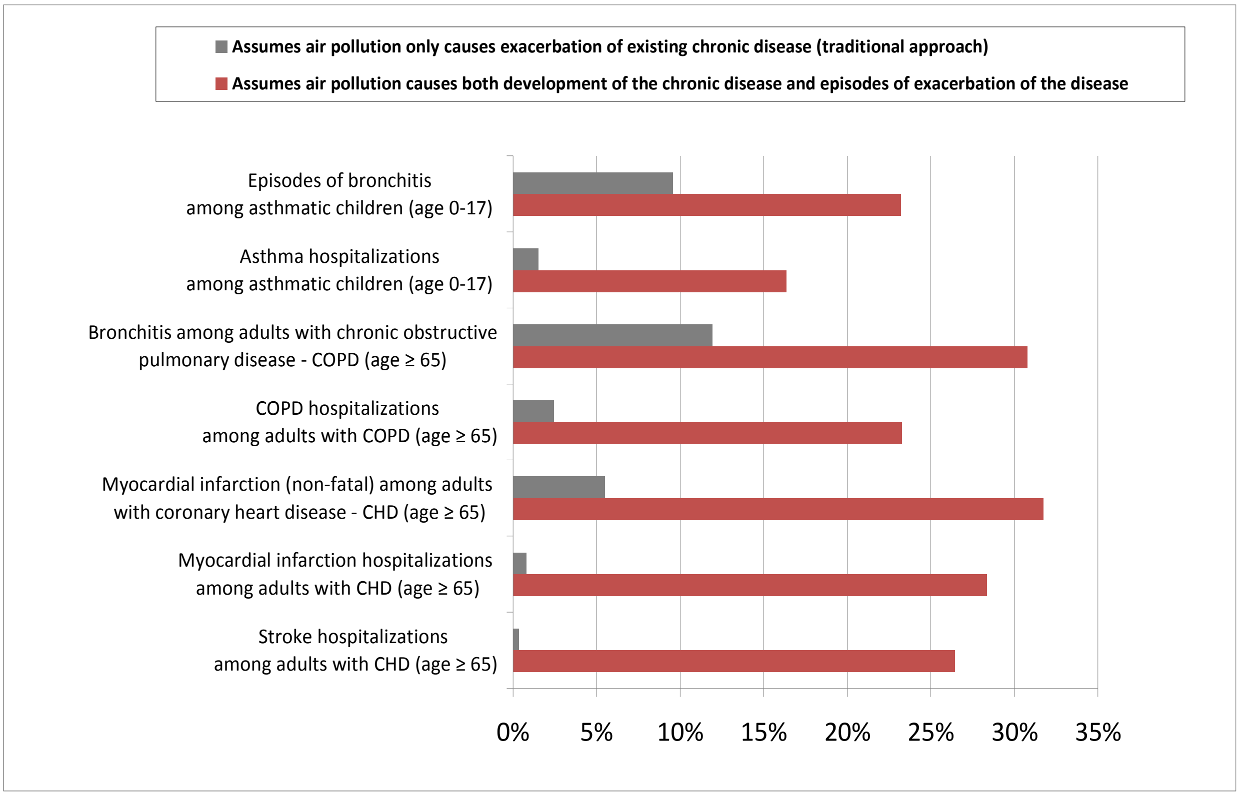


Figure 11 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

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

As part of the work of the Aphekom an extensive review of the scientific literature on interventions, both legislative and coincidental which have resulted in reductions in air pollution, was conducted. This review shows that air pollution interventions have been successful at reducing air pollution levels. It has also shown that there is consistent (significant) published evidence that most of these interventions have been associated with health benefits, mostly by way of reduced cardiovascular or respiratory mortality and or morbidity. Throughout the majority of reviewed interventions the found decrease in mortality exceeded by far the expected predicted figures based on observations of European multicity studies.

In addition to that, 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). In detail the effect on air pollution levels of the implementation of the Council Directive 93/12/EEC and its amended version Council Directive 1999/32/EC including marine oils were analysed. The implementation of the two Council Directives encompassed three stages of implementation gradually reducing the sulphur content in certain fuels in the EU member states with stage (I) being implemented as laid down in the directive on 1st Oct. 1994, stage (II) on 1st Oct. 1996 and stage (III) on 1st July 2000.

Air quality analysis

The general decreasing trend in daily urban background (UB) SO2 concentrations that has been observed across all centres (except the French centres excluding Paris) over the time period of the study is illustrated in Figure 12. Overall there was no clear steep change in SO2 concentrations after implementation of the Directives; rather a gradual decline in SO2 levels was observed.

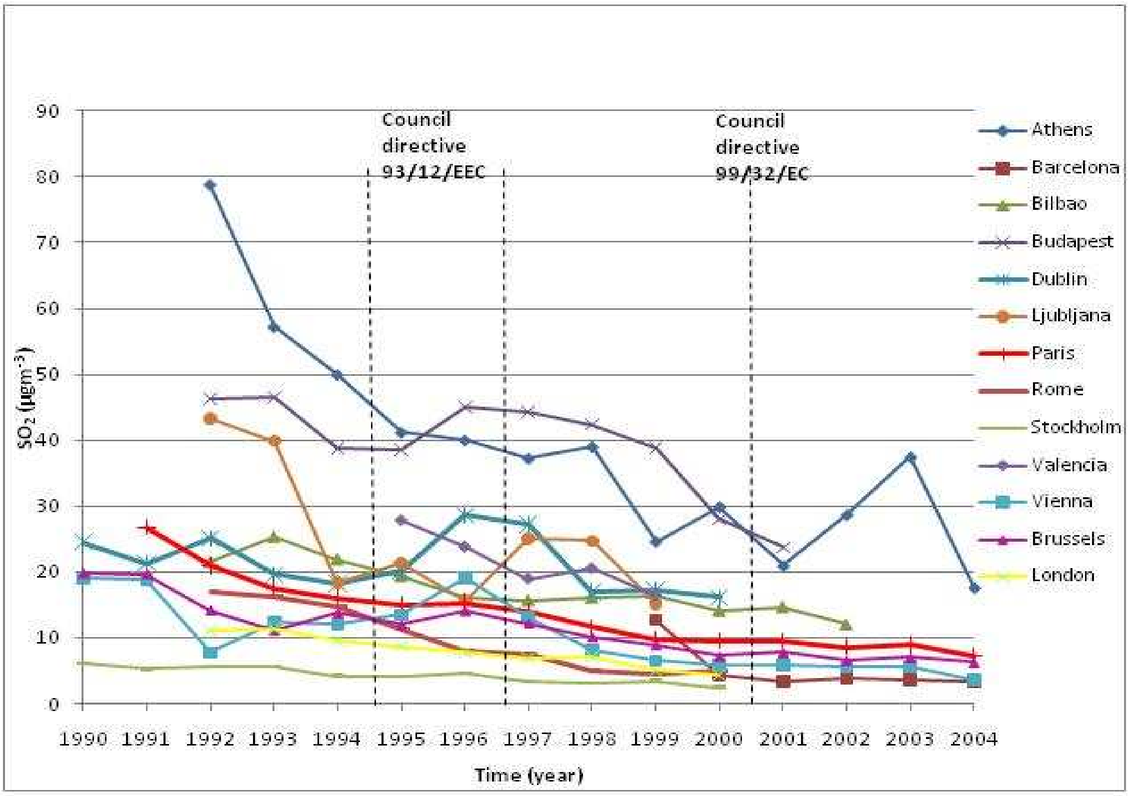


Figure 12 – Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

Figures 13 and Figure 14 show preliminary work done using hourly SO2 data from Vienna, Austria showing seasonal plots for winter and summer 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 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 shows a clear reduction in peak SO2 levels for the before 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.

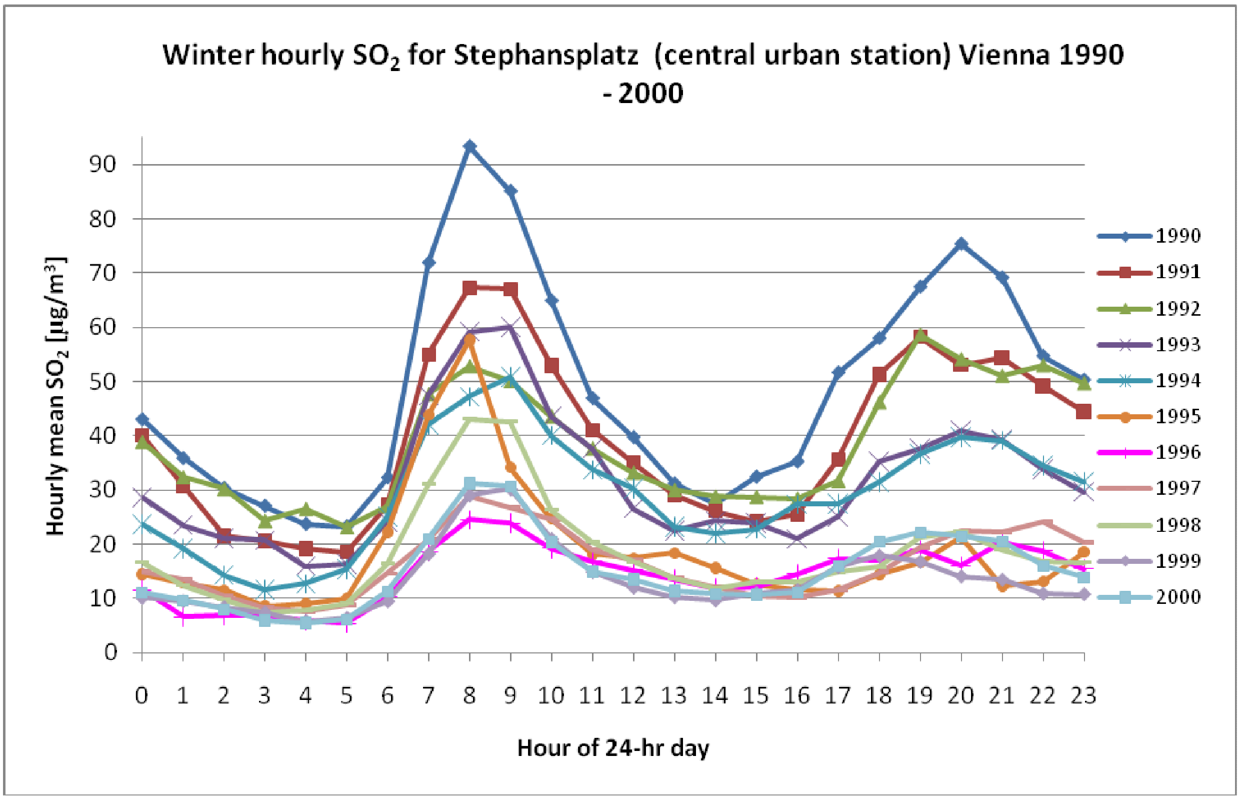


Figure 13 – Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000

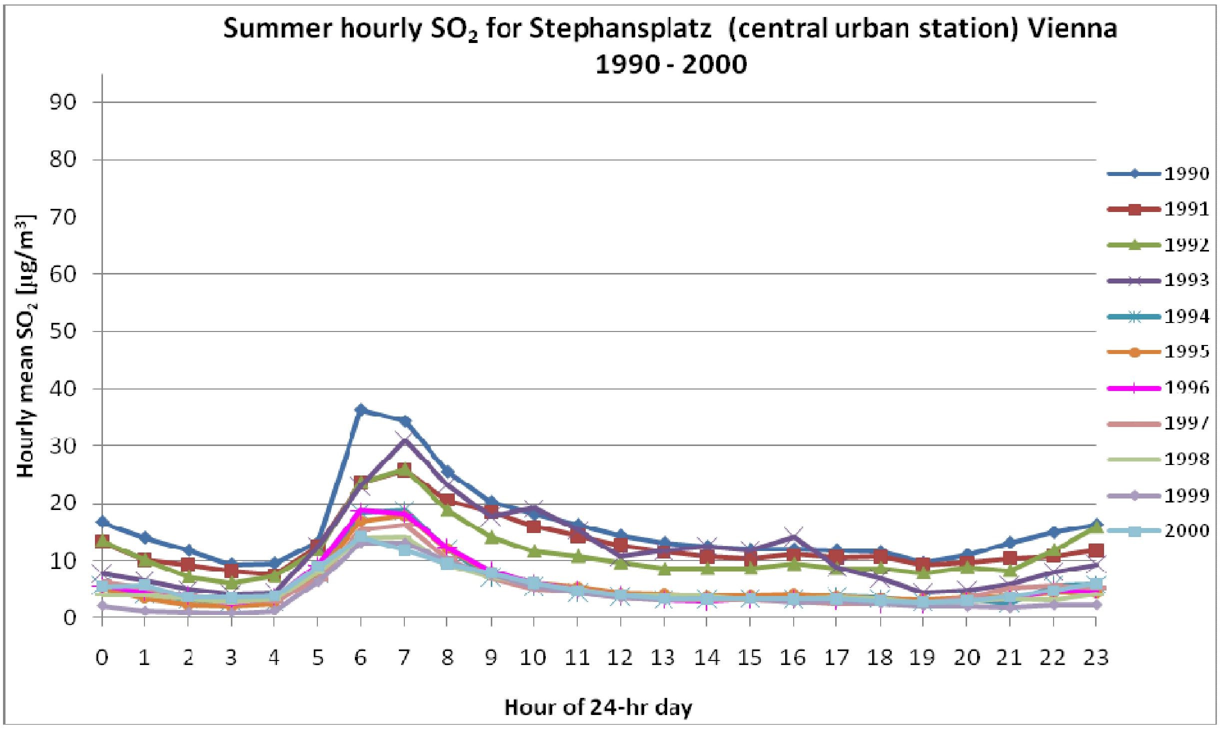


Figure 14 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

Figure 15 shows a 24hr-plot of hourly SO2 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 SO2 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.

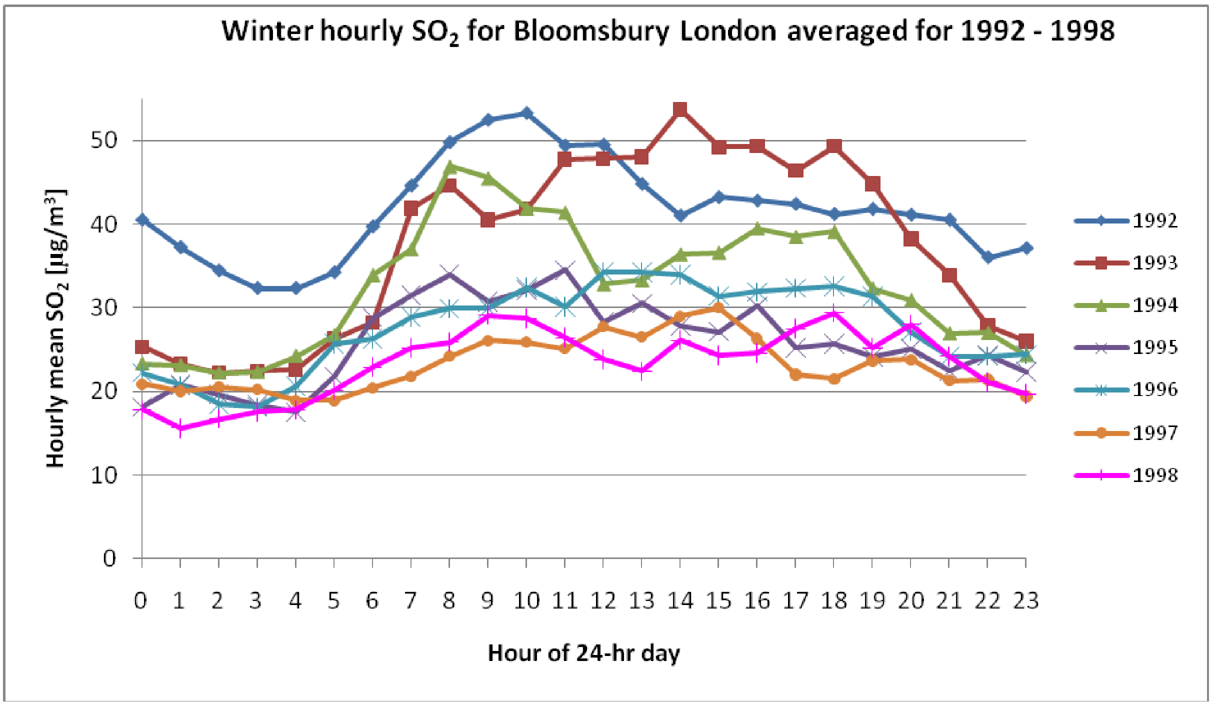


Figure 15 – Diurnal plot of winter hourly SO_2 for an urban background station in London 1992-1998

Time-series analysis

It has to be noted that not all countries with collaborating cities have complied with the implementation dates laid down in the Council Directives due to various reasons, e.g. local derogations sought etc., and thus the implementation dates and the number of stages implemented are not all the same. Therefore the 14 centres including Athens, Bordeaux, Brussels, Dublin, Le Havre, Lille, London, Lyon, Marseille, Paris, Rome, Rouen, Stockholm and Strasbourg that implemented all three stages of the Council Directives were analysed separately (Table 11).

The health data analysis showed no evidence of change of slope in the dose-response curve after implementation of the legislations and hence observed effects were related to level changes.

The implementation of the first stage in 1994 reduced annual deaths by 639 deaths from all causes, by 47 deaths from respiratory and by 361 deaths from cardiovascular causes compared to the baseline period prior to October 1994 with no directive being implemented.

The implementation of the 2nd stage in 1996 reduced annual deaths by 1093 deaths from all causes, by 83 deaths from respiratory and by 610 deaths from cardiovascular causes compared to the baseline period with no directive being implemented.

The implementation of the 3rd stage in 2000 reduced annual deaths by 1616 deaths from all causes, by 127 deaths from respiratory and by 889 deaths from cardiovascular causes compared to the baseline period with no directive being implemented.

Table 11 – Summary of the HIA for 14 EU cities that implemented all 3 stages of the EU Council Directives using the effect estimates generated by the meta-analysis

14 centres that implemented all three intervention stages									
	All cause mortality			Respiratory mortality			Cardiovascular Mortality		
Time period	# cases per year	95 CI -	95 CI +	# cases per year	95 CI -	95 CI +	# cases per year	95 CI -	95 CI +
sum of intervention 1	639	223	1056	47	-15	109	361	107	618
sum of intervention 2	1093	382	1808	83	-27	195	610	180	1043
sum of intervention 3	1616	564	2676	127	-41	298	889	262	1523

On a city specific level for Budapest

The implementation of the 3rd stage in 2000 reduced annual deaths by 390 deaths from all causes, by 13 deaths from respiratory and by 296 deaths from cardiovascular causes compared to the baseline period with no directive being implemented (Table 12).

Table 12 – Summary of the HIA for 6 EU cities that implemented one common stage of the EU Council Directives (the 99/32/EC Directive) using the effect estimates generated by the meta-analysis

6 centres that implemented 1 common intervention stage										
		All cause mortality			Respiratory mortality			Cardiovascular Mortality		
Centre	Time period	# cases per year	95 CI -	95 CI +	# cases per year	95 CI -	95 CI +	# cases per year	95 CI -	95 CI +
Barcelona	intervention 3	35	12	58	4	-1	9	17	5	29
Bilbao	intervention 3	14	5	24	1	0	3	7	2	12
Budapest	intervention 3	390	136	647	13	-4	32	296	87	507
Ljubljana	intervention 3	31	11	52	2	-1	5	17	5	29
Toulouse	intervention 3	35	12	58	2	-1	5	15	5	26
Vienna	intervention 3	90	31	148	4	-1	8	70	21	120
sum		596	208	987	26	-9	61	423	124	724

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 has been decided that, to take a conservative standpoint, mortality effects will be considered as short-term effects.

Consequently, a VOLY of €86,600 should be applied to each premature deaths 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.

This analysis showed not only a marked, sustained reduction in ambient SO2 levels, but also saved 2212 lives from all-cause mortality, 153 lives from respiratory-cause and 1312 lives from cardiovascular-cause mortality per year attributable to reduced ambient SO2 for 20 European cities, spread all across Europe, from the year 2000 onwards compared to the baseline period with no directive being implemented.

As a result overall for the 14 cities that implemented all 3 stages of the fuel legislation it was found that the efficiency/effectiveness/impact of the legislation based on lives saved, if we didn't apply any regulation, increased throughout the different stages of implementation overtime with more lives being saved after implementation of the 2nd stage of implementation compared to the first stage and with more lives being saved after implementation of the 3rd stage of implementation compared to the 2nd one.

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

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 stakeholders have been interested in the international evaluations, the results are understood as convincing evidences of the health impact of air pollution through Europe. The public health sector is especially interested in the methodology of health impact assessment. The HIA methodologies (APHEIS, ENHIS) have been used in several national studies, the results were presented in scientific journals and conferences attended by public health workers. The decision makers expressed high interest towards evidence based health impact assessments, the modification of the legislation of smog alert was based on the APHEIS results. The National Institute of Environmental Health has been evaluating the air quality of Budapest and several cities of the country from public health point of view. Special advises are give for the public to lower the short term health impacts of air pollution.

The results of the APHEKOM study will be published for the scientific community as well as for policy makers and other stakeholders resp. for the public in journals, newspapers and on the web of the National Institute of Environmental Health and of the municipalitiy of Budapest. The cost-benefit analysis carried out within APHEKOM is a novelty, a very important tool for policy making.

The Budapest results will be communicated to the decision makers at different levels (Municipality, Parliament Sustaniable Development Committee, Office of the Parliamentary Comissionar for Future Generation, Ministry of National Resources) as well as to NGOs. The results of the present HIA will be used in local, regional and national plans aiming at the reduction of air pollution level.

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

- Scenario 2, if $[O_3]_i \geq 100$ µg/m^3, $O_i = ([O_3]_i - 100)$
  if $[O_3]_i < 100$ µg/m^3, $O_i = 0$
- Scenario 3, where the ozone yearly mean is decreased by 5 µg/m^3. $\Delta x = 5$ 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, $\Delta x = 5$ 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 $\mu g/m^3$ 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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