Aphekom

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

Aphekom

Local city report for

Ljubljana

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Summary

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

The air quality in Ljubljana is still due to many reasons important public health issue. Ljubljana is located in basin with regular temperature inversions. The meteorological conditions are extremely unfavourable and dramatically contribute to build up of pollution. The main source of pollution is still traffic.

Transportation constitutes the main source of air pollution in Ljubljana: 70 % of the emissions of PM10 and PM2.5. The most important vehicle category is diesel vehicles (city buses).

The pollution indicators are monitored by Agency for Environment. Daily mean level in the period 2004-2006 for ozone is 76 µg/m^3, for PM10 is 38 µg/m^3 and for PM2.5 (study period 2005-2006) is 29 µg/m^3.

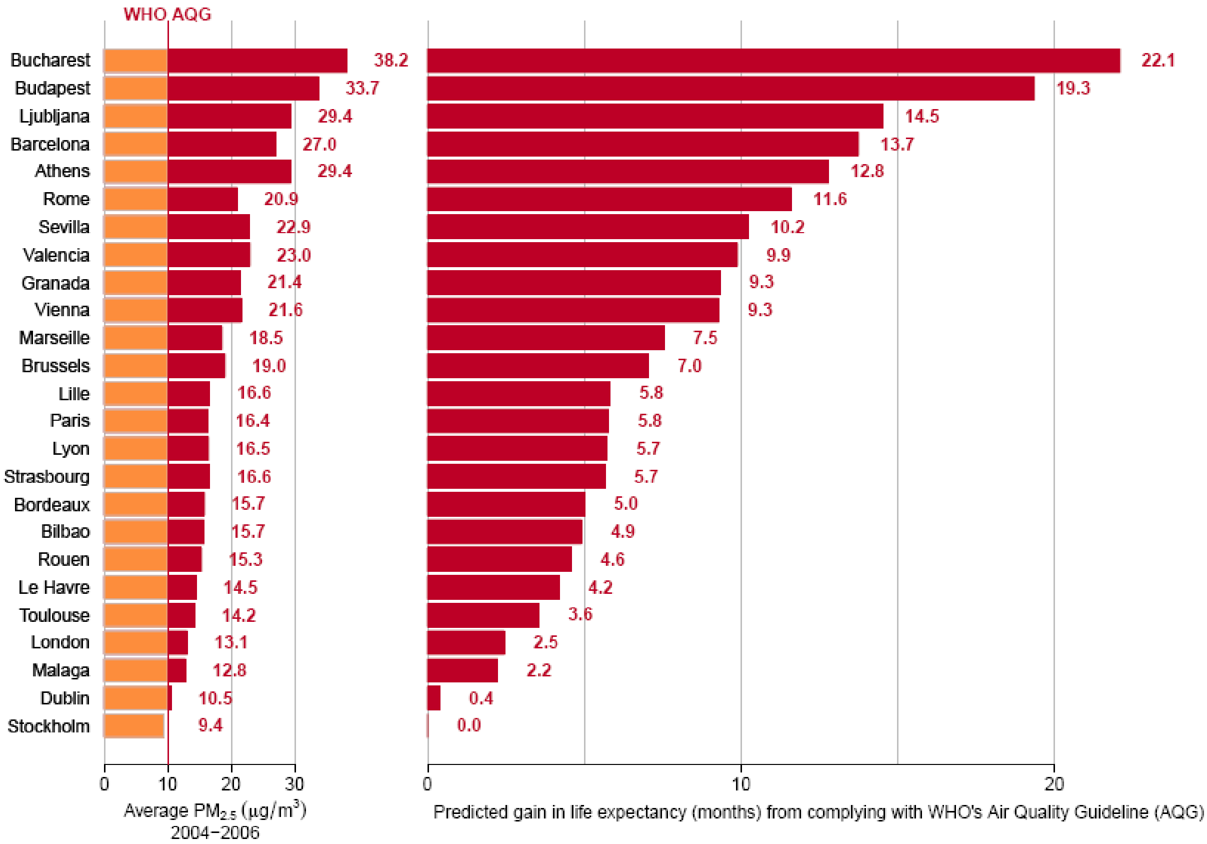
In case that the annual mean of PM10 was decreased by 5µg/m^3 per year, annual number of deaths postponed on short term would be 8, and if annual mean of PM10 was decreased to 20µg/m^3 per year, annual number of deaths postponed on short term would be 28.

In case that all daily values of ozone level were reduced to 100 µg/m^3, a total number of deaths postponed would be 3. In case that daily mean ozone level was decreased by 5 µg/m^3, a total number of deaths postponed would be 4.

In case, that the annual mean of PM2.5 was decreased by 5 µg/m^3, a total number of deaths postponed would be 66 and a gain in life expectancy approximately 4 months. In case that the annual mean of PM2.5 was decreased to 10 µg/m^3, a total number of deaths postponed would be 247 and a gain in life expectancy approximately 14 months.

In Ljubljana 47 % of inhabitants live near busy roads. Due to that fact we can claim, that around 12 % of children of age 0-17 are having asthma because they live near busy roads. We can also ascribe 18 % of COPD of people aged > 65 to living near busy road and 30 % of people with coronary heart disease aged > 65 to the same fact.

Across the 25 European cities the benefits of reducing levels of $PM_{2.5}$ fine particles (WHO's annual air-quality guideline) could add up to an additional 22 months of life expectancy for persons 30 years of age and older, depending on the city and its average level of $PM_{2.5}$. Hence, exceeding the WHO air-quality guideline on $PM_{2.5}$ leads to a burden on mortality of nearly 19,000 deaths per annum, more than 15,000 of which are caused by cardiovascular diseases. Aphekom also determined that the monetary health benefits from complying with the WHO guideline would total some €31.5 billion annually, including savings on health expenditures, absenteeism and intangible costs such as well being, life expectancy and quality of life. The results for $PM_{2.5}$ are summarised in the figure below:



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

Acronyms

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

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

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.

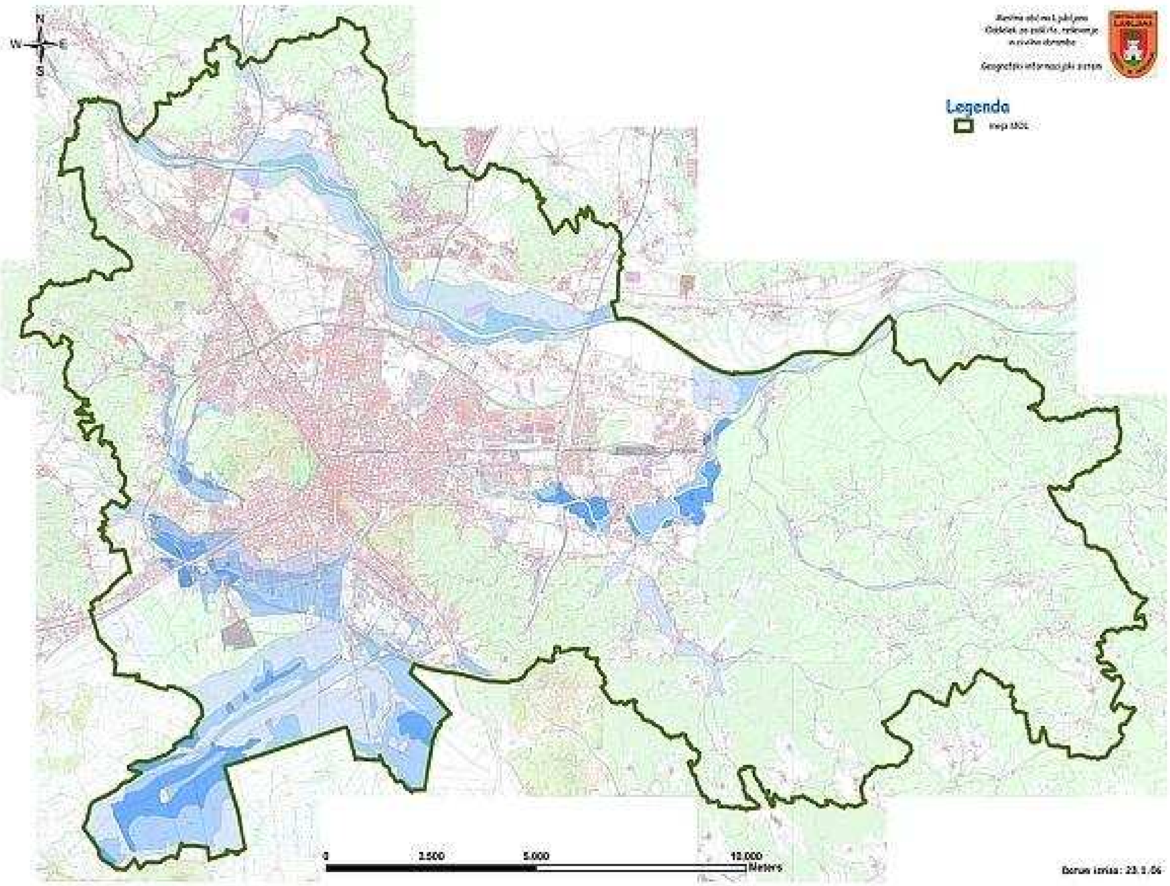
Building on the experience gained in the earlier Apheis project, Aphekom conducted a standardised HIA of urban air pollution in the 25 Aphekom cities totalling nearly 39 million inhabitants: Athens, Barcelona, Bilbao, Bordeaux, Brussels, Bucharest, Budapest, Dublin, Granada, Le Havre, Lille, Ljubljana,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

1.1. Description of the study area

Table 1.1.1: Important facts about Ljubljana

Ljubljana in numbers	
Number of inhabitants	258.873
Number of men	122.728
Number of women	136.145
Settlement area, sq km	163,8
Population density, persons per sq km	1.581
Number of families	72.892
Number of households	100.399
Average household size	2,6
Number of dwellings	109.953

Source: 2002 Census of Population, Households and Housing, SORS and Register of Spatial units, SMA



Source: The City of Ljubljana

Figure 1.1.1: Map of the study area

Climatology

Ljubljana lies between Ljubljansko barje and Ljubljansko polje at an altitude of about 300 meters. Ljubljana is located in the basin of the river Sava. This is also reflected in the climatic characteristics. Ljubljana has a climate that is transition between continental and alpine, with prevailing weak local winds, influenced by urban heat island. Typical of this area is the low air temperatures in winter, a high frequency of temperature inversions, a lot of rain, a lot of cloud cover and frequent fog. The meteorological conditions are extremely unfavourable and dramatically contribute to build up of pollution. The average wind speed is below 1 m/s.

Period between 1991 and 2006:
Yearly average temperature : 11,0℃
Absolute minimal temperature: -16,2 ℃
Absolute maximal temperature: 37,3 ℃

Population in the study area

Table 1.1.2: Population for Ljubljana, 2002

Ages	Women	Men	Total
all ages	**139644**	**126237**	**265881**
0-1	2163	2271	4434
<18	22318	23300	45618
18-64	91304	87645	178949
65-75	15630	10816	26446
>75	10392	4476	14868

Source: Statistical Office of the Republic Of Slovenia, 2002

Commuting

Today, the primary means of transport in Ljubljana is a car. In 2006, Ljubljana had 611 registered vehicles per 1000 inhabitants, the whole urban region had 608 vehicles per 1000 inhabitants. Approximately 130.000 cars arrive to Ljubljana every day. 70 % of daily migrants come to work by car, 16 % by bus, 10 % on bicycle or on foot, 3 % by train, 1 % of daily migrants take other type of transportation. The daily routes to the major shopping centers also contribute a lot to the increased traffic in Ljubljana.

1.2. Sources of air pollution and exposure data

Sources

The pollution indicators are monitored by Agency for Environment. Only measurements from urban background stations that are geographically representative of the study area and not directly influenced by local sources of air pollution were selected: one station for PM10, one station for PM2.5 and one station for ozone.

The main source for SO_2 is heating followed by industry and road traffic. The total emission of SO_2 in 2006 was 1200 tons. The main source for NO_2 is road traffic followed by heating and industry. The total emission of NO_2 in 2006 was 6200 tons. The main source for PM10 is road traffic followed by heating and industry. The total emission of PM10 in 2006 was 920 tons (Table 1.2.1).

Outdoor air in the city was in the last few years, overly polluted with PM10. The limit values were most often exceeded at the urban sites and mostly influenced by emissions from traffic.

Table 1.2.1: Main sources of air pollution (tons/year)

Pollutant	Road	Heating	Industry	Other sources (transportation other than road, incineration of garbage…)
SO_2	40	1100	60	**/**
NO_2	4200	1800	200	**/**
Primary PM_{10}	600	250	70	/
Primary $PM_{2.5}$	/	/	/	/

Exposure data

The provider of air pollution data is The Environmental Agency of Slovenia (http://www.arso.gov.si/en/about%20the%20agency/). Agency is a body of the Ministry of the Environment and Spatial Planning. The Agency's mission is among others to monitor environmental contamination and to provide reliable public environmental data (air quality, ground water quality). The data are quality assured and checked. The access to data base is not restricted and most of the data are available on their Internet site.

Table 1.2.2: Data regarding exposure indicators

Exposure Indicators	***PM_{10}**	****$PM_{2.5}$**	**Ozone**
Measurement Method	TEOM	Gravimetric method	UV photometry
Location/Source	Environmental Agency of the Republic of Slovenia	Environmental Agency of the Republic of Slovenia	Environmental Agency of the Republic of Slovenia
Number of Urban Background Monitors	1	1	1
Raw/Corrected Data	corrected data		
Correction Factor to Apply if Raw Data	winter 1,24 summer 1,03		

Daily mean level in the period 2004-2006 for ozone is 76 μg/m^3, for PM10 it is 38 μg/m^3 and for PM2.5 (study period 2005-2006) it is 29 μg/m^3. Standard Deviation for ozone it is 32 μg/m^3, for PM10 it is 26 μg/m^3 and for PM2.5 (study period 2005-2006) it is 21 μg/m^3. 5th percentile for ozone it is 20 μg/m^3, for PM10 it is 13 μg/m^3 and for PM2.5 (study period 2005-2006) it is 9 μg/m^3. 95th percentile for ozone is 124 μg/m^3, for PM10 it is 82 μg/m^3 and for PM2.5 (study period 2005-2006) it is 69 μg/m^3.

Table 1.2.3: 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)	76	32	20	124
PM10 (daily average)	38	26	13	82
PM2.5 * (daily average)	29	21	9	69

* Study period 2005 - 2006

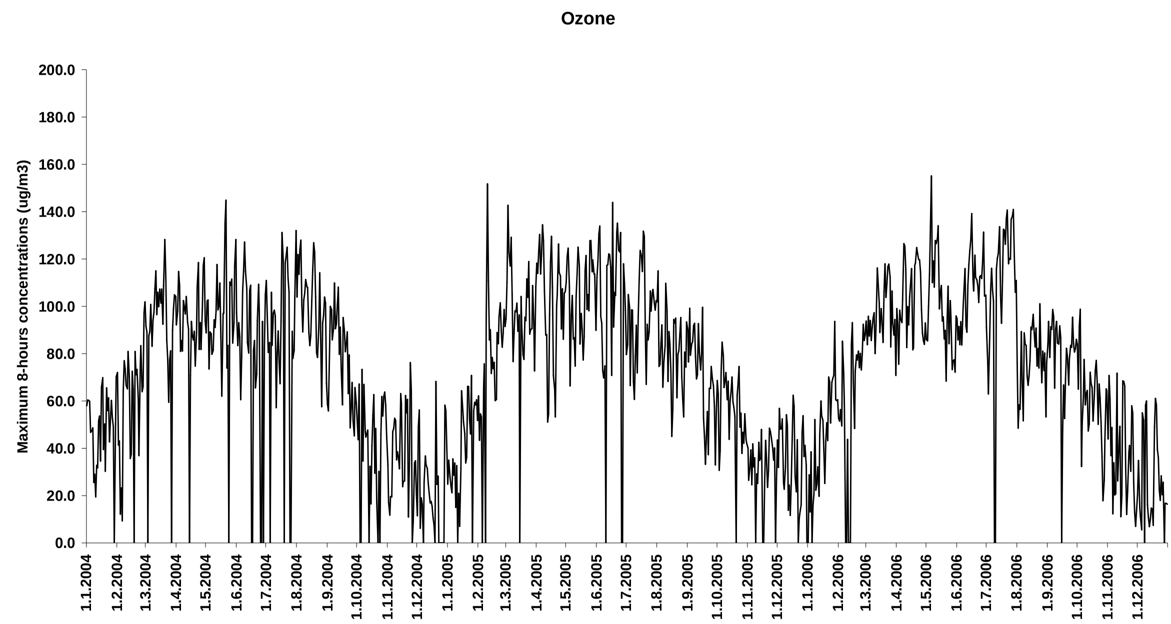


Figure 1.2.1: Ozone concentration in the study area

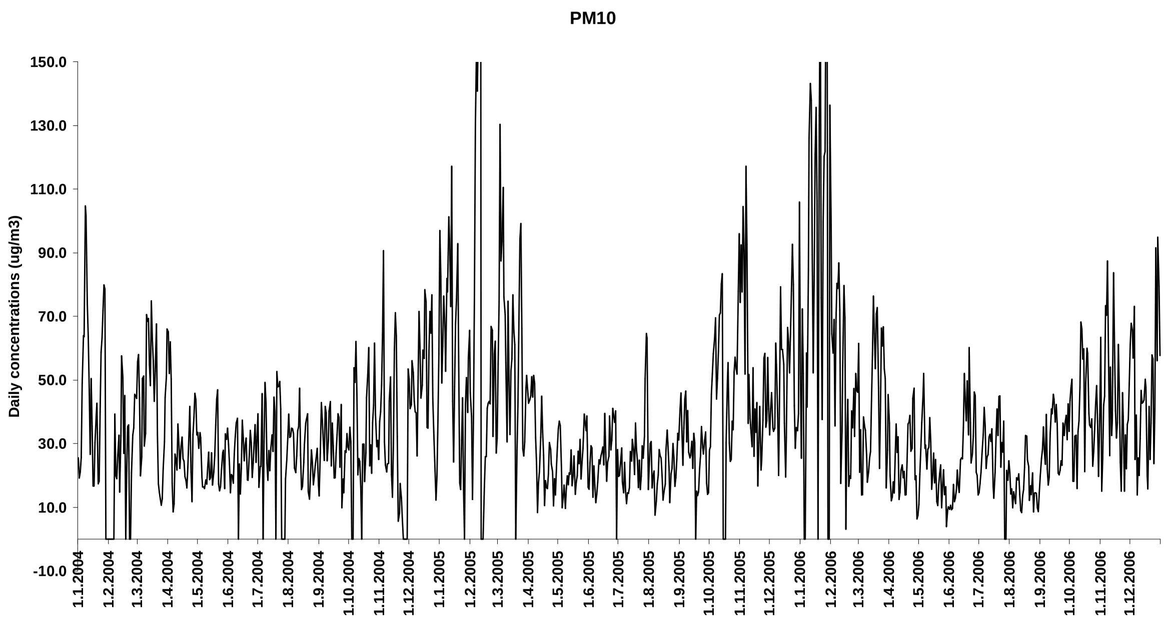


Figure 1.2.2: PM10 concentration in the study area

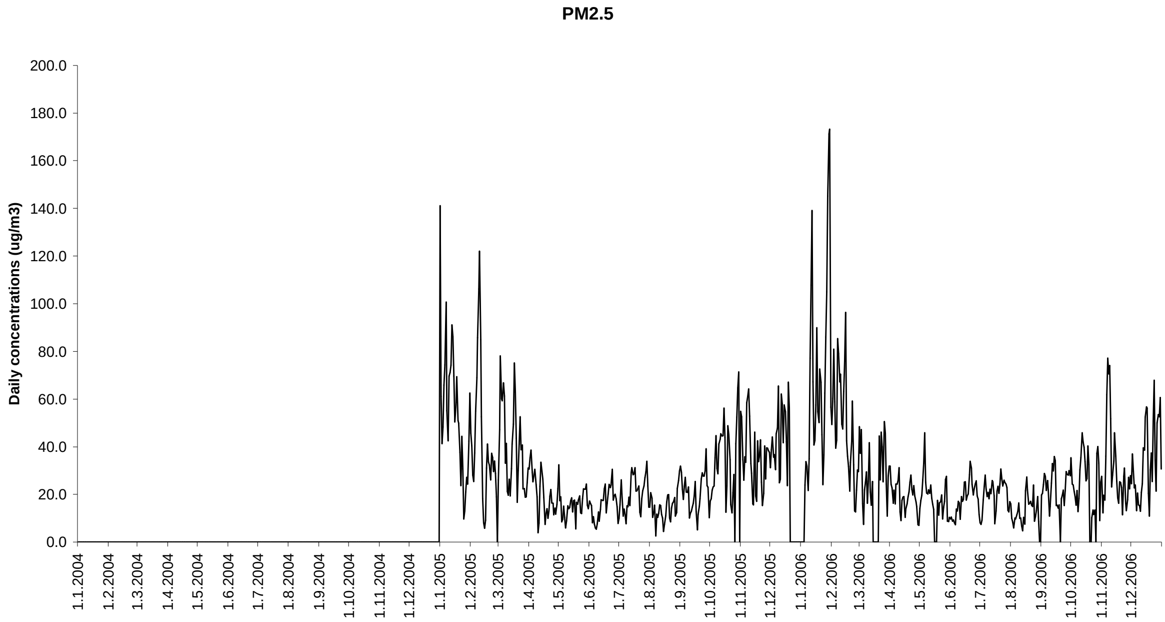


Figure 1.2.3 PM2.5 concentration in the study area

1.3. Health data

The health data are available on National Institute of Public Health (NIPH) (http://www.ivz.si/index.php?akcija=oddelek&o=7). It is a major research centre for epidemiology, and the prevention of disease and promotion of health. NIPH collects data and manages Mortality Database and Hospital Morbidity Database.

Annual mean for non external mortality for all ages is 2578, annual mean in adults over age 30 is 1537. Annual mean for cardiovascular mortality in adults over age 30 is 898 in the study period (2004 – 2006).

Annual mean for cardiac hospitalizations for all ages is 2270. Annual mean for respiratory hospitalizations for all ages is 2684, annual mean in adults age 15-64 is 776 and annual mean in adults over age 65 is 980 in the study period (2004 – 2006).

Table 1.3.1: 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	2578	966
Non-external mortality	< 800	A00-R99	> 30	1537	854
Cardiovascular mortality	390-429	I00-I52	> 30	898	499
Cardiac hospitalizations	390-429	I00-I52	All	2270	850
Respiratory hospitalizations	460-519	J00-J99	All	2684	1005
Respiratory hospitalizations	460-519	J00-J99	15-64 yrs	776	291
Respiratory hospitalizations	460-519	J00-J99	≥ 65 yrs	980	367

* 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).

In case of scenario 1, the annual mean of PM10 was decreased by 5 µg/m^3, a total number of deaths postponed would be 7.70. In case of scenario 2, the annual mean of PM10 was decreased to 20 µg/m^3, a total number of deaths postponed would be 28.24. In case of scenario 1, the annual mean of PM10 was decreased by 5 µg/m^3, a total annual number of respiratory hospitalisations postponed would be 15.17, and total annual number of cardiac hospitalisations postponed would be 6.78. In case of scenario 2, the annual mean of PM10 was decreased to 20 µg/m^3, a total annual number of respiratory hospitalisations postponed would be 55.44, and total annual number of cardiac hospitalisations postponed would be 24.86.
Assessing both scenario we can see, that already a decrease of annual mean of PM10 by 5 µg/m^3 has important influence on number of deaths postponed and on number of hospitalisations postponed (almost half of cases less).

Table 1.4.1.1: 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	7,70	3
Decrease to 20 µg/m^3	28,24	11

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

Table 1.4.1.2: Potential benefits of reducing annual PM10 levels on hospitalisations

	Respiratory hospitalisations		Cardiac hospitalisations	
Scenarios	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**
Decrease by 5 µg/m^3	15,17	6	6,78	3
Decrease to 20 µg/m^3	55,44	21	24,86	9

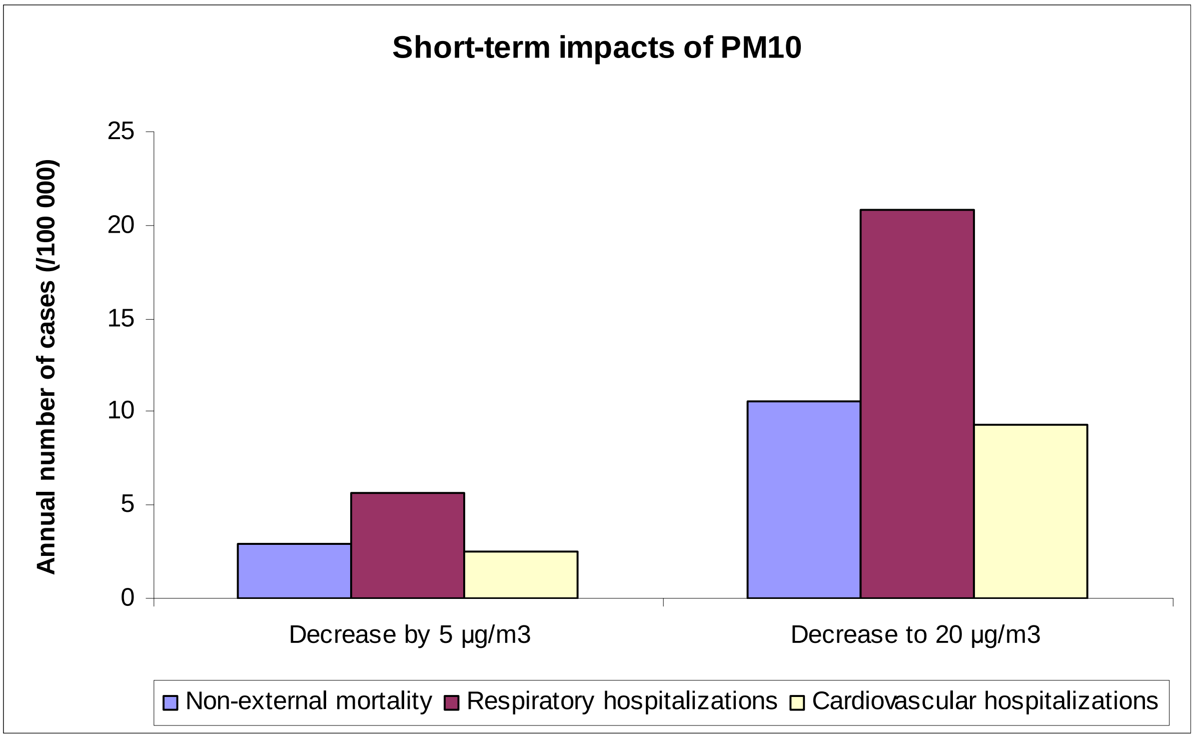


Figure 1.4.1.1: Potential benefits of reducing annual PM10 levels on mortality and on hospitalisations

1.4.2. Short-term impacts of ozone

For ozone, WHO set two guideline values for daily the maximum 8-hours mean. The interim target value (WHO-IT1) is set at 160 µg/m^3. The purpose of the interim value is to define steps in the progressive reduction of air pollution in the most polluted areas. The second value, the air quality guideline value (WHO-AQG) is set at 100 µg/m^3.

We first considered a scenario where all daily values above 160 µg/m^3 were reduced to WHO-IT (160 µg/m^3), then a scenario where all daily values above 100 µg/m^3 were reduced to WHO-AQG (100 µg/m^3), and lastly a scenario where the daily mean is decreased by 5 µg/m^3.

In case of scenario 2, all daily values of ozone were reduced to 100 µg/m^3, a total number of deaths postponed would be 2.95. In case of scenario 3, daily mean ozone level was decreased by 5 µg/m^3, a total number of deaths postponed would be 3.99.

In case of scenario 2, all daily values of ozone were reduced to 100 µg/m^3, a total annual number of respiratory hospitalisations of people age >64 postponed would be 1.81. In case of scenario 3, daily mean ozone level was decreased by 5 µg/m^3, a total annual number of respiratory hospitalisations (>64) postponed would be 2.44.

Table 1.4.2.1: 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	2,95	1
Decrease by 5 µg/m^3	3,99	1

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

Table 1.4.2.2: Potential benefits of reducing daily ozone levels on hospitalizations

	Respiratory hospitalizations (15-64)		Respiratory hospitalizations (>64)	
Scenarios	**Total annual number of cases potsponed**	**Annual number of cases potsponed per 100 000**	**Total annual number of cases potsponed**	**Annual number of cases potsponed per 100 000**
8h max daily values >160 μg/m^3 = 160 μg/m^3	0	0	0	0
8h max daily values >100 μg/m^3 = 100 μg/m^3	0,29	0	1,81	4
Decrease by 5 μg/m^3	0,39	0	2,44	5

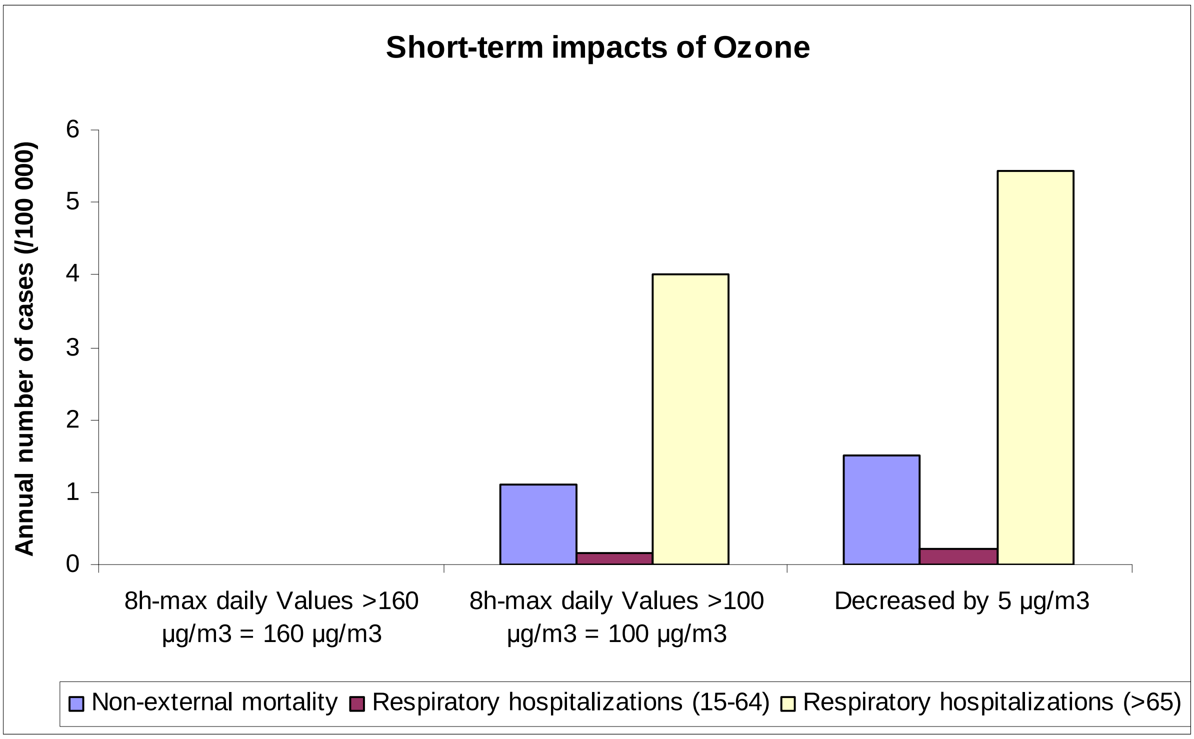


Figure 1.4.2.1: Potential benefits of reducing daily ozone levels on mortality and on hospitalisations

1.4.3. Long-term impacts of PM2.5

For PM2.5, we first considered a scenario where the PM2.5 annual mean is decreased by 5 μg/m^3, and then a scenario where the PM2.5 annual mean is decreased to 10 μg/m^3 (WHO AQG).

In case of scenario 1, the annual mean of PM2.5 was decreased by 5 μg/m^3, a total number of deaths postponed would be 66.44 and a gain in life expectancy 0.3, what represents approximately 4 months. In case of scenario 2, the annual mean of PM2.5 was decreased to 10 μg/m^3, a total number of deaths postponed would be 247.36 and a gain in life expectancy 1.2, what represents approximately 14 months.

Regarding potential benefits of reducing annual PM2.5 levels on total cardiovascular mortality: In case of scenario 1, the annual mean of PM2.5 was decreased by 5 µg/m^3, annual number of deaths postponed would be 49.45. In case of scenario 2, the annual mean of PM2.5 was decreased to 10 µg/m^3, a total annual number of cardiac hospitalisations postponed would be 177.19.

Table 1.4.3.1: 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	66,44	37	0,3
Decrease to 10 µg/m^3	247,36	138	1,2

Table 1.4.3.2: 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	49,45	27
Decrease to 10 µg/m^3	177,19	98

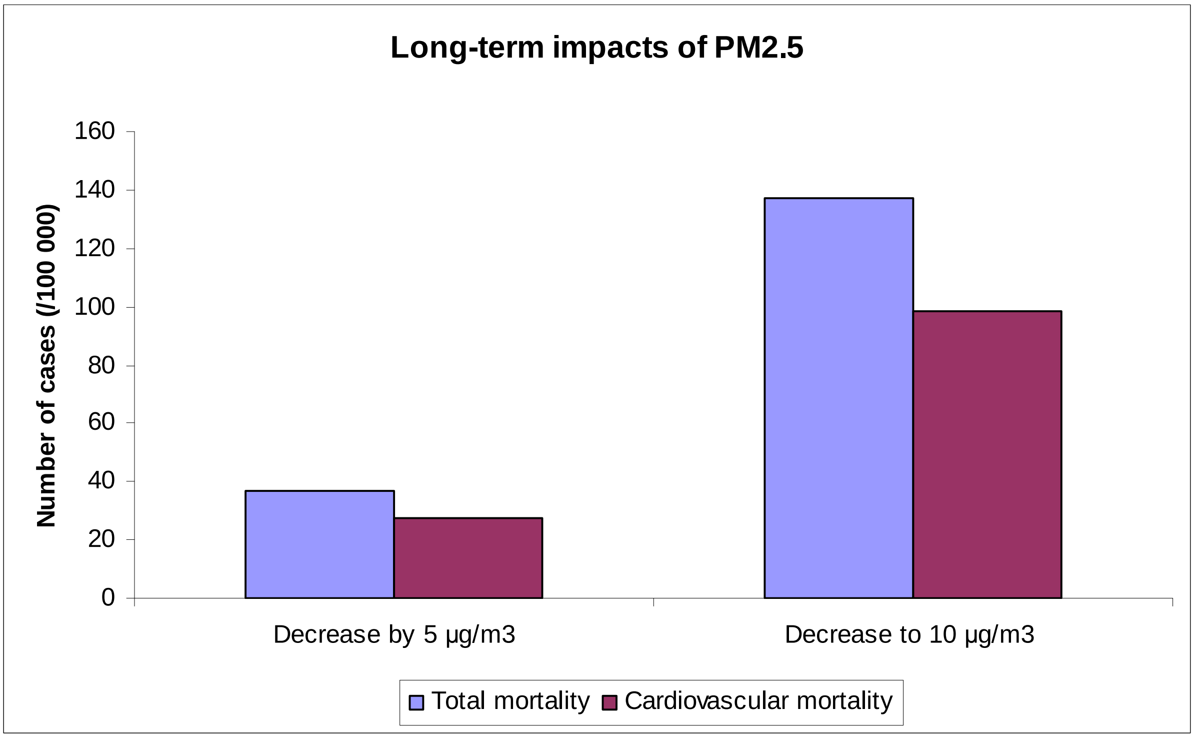


Figure 1.4.3.1: Potential benefits of reducing annual PM2.5 levels on mortality

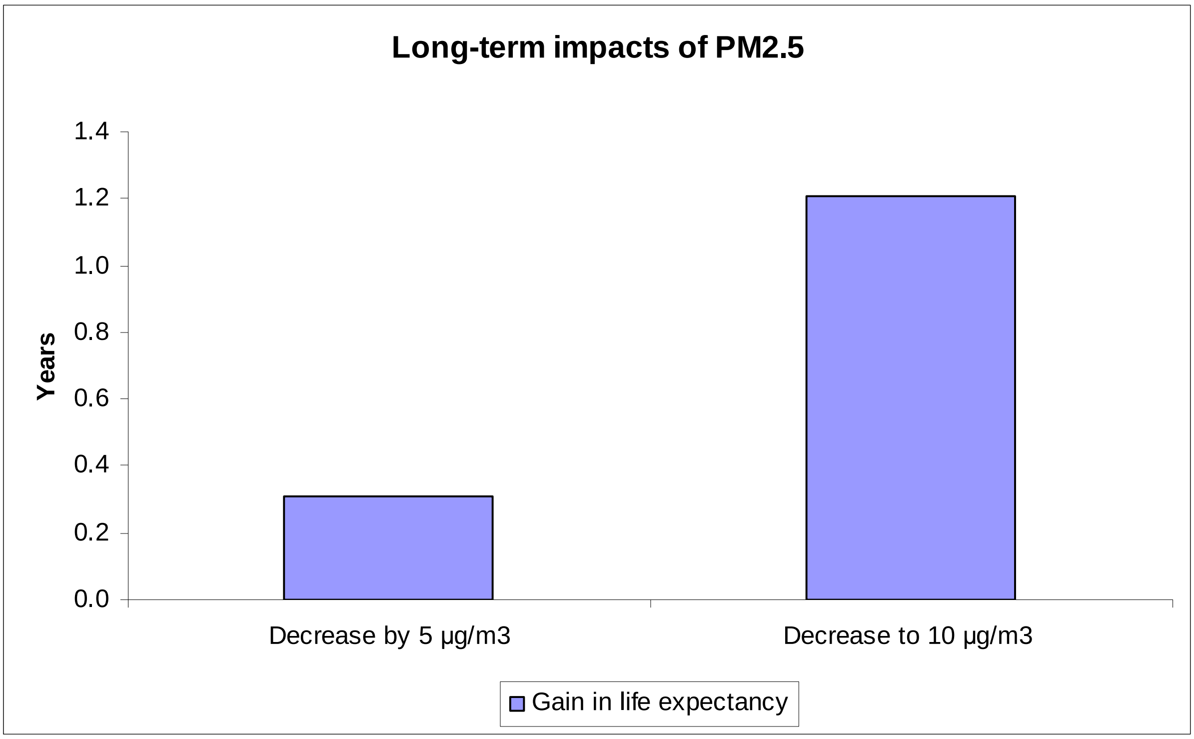


Figure 1.4.3.2: Potential benefits of reducing annual PM2.5 levels on life expectancy

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

Short-term impacts

PM 10
In case of scenario 1 (decrease by 5 µg/m^3) the monetary values spared would be 666.820€.
In case of scenario 2 (decrease to 20 µg/m^3) the monetary values spared would be 2.445.584€.

Ozone
In case of scenario 2 (8h max daily values >100 µg/m^3=100 µg/m^3) the monetary values spared would be 255.470€.
In case of scenario 3 (decrease by 5 µg/m^3) the monetary values spared would be 345.534€.

Long-term impacts

PM 2.5
In case of scenario 1 (decrease by 5 µg/m^3) the monetary values spared would be 109.958.200€.
In case of scenario 2 (decrease to 10 µg/m^3) the monetary values spared would be 409.380.800€.

Long-term life expectancy

The gain in life expectancy is calculated by long-term life expectancy calculations. The annual corresponding benefit is obtained: 144.203.462 €.
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 PM 2.5 (WHO`s Air Quality Guideline) instead of the current existing air pollution level in Ljubljana.

NOTE: the valuation of mortality benefits is based on stated preferences studies and will use common values for all cities together. Indeed, accounting for differences in country's GNP per capita seems ethically unacceptable to stand for the valuation of life benefits.

Hospitalisations

The standard cost of illness approach is used for short-term hospitalisations, and consists in applying unit economic values to each case, including direct and indirect costs.

The economic benefits related to a reduction in air pollution exposure is computed by multiplying the number of hospitalisations in Ljubljana by the corresponding unit economic value.

PM 10

In case of scenario 1 (decrease by 5 μg/m^3) the standard cost of illness is 34.102€ due to respiratory hospitalisations and 17.960€ due to cardiac hospitalisations.
In case of scenario 2 (decrease to 20 μg/m^3) the standard cost of illness is 124.629€ due to respiratory hospitalisations and 65.854€ due to cardiac hospitalisations.

Ozone

In case of scenario 2 (8h max daily values >100 μg/m^3=*100* μg/m^3) the standard cost of illness is 652 € due to respiratory hospitalisations (15-64) and 4069€ due to respiratory hospitalisations (>64).
In case of scenario 3 (decrease by 5 μg/m^3) the standard cost of illness is 877 € due to respiratory hospitalisations (15-64) and 5485€ due to respiratory hospitalisations (>64).

1.4.5. Interpretation of findings

Assessing both scenario we can see that already a small decrease in PM10 and ozone level has important influence on number of deaths postponed and on number of hospitalisations.

In case that the annual mean of PM10 was decreased by 5 μg/m3, a total number of deaths postponed would be 7.70, a total annual number of respiratory hospitalisations postponed would be 15.17 and total annual number of cardiac hospitalisations postponed would be 6.78. In case that the annual mean of PM10 was decreased to 20 μg/m3, a total number of deaths postponed would be 28.24, a total annual number of respiratory hospitalisations would be 55.44 and cardiac hospitalisations postponed would be 24.86.

In case that all daily ozone levels were reduced to 100 μg/m3, a total number of deaths postponed would be 2.95 and in case daily ozone level was decreased by 5 μg/m3, a total number of deaths postponed would be 3.99. This figures are not high because the level of ozone in Ljubljana is not so high - daily mean is 76 μg/m3 and the value of 160 μg/m^3 has not been reached from 2004 to 2006.

In case the annual mean of PM2.5 was decreased by 5 μg/m^3, a total number of deaths postponed would be 66.44, a gain in life expectancy would be 4 months and a total annual number of cardiac hospitalisations postponed would be 49.45. In case the annual mean of PM2.5 was decreased to 10 μg/m^3, a total number of deaths postponed would be 247.36 and a gain in life expectancy 14 months, a total annual number of cardiac hospitalisations postponed would be 177.19..

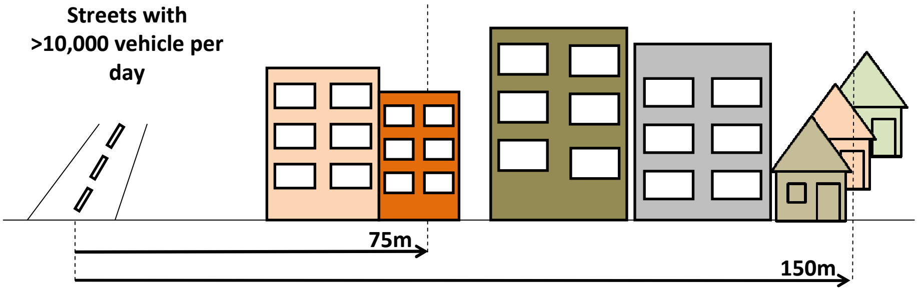
There are sources of uncertainty in our models like change of pollution during the day because of very local climatological characteristics, lifestyle (e.g. ventilation systems). We think that transferred CFS`s are appropriate even for local conditions, therefore we think, that we can take the results of the HIA with high confidence and consider them as real.

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 2.1: Estimated percentage of people leaving 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.

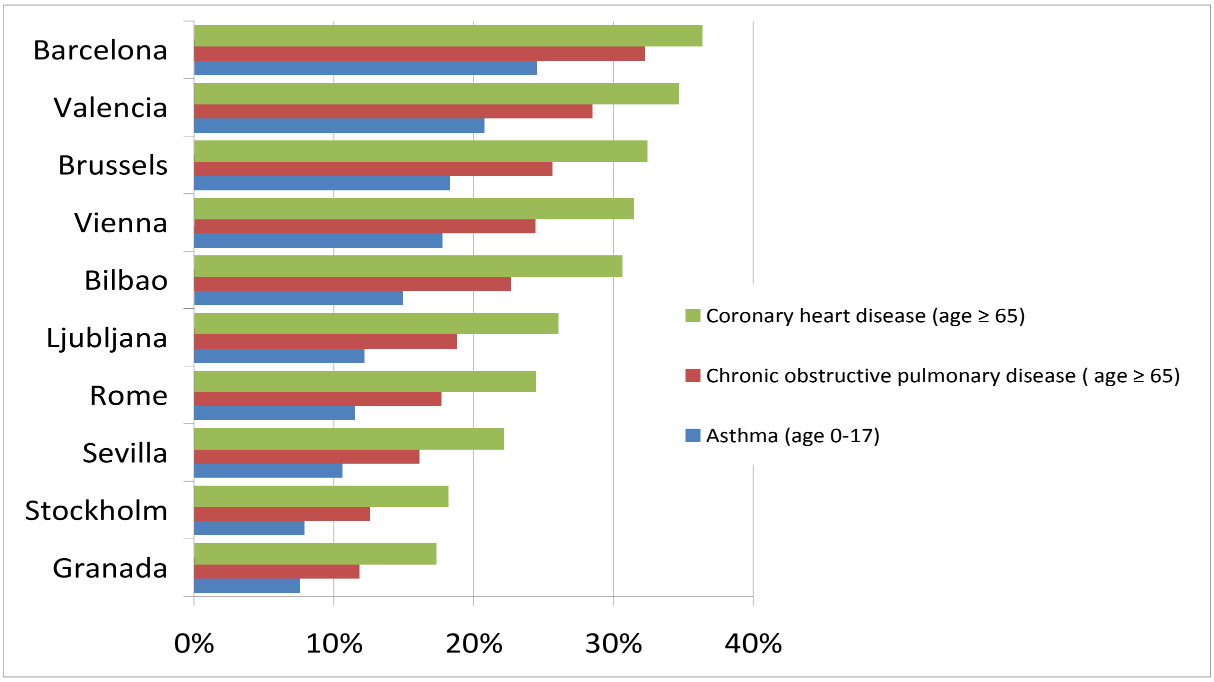


Figure 2.2: Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

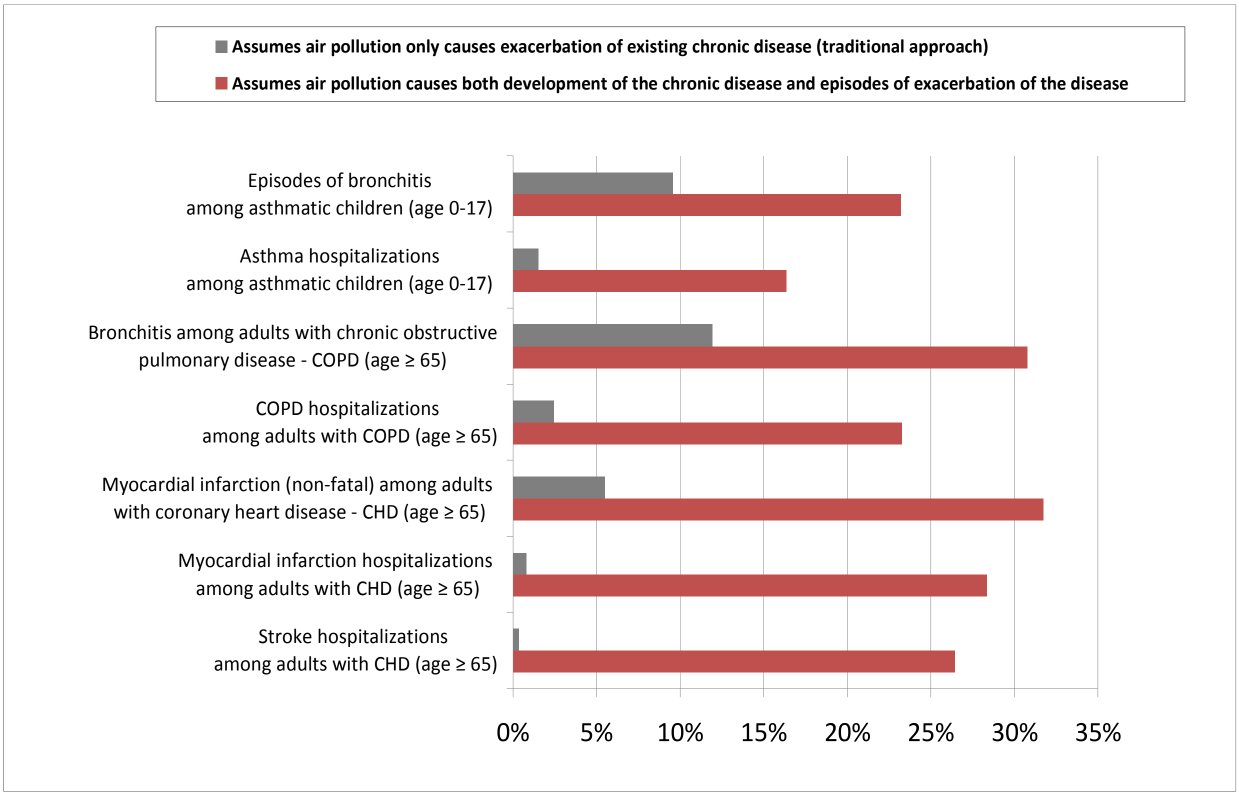


Figure 2.3: Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

In addition, for the population studied Aphekom estimated an economic burden of more than €300 million every year attributable to chronic diseases caused by living near heavy traffic. This burden is to be added to some €10 million attributable to exacerbations of these diseases.

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

Chapter 3. Health Impacts of Implemented Policies in Air Pollution

Beyond reviewing the documented benefits to health of the historic Dublin coal ban in 1990 and the recent implementation of congestion charges in London and Stockholm, Aphekom investigated the effects of EU legislation to reduce the sulphur content of fuels (mainly diesel oil used by diesel vehicles, shipping and home heating).

Our analysis in 20 cities showed not only a marked, sustained reduction in ambient SO2 levels but also the resulting prevention of some 2,200 premature deaths valued at €192 million.

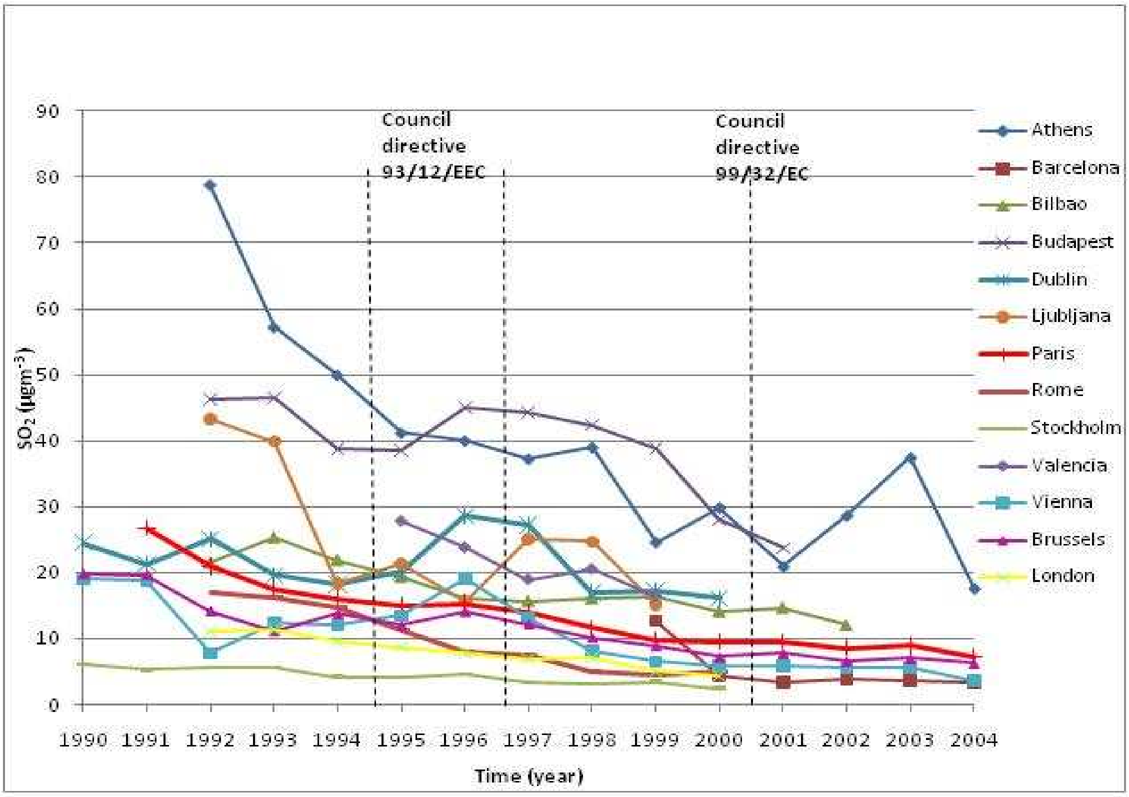


Figure 3.1: Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

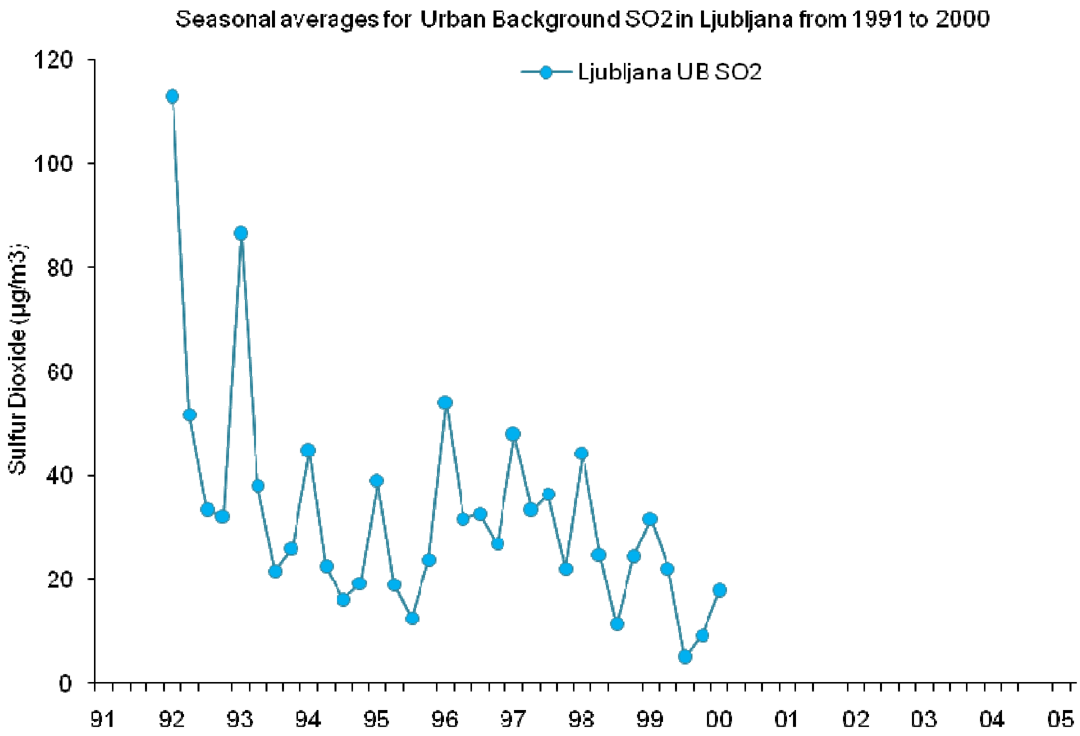


Figure 3.2: Plot of seasonal urban background SO_2 averages for Ljubljana from 1991 – 2000

Furthermore city specific observations for Ljubljana of decreasing UB SO_2 levels are presented in Figure 3.2 showing seasonal averages of UB SO_2 (please note change in scaling compared to Fig. 3.1).

A rather abnormal peak of very high urban background SO_2 levels was observed simultaneously in a number of centres in the winters of 1995/6 and 1996/7. This does not mean that there are no outlying peaks now and then during the studied period in SO_2 levels for individual centres. The fact that those peaks were observed in many centres simultaneously and that individual levels were quite high compared to years before and after the observed peaks caught the attention of the WP6 team. Ljubljana observed a slight peak from Dec 1995 to Feb 1996 and again in Jan 1997. The highest peaks were observed in Feb 1996.

Based on the feedback received from the individual centres the most likely reason for the observed peaks happening simultaneously in a number of cities was cold wave in the winter months with peaking SO_2 levels. This coincided with observation made for a number of cities analysing daily averaged temperature data that showed prolonged periods with peaks in minimum temperatures reached in this time period. These observed cold waves went with increased fuel usage due to the increased space heating and electricity usage and as well as inversion. Another possible factor contributing to the observed SO_2 peaks could be that countries used up old stockpiles of fuel that did not comply with the directives. That might have happened independently from the cold wave or due to the fuel shortage during the prolonged cold weather.

Figures 3.3 and Figure 3.4 show preliminary work done using hourly SO2 data from Vienna, Austria showing seasonal plots for winter (Fig.3.3) and summer (Fig 3.4) for a central urban station for the years 1990 to 2000. For example: In Figure 3.3 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. 3.3) 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. 3.4) 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. 3.3 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.

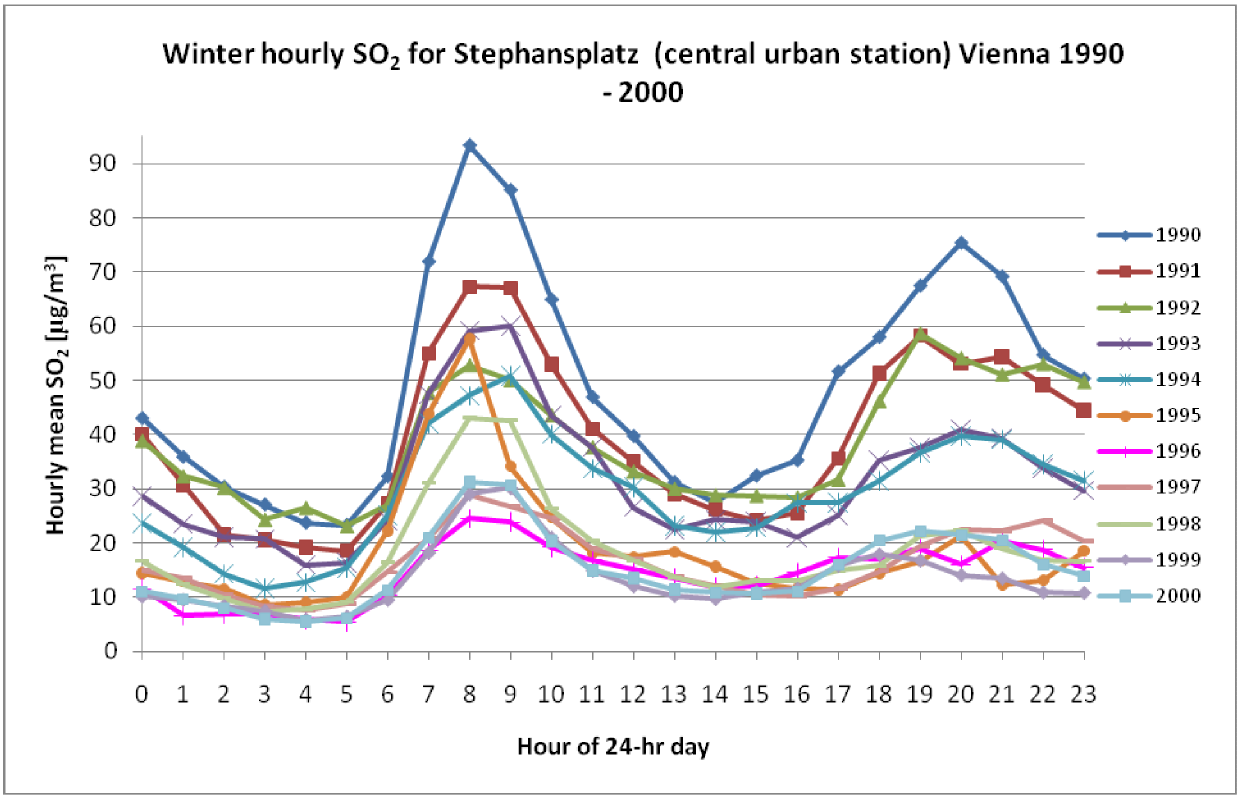


Figure 3.3: Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000

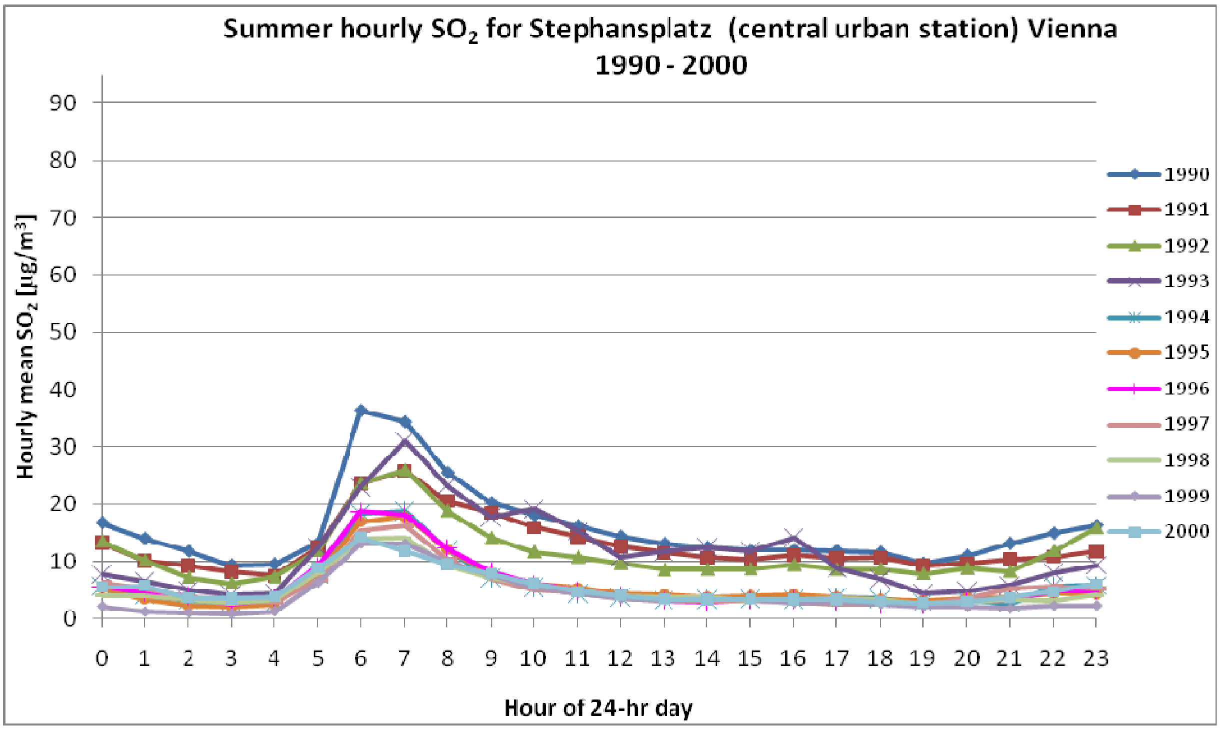


Figure 3.4: Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

Figure 3.5 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. 3.3 for Vienna, where 2 distinct peaks throughout the day for the winter months were observed, here in Fig.3.5 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.

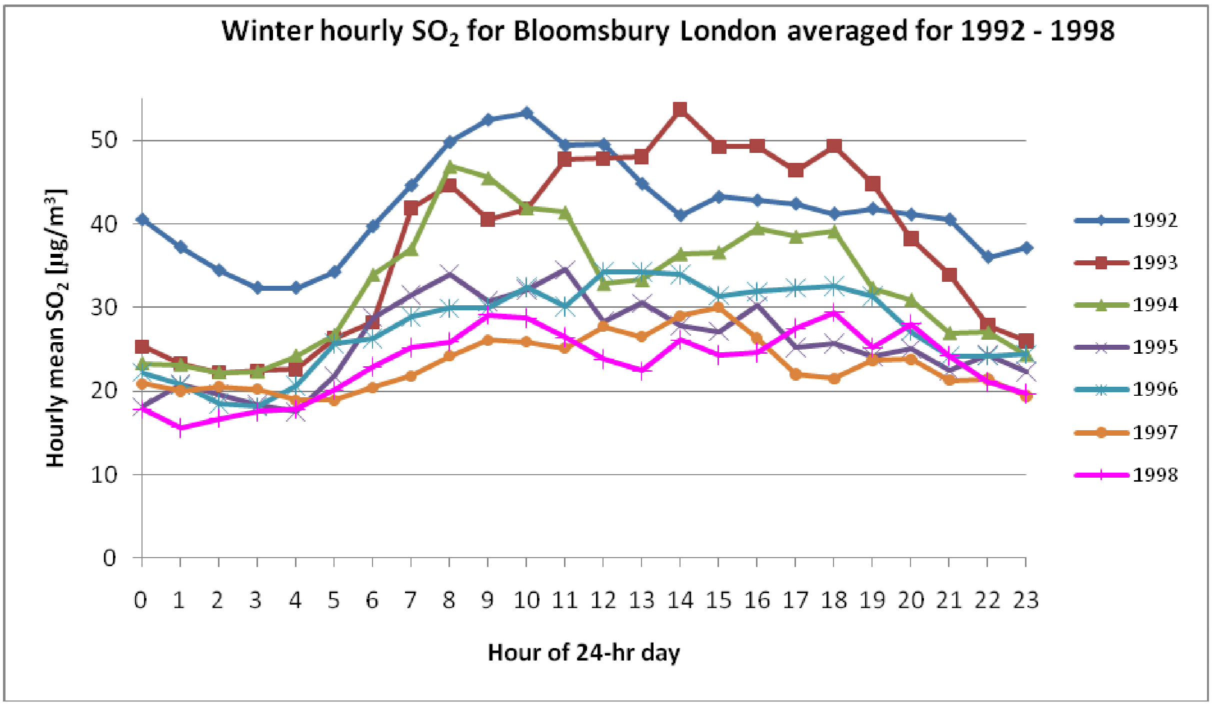


Figure 3.5: Diurnal plot of winter hourly SO_2 for an urban background station in London 1992-1998

Table 3.1: 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										
Centre	Time period	All cause mortality			Respiratory mortality			Cardiovascular Mortality		
		# 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 of intervention 3		596	208	987	26	-9	61	423	124	724

In Ljubljana, the implementation of one intervention stage in 2000 reduced annual deaths by 31 deaths from all causes, by 2 deaths from respiratory and by 15 deaths from cardiovascular causes compared to the baseline period with no directive being implemented.

One intervention stage in 2000 for 6 EU cities reduced annual deaths by 596 deaths from all causes, by 26 deaths from respiratory and by 423 deaths from cardiovascular causes compared to the baseline period with no directive being implemented.

Valuation of the benefits of EU legislation to reduce the sulphur content of fuels

The local estimates are not sufficiently robust at the city level to allow a local HIA so it has been decided to use the meta-results for the local economic valuation. The legislation has two potential effects on mortality: short-term and long-term. It was decided that, to take a conservative standpoint, mortality effects would be considered as short-term effects. The value of a life year (VOLY) was estimated to be €86,600. Our analysis in 20 cities showed not only a marked, sustained reduction in ambient SO_2 levels but also the resulting prevention of some 2,200 premature deaths valued at €192 million. The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation.

Chapter 4. Sharing Knowledge and Uncertainties with Stakeholders

Uncertainties perceived by scientists, policy makers and other stakeholders can undermine their confidence in the findings of HIAs. For this reason, Aphekom has developed a method that helps them discuss and share their views on both the uncertainties in HIA calculations and their impact on the decision-making process.

In addition, to help decision makers draft policies on air quality and related environmental-health issues, Aphekom has developed a process, based on a deliberation-support tool, that helps frame and structure exchanges between stakeholders working together. Using this process enables them to propose and discuss multiple criteria for evaluating, prioritising and aligning their various needs, and for choosing actions that match their objectives and preferences.

Chapter 5. Overview of findings and local recommendations

Traffic is the first and most important source of air pollution in most urban areas, also in Ljubljana. Traffic pollution is reflected in the emissions of nitrogen oxides, carbon monoxide, volatile organic compounds and particulate matter. It is estimated that air pollution in Ljubljana with PM10 causes the premature death. Moreover, this pollution causes a long-term highly adverse health effects on children, including poor lung development, asthma, allergies and respiratory infections. In this study we demonstrated that decrease in PM10 or PM2.5 will result in a lower number of deaths.

Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOC, also known as ozone precursors. Strong sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. Many urban areas tend to have higher levels of "bad" ozone and Ljubljana is not the exception even though the ozone levels are not so dangerously high. In this study we found out that fall in daily ozone level will result in lower number of deaths.

The city of Ljubljana has adopted Environmental Protection Program, which dictates the objectives and actions for the period from 2007 to 2013 (9).

They determined the order of priority problems and based on these they set four strategic objectives, which they will follow in the next five years:
- to establish a system of sustainable mobility,
- to ensure energy efficiency and renewable energy sources,
- to ensure long-term supply with a healthy drinking water,
- to establish environmental protection and green areas.

In order to reduce negative outcomes in Ljubljana, we suggest additional policy proposals and actions:

Use of technologies with low emissions
The sources of low emission technologies are often traditional fuels like coal, gas and oil. Low emission technologies use a range of key advanced technologies to significantly reduce greenhouse gas emissions levels, air-borne pollutants and other environmental impacts. Low emission technology also refers to vehicles that are electric, hybrid, gas or air powered.

Lowered taxes for low emission cars
Lower taxes for low emission cars encourage people to buy environmentally friendly cars at lower prices.
Amendment to the Motor Vehicles Tax Act proposed change in the level of taxation on gasoline automotive engines and diesel-powered engines and taxation of mopeds and motorcycles in 2012.

Better access to public services
Public transit can help achieve energy conservation, pollution emission reduction and greenspace preservation objectives.

'Back to nature' attitude
Walking or cycling, recycling, composting, use reusable bags, try and go for locally produced items with minimal food miles, turn the thermostat down a degree or two, ensure energy guzzling products are kept in a good working condition, Public Health Services should go on with oromoting new lifestyle.

Green transportation
Instead of using a diesel- or gasoline-based engine, we can use engines that work on a different fuel type. There are opportunities to make cars drive by using gas, hot air, steam or hydrogen as a car fuel, or by letting cars drive on electricity, for example through solar cells. All these opportunities have been researched and right now the electro engine seems most likely to be the solution of the future.
There are plans to replace part of the bus fleet with new buses, using gas and electric engines.

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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).

Health outcome and relative risks used in the HIA

HIA	Health outcome	Ages	RR per 10 µg/m^3	Ref
Short-term impacts of PM10	Non-external mortality	All	1.006 [1.004-1.008]	(4)
	Respiratory hospitalizations	All	1.0114 [1.0062-1.0167]	(5)
	Cardiac hospitalizations	All	1.006 [1.003-1.009]	(5)
Short-term impacts of O_3	Non-external mortality	All	1.0031 [1.0017-1.0052]	(6)
	Respiratory hospitalizations	15-64	1.001 [0.991-1.012]	(4)
	Respiratory hospitalizations	>=65	1.005 [0.998-1.012]	(4)
Long-term impacts of PM2.5	Non-external mortality	>30	1.06 [1.02-1.11]	(7)
	Cardiovascular mortality	>30	1.12 [1.08-1.15]	(8)

PM10

For PM10, we first considered a scenario where the annual mean of PM10 is decreased by 5 µg/m^3, and then a scenario where the same PM10 annual mean is decreased to 20 µg/m^3, the WHO air quality guideline (WHO-AQG).
The exposure indicator of PM10 was the annual mean, calculated as the arithmetic mean of the daily concentrations of the selected stations. The corresponding Δx for the two scenarios are:

- Scenario 1, $\Delta x = 5\ \mu g/m^3$
- 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 $\mu g/m^3$. 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 $\mu g/m^3$.

We first considered a scenario where all daily values above 160 $\mu g/m^3$ were reduced to WHO-IT (160 $\mu g/m^3$), then a scenario where all daily values above 100 $\mu g/m^3$ were reduced to WHO-AQG (100 $\mu g/m^3$), and lastly a scenario where the daily mean is decreased by 5 $\mu g/m^3$.

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 $\mu g/m^3$. $\Delta x = 5\ \mu g/m^3$

PM2.5

For PM2.5, we first considered a scenario where the PM2.5 annual mean is decreased by 5 $\mu g/m^3$, and then a scenario where the PM2.5 annual mean is decreased to 10 $\mu g/m^3$ (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.

Average lengths of stay, daily hospitalisation costs and work loss, and total hospitalisations cost per patient.

Country	Average length of stay in days[a]		Average cost per day (€ 2005)		Total costs related to hospitalisation (€ 2005)	
	Circulatory system	Respiratory system	Hosp. all causes[b]	Work loss[c]	Circulatory system	Respiratory system
Austria	8.2	6.6	319	83	3,977	3,201
Belgium	9.2	8.8	351	98	5,032	4,814
France	7.1	7.1	366	83	3,777	3,777
Greece	7.0	5.0	389	48	3,395	2,425
Hungary	7.4	6.5	59	18	703	618
Ireland	10.5	6.9	349	81	5,366	3,526
Italy	7.7	8.0	379	62	3,873	4,024
Romania	8.5[d]	7.4[d]	57	6	587	511
Slovenia	8.6	7.3	240	34	2,649	2,248
Spain	8.5	7.4	321	55	3,664	3,189
Sweden	6	5.2	427	92	3,666	3,177
United Kingdom	11.4	8.0	581	116	9,268	6,504
Mean[d]	**8.5**	**7.4**	**373**	**73**	**4,411**	**3,840**

Sources: *[a] OECD Health Data (2010); [b] CEC (2008), annex 7, cost/bed/day corr; [c] Eurostat (2003); [d] population-weighted average, 2005 population data from OECD Health Data (2010).*

For instance, based on Table 1, the average direct cost of a cardiac hospital admission is:

8.5 days x € 373= € 3,171

and the corresponding indirect cost related to work loss is:

2 x 8.5 days x € 73= € 1,241.

Overall, the unit economic value related to a cardiac hospital admission is € 4,412.

For city-specific valuation, the last two columns of Table 1 provide average hospitalisation costs computed following the same rationale but using country-specific average lengths of stay, cost per day of hospitalization and daily work loss.

Valuation of the benefits of EU legislation to reduce the sulphur content of fuels

The legislation has two potential effects on mortality: short-term and long-term. It has been decided that, to take a conservative standpoint, mortality effects will be considered as short-term effects. Consequently, *a VOLY of €86,600 is applied to each premature deaths to compute the benefits of the legislation.* The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation.

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To learn more

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