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

Local city report

Toulouse

G. Falq[1], N. Sauthier[2], M.Pascal[1], M. Corso[1], A. Ung[1], O. Chanel[3], C. Declercq[1], S. Medina[1]

[1]French Institute for Public Health Surveillance, InVS, Saint-Maurice, France

[2]Regional Office of InVS, Toulouse, France

[3]National Center for Scientific Research, GREQAM and IDEP, Marseille, France

Summary

The Psas program (www.invs.sante.fr/surveillance/psas9/), which monitors air pollution and health in France, has contributed to the health impact assessments (HIA) of urban air pollution carried out in 25 European cities by the Aphekom project (Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe, www.aphekom.org). Institut de Veille Sanitaire (InVS) has coordinated both projects.

Because informing decision-making at the city level remains a core focus of both projects, we have broken the HIAs out for each participating city to highlight its local specificities.

We chose various scenarios for reducing exposure to particulate matter and ozone and we used different tools and exposure/response functions to estimate the short and long term health impacts of the different pollutants. Below appears the HIA findings for the city of Toulouse.

A health gain would be achieved by lowering the PM concentrations. The compliance with the WHO-AQG for PM10 (20µg/m3) would induce benefits on mortality and hospital admissions (5 deaths and 24 hospital admissions avoided per year). The associated monetary gain would be of more than €1 million.

Lowering PM2.5 would have a greater impact. Compliance with the WHO-AQG of 10 µg/m3 would postpone 105 deaths, corresponding to a gain in life expectancy of 0.3 years per inhabitants. Considering the reduced mortality, the associated monetary gain would be more than €170 million. The gain in life expectancy would be valued approximately €290 million.

The results from the present HIAs may help promoting measures aiming at reducing air pollutant emissions, especially traffic linked emissions, as health benefits are a powerful way of motivating changes in individuals comportments.

In addition, the Aphekom project was able to show that living near streets and roads carrying heavy traffic may have serious health effects, particularly on the development of chronic diseases. Aphekom also investigated the effects of EU legislation to reduce the sulphur content of fuels (mainly diesel oil used by diesel vehicles, shipping and home heating) showing in 20 cities 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.

Together these findings show that policies aiming at reducing air pollution would be associated with a significant improvement in the health status and quality of life of European citizens.

Acronyms

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

HIA: health impact assessment

O3: ozone

PM10: particulate matter with an aerodynamic diameter <10 µm

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

Introduction

Much has been done in recent years in European cities to reduce air pollution and its harmful effects on health. Yet gaps remain in stakeholders' knowledge and understanding of this continuing threat that hamper the planning and implementation of measures to protect public health more effectively.

Sixty Aphekom scientists have therefore worked for nearly 3 years in 25 cities across Europe to provide new information and tools that enable decision makers to set more effective European, national and local policies; health professionals to better advise vulnerable individuals; and all individuals to better protect their health.

Ultimately, through this work the Aphekom project hopes to contribute to reducing both air pollution and its impact on health and well being across European cities.

Section 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.

In 2002, the Apheis project found that in Toulouse, 60 deaths per year could be avoided by reducing PM2.5 levels to 15 µg/m3. This corresponded to a gain in life expectancy of 28 years cumulated for the whole population. Reducing PM10 levels to 20 µg/m3 would avoid 15 deaths and 39 hospitalisations for respiratory diseases per year. The following Enhis project further found that reducing PM10 daily mean values to 20 µg/m3 would prevent 5 hospital respiratory admissions of children under 15 years old. Each reduction by 10 µg/m3 of the daily maximum 8-hour moving average ozone concentrations would delay 7 deaths per year in the general population in the study area, 3 from cardiovascular diseases, and 2 from respiratory causes. In terms of hospital admissions, this would represent 1.5 respiratory admissions in the adult (15-64 years old) population and 5 in the population over 64 years.

Building on the experience gained in the 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.

This work shows that a decrease to 10 micrograms/cubic metre of long-term exposure to PM2.5 fine particles (WHO's annual air-quality guideline) could add up to 22 months of life expectancy at age 30, depending on the city and its average level of PM2.5.

Hence, exceeding the WHO air-quality guideline on PM2.5 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.

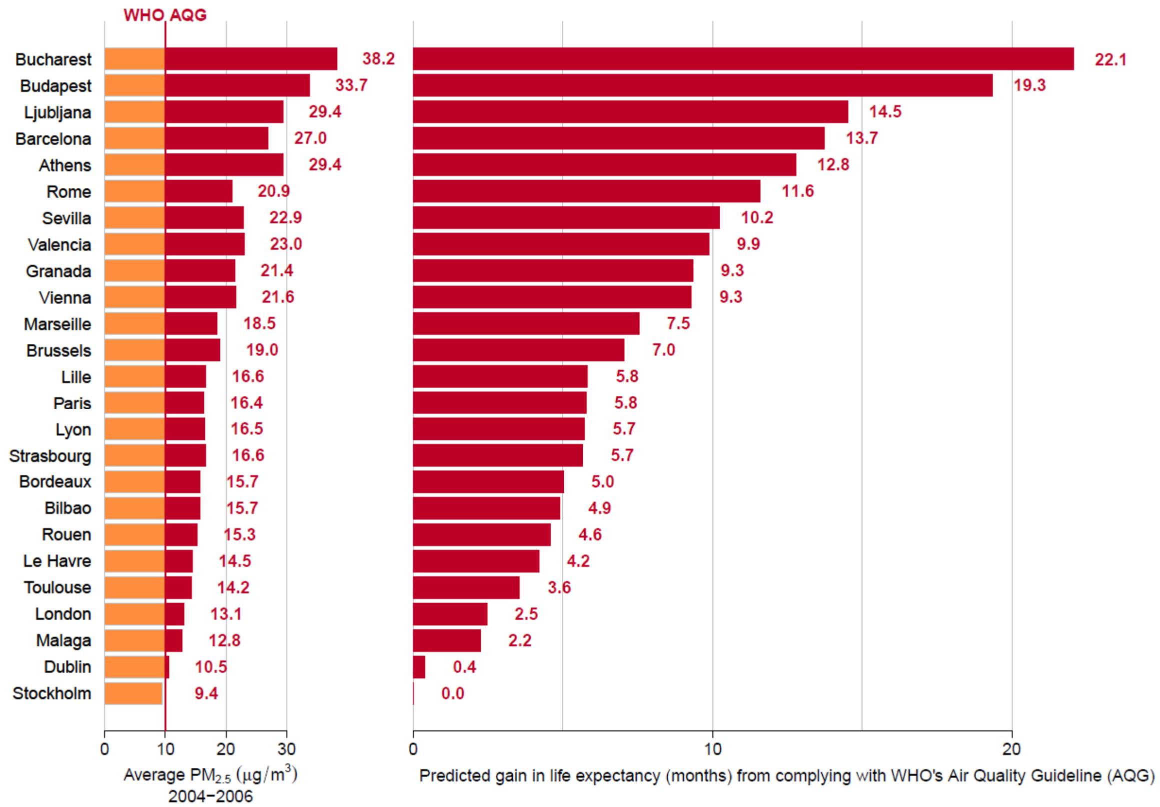


Figure 1: Predicted average gain in life expectancy (months) for persons 30 years of age in 25 Aphekom cities for a decrease in average annual level of PM2.5 to 10 µg/m3 (WHO's Air Quality Guideline)

1.1. Description of the study area for Toulouse

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.

The Toulouse study area is situated in the district of Haute-Garonne and includes 51 municipalities. It covers 530 km2. The area is characterized by a low population density compared to other urban centres, and by heavy traffic between the suburbs and the town centre.

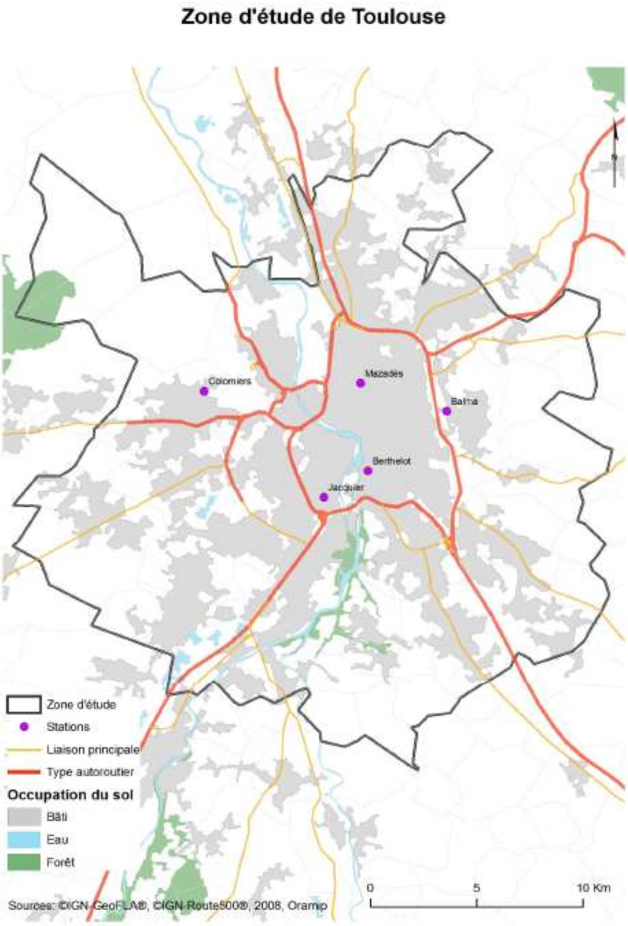


Figure 2 – Map of the study area

Climatology

Toulouse is located in a plain influenced by an oceanic climate. There are two types of prevailing winds, the first from west is wet and the second (Autan wind) from south-east is drier and warmer. The mean temperatures vary between 9.6℃ in winter and 18.7℃ in summer. Most of the rains come from Atlantic Ocean: annual mean of 650 mm of rain and 715 hours of rain. The mean relative humidity is 53.3%.

Population in the study area

The population in the study area in 2006 is estimated to 744,281 inhabitants, corresponding to a population density 1 404 inhabitants/km2. 170 301 inhabitants (13.3%) were older than 65.

Commuting

About 90% of the commuting occurred within the study area.

Table 1 – List of the municipalities in the study area

Municipality	ZIP Code	Communes	ZIP Code
Aucamville	31022	Mondonville	31351
Aureville	31025	Mondouzil	31352
Auzeville-Tolosane	31035	Montberon	31364
Auzielle	31036	Montrabe	31389
Balma	31044	Pechabou	31409
Beaupuy	31053	Pechbonnieu	31410
Beauzelle	31056	Pechbusque	31411
Blagnac	31069	Pin-Balma	31418
Castanet-Tolosan	31113	Pinsaguel	31420
Castelginest	31116	Plaisance-Du-Touch	31424
Colomiers	31149	Portet-Sur-Garonne	31433
Cornebarrieu	31150	Quint-Fonsegrives	31445
Cugnaux	31157	Ramonville-Saint-Agne	31446
Daux	31160	Rebigue	31448
Escalquens	31169	Roques	31458
Flourens	31184	Roquettes	31460
Fonbeauzard	31186	Saint-Alban	31467
Frouzins	31203	Saint-Jean	31488
Goyrans	31227	Saint-Loup-Cammas	31497
La Salvetat-Saint-Gilles	31526	Saint-Orens-De-Gameville	31506
Labege	31254	**Toulouse**	**31555**
Lacroix-Falgarde	31259	Tournefeuille	31557
Launaguet	31282	Vieille-Toulouse	31575
Lauzerville	31284	Vigoulet-Auzil	31578
L'Union	31561	Villeneuve-Tolosane	31588
Mervilla	31340		

1.2. Sources of air pollution and exposure data

Sources

Regarding sulfur dioxide, about 43% of the emissions are represented by tertiary and residential sectors, 38% by industry/ garbage incineration, and 19% by traffic. Conversely, traffic is the main source of PM10 emissions and represents about 70% of nitrogen oxides emissions. In the study area, the levels of nitrogen oxides measured near road traffic areas are higher than the national air quality guideline (40 µg/m3).

Table 1 – Main sources of air pollution (Oramip 1999/2000)

Pollutant	Transportation (road, planes, trains)	Residential/tertiary sector	Industry/waste management	Other sources
SO2	38%	43%	19%	-
NO_2	74%	8%	18%	-
Primary PM_{10}	NA*	NA*	NA*	NA*
Primary $PM_{2.5}$	NA*	NA*	NA*	NA*

* Not available

Exposure data

Air pollutants have been monitored by the Toulouse air-quality network Oramip. All the background stations within study area were used to build the exposure indicators for the period 2004-2006: 3 urban stations were used (Berthelot: PM10, PM2,5, O3), Mazades (PM10, PM2,5, O3) and Jacquier: PM10, O3) and 2 peri-urban stations were used for ozone (Balma and Colomiers).

Ozone concentrations are measured by Ultraviolet photometric method. PM10 and PM2.5 concentrations are measured by quartz microbalance method (TEOM).

Since the concentration response functions were obtained using a gravimetric method, Aphekom recommended to correct TEOM PM in order to compensate losses of volatile compounds. In Toulouse, as part of the French national pilot program for PM surveillance, specific polynomial regression has been used for each city PM10 correction. The coefficients of these regressions were derived from parallel PM measurements within each city.

PM10 and PM2.5 daily exposure indicator has been calculated as the arithmetic mean of the daily concentrations of the three urban stations. The daily maximum 8-hour moving average of each day has been calculated as the arithmetic mean of the maximum 8-hour moving averages of the stations.

Corrected PM10 annual mean were below the limit value for 2005 (40µg/m3), but higher than the limit value for 2010 (20µg/m3). The daily maximum 8-hour moving average has been higher than 100µg/m3 during 251 days between 2004 and 2006.

Daily 8-hour maximum ozone levels (Figure) show a large variability between winter and summer, while daily corrected PM10 (Figure) and PM2.5 (Figure) levels show a smaller variability.

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)	78	29	31	122
PM10 corrected (daily average)	22	10	9	41
PM2.5 corrected (daily average)	14	7	6	28

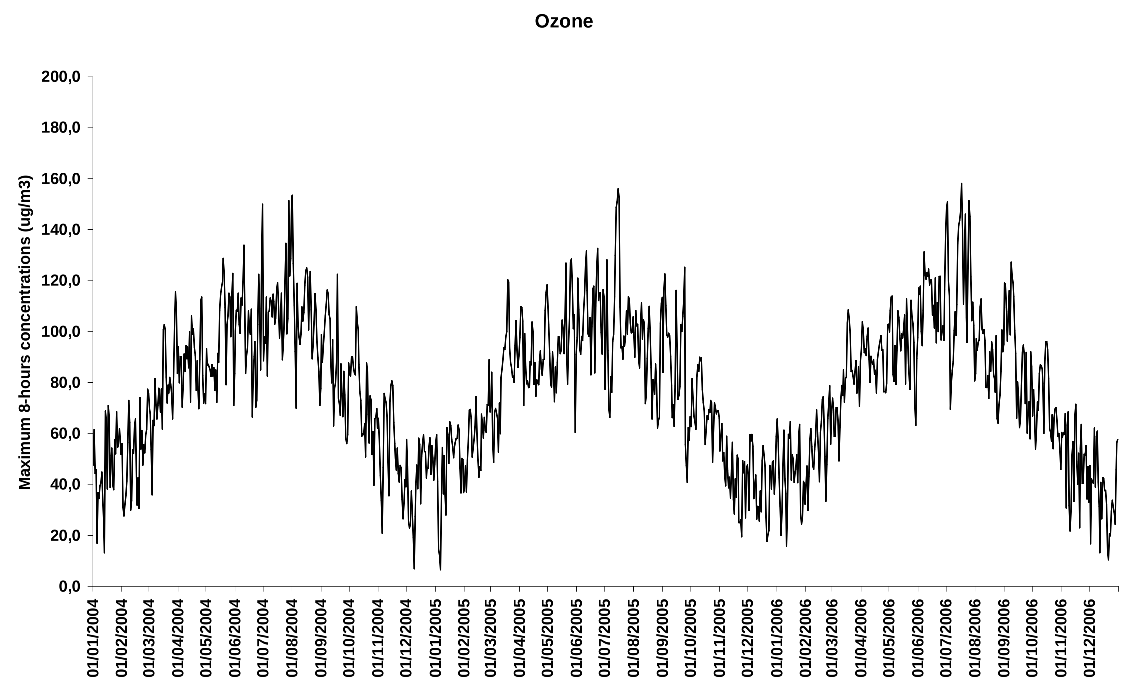


Figure 3 – Ozone concentration in the study area

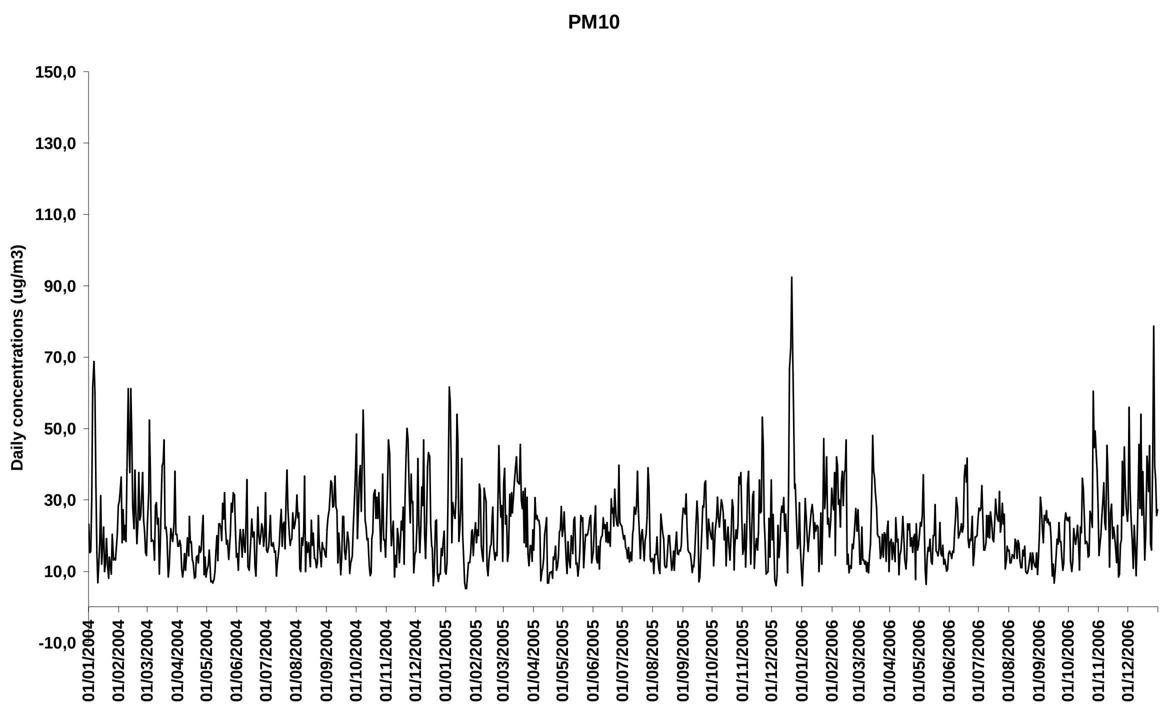


Figure 4 – PM10 concentration in the study area

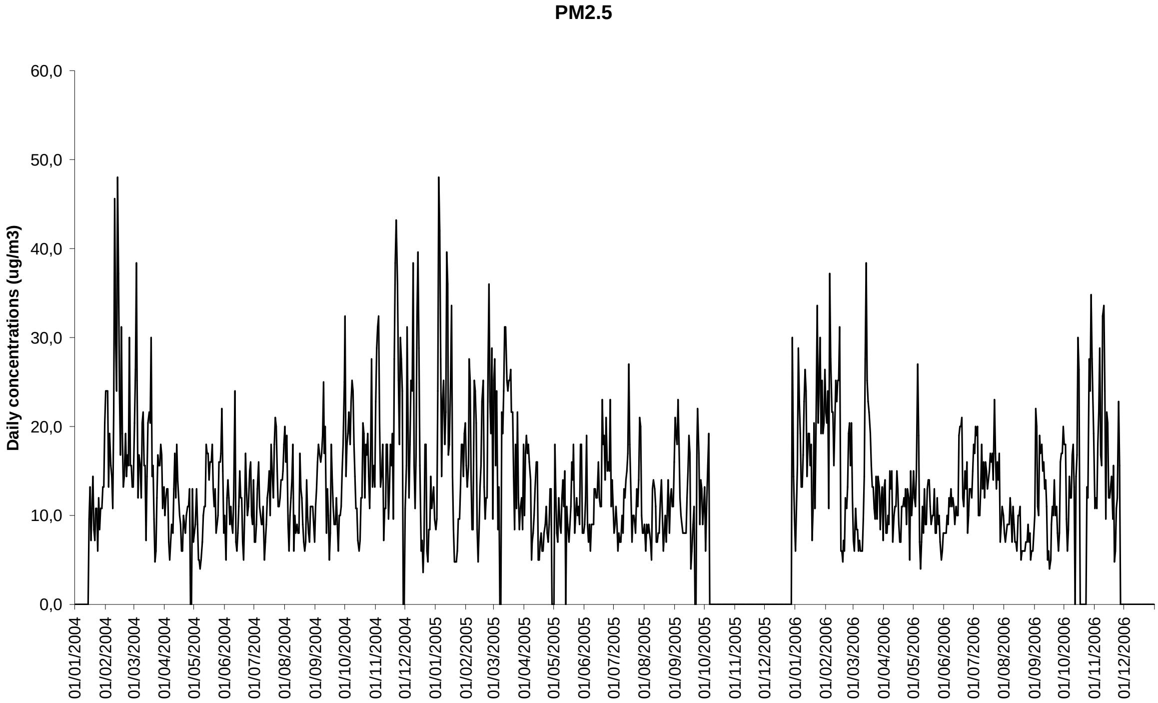


Figure 5 – PM2.5 concentration in the study area

1.3. Health data

Mortality data were obtained from the CepiDC at the National Health and Medical Research Institute (INSERM). Death causes were coded according to ICD-10.

Data on hospitalisations for cardiovascular and respiratory diseases were provided by the Hospital Information Technical Agency (ATIH), from the hospital information system PMSI (Programme de médicalisation des systèmes d'information) for public and private hospitals in Toulouse. Respiratory diseases were coded according to ICD-10.

The number of non-external deaths in the general population was 4179 (annual rate 562 per 100,000 inhabitants). The number of deaths for total mortality in the population aged 30 years and more was 4340 (annual rate 1023 per 100,000 inhabitants), among which 1287 (annual rate 303 per 100,000 inhabitants) were due to cardiovascular causes.

Table 3 ─ Annual mean number and annual rate of deaths and hospitalisations per 100 000 inhabitants (2004 - 2006)

Health outcome	ICD9	ICD10	Age	Annual mean number	Annual rate per 100 000
Non-external mortality*	< 800	A00-R99	All	4179	562
Total mortality	000-999	A00-Y98	> 30	4340	1023
Cardiovascular mortality	390-429	I00-I52	> 30	1287	303
Cardiac hospitalisations	390-429	I00-I52	All	6876	924
Respiratory hospitalisations	460-519	J00-J99	All	7583	1019
Respiratory hospitalisations	460-519	J00-J99	15-64 yrs	2992	402
Respiratory hospitalisations	460-519	J00-J99	≥ 65 yrs	2499	336

* 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 and HIA tools are provided in http://si.easp.es/aphekom.

Here we present a summary of our HIA method.

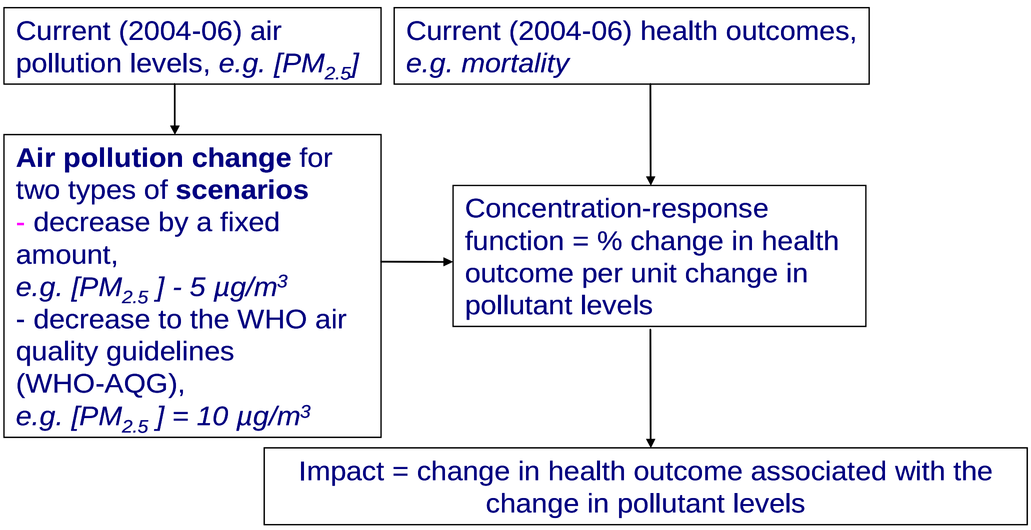


Figure 6 – Principles of local health impact assessment (HIA)

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/m3, and then a scenario where the PM10 annual mean is decreased to 20 µg/m3, the WHO annual air quality guideline (WHO-AQG).

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	12	2
Decrease to 20 µg/m^3	5	1

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

Table 5 – Potential benefits of reducing annual PM10 levels on hospitalisations

	Respiratory hospitalisations		Cardiac hospitalisations	
Scenarios	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**	**Total annual number of cases postponed**	**Annual number of cases postponed per 100 000**
Decrease by 5 µg/m^3	43	6	21	3
Decrease to 20 µg/m^3	16	2	8	1

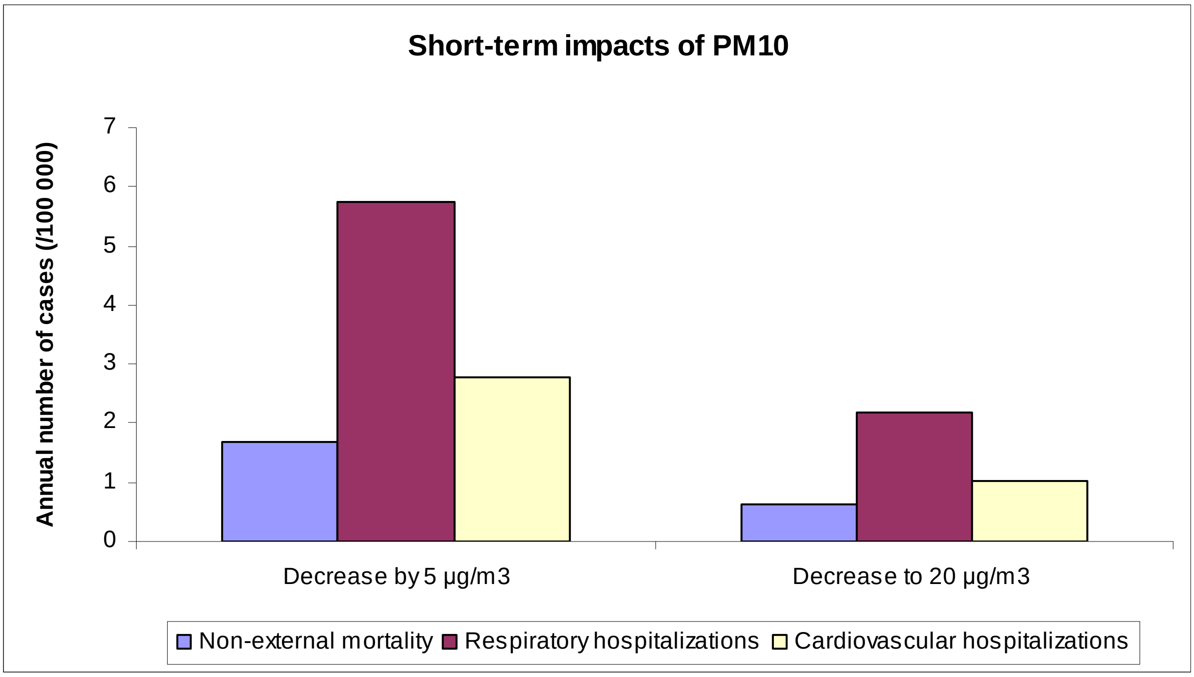


Figure 7 – Potential benefits of reducing annual PM10 levels on mortality and on hospitalisations

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/m3. 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/m3.

We first considered a scenario where all daily values above 160 µg/m3 were reduced to WHO-IT (160 µg/m3), then a scenario where all daily values above 100 µg/m3 were reduced to WHO-AQG (100 µg/m3), and lastly a scenario where the daily mean is decreased by 5 µg/m3.

Ozone values were below 160 µg/m3 during the whole study period. Decreasing values above 100 µg/m3 to 100 µg/m3 would postpone 4 deaths, 1 hospitalisation for respiratory diseases for people aged 15 to 64, and 4 hospitalisations for respiratory diseases for people older than 65.

Reducing all concentrations by 5 µg/m^3, would postpone 6 deaths, 1 hospitalisations for respiratory diseases for people between 15 to 64 year and 6 hospitalisations for respiratory diseases for people older than 65.

Table 6 – Potential benefits of reducing daily ozone levels on total non-external* mortality

Scenarios	Total annual number of deaths postponed	Annual number of deaths postponed per 100 000
8h max daily values >160 µg/m^3 = 160 µg/m^3	0	0
8h max daily values >100 µg/m^3 = 100 µg/m^3	4	1
Decrease by 5 µg/m^3	6	1

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

Table 7 – Potential benefits of reducing daily ozone levels on hospitalisations

	Respiratory hospitalisations (15-64)		Respiratory hospitalisations (>64)	
Scenarios	**Total annual number of cases potsponed**	**Annual number of cases potsponed per 100 000**	**Total annual number of cases potsponed**	**Annual number of cases potsponed per 100 000**
8h max daily values >160 µg/m^3 = 160 µg/m^3	0	0	0	0
8h max daily values >100 µg/m^3 = 100 µg/m^3	1	0.2	4	4
Decrease by 5 µg/m^3	1	0.3	6	6

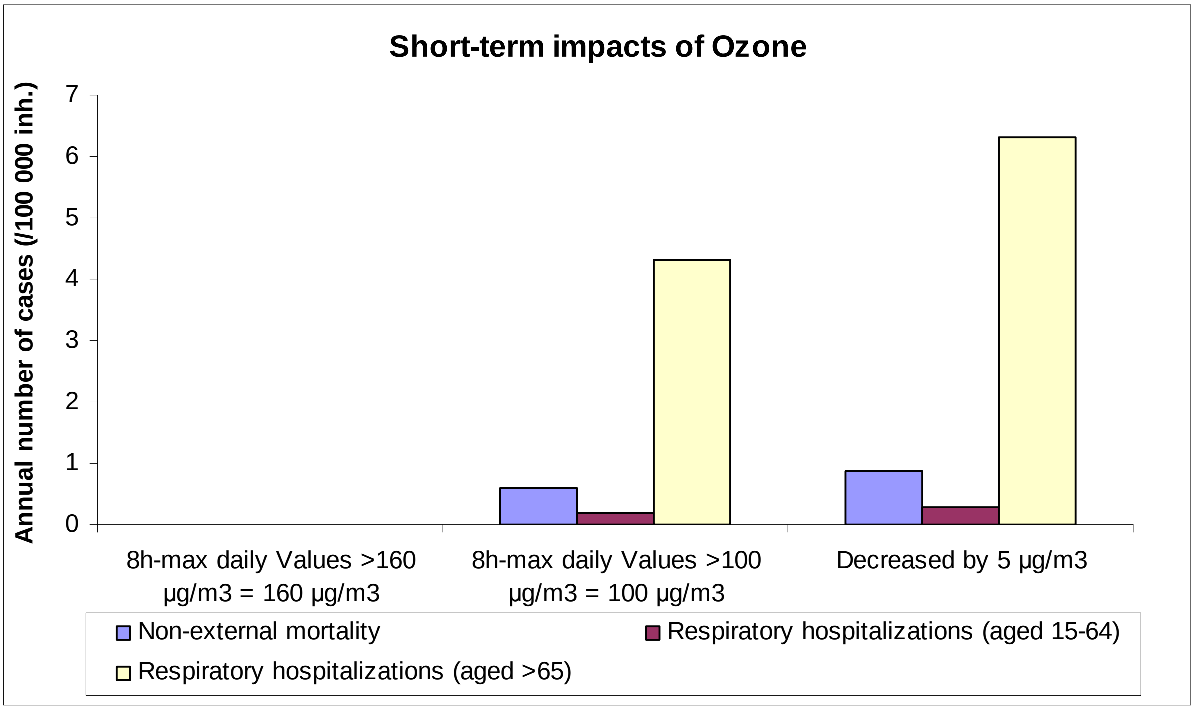


Figure 8 – Potential benefits of reducing daily ozone levels on mortality and on hospitalisations

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/m3, and then a scenario where the PM2.5 annual mean is decreased to 10 µg/m3 (WHO AQG).

Decreasing concentrations by 5 µg/m3 would postpone 125 deaths, and 71 deaths for cardiovascular causes. This corresponds to a gain in life expectancy of 0.4 years per inhabitant.

Decreasing concentrations to 10 µg/m3 would postpone 105 deaths, and 60 deaths for cardiovascular causes. This corresponds to a gain in life expectancy of 0.3 years per inhabitant.

Table 8 – Potential benefits of reducing annual PM2.5 levels on total non-external* mortality and on life expectancy

Scenarios	**Total annual number of deaths postponed**	**Annual number of deaths postponed per 100 000**	**Gain in life expectancy**
Decrease by 5 µg/m^3	125	29	0.4
Decrease to 10 µg/m^3	105	25	0.3

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

Table 9 – Potential benefits of reducing annual PM2.5 levels on total cardiovascular mortality

Scenarios	**Total annual number of deaths posponed**	**Annual number of deaths postponed per 100 000**
Decrease by 5 µg/m^3	71	17
Decrease to 10 µg/m^3	60	14

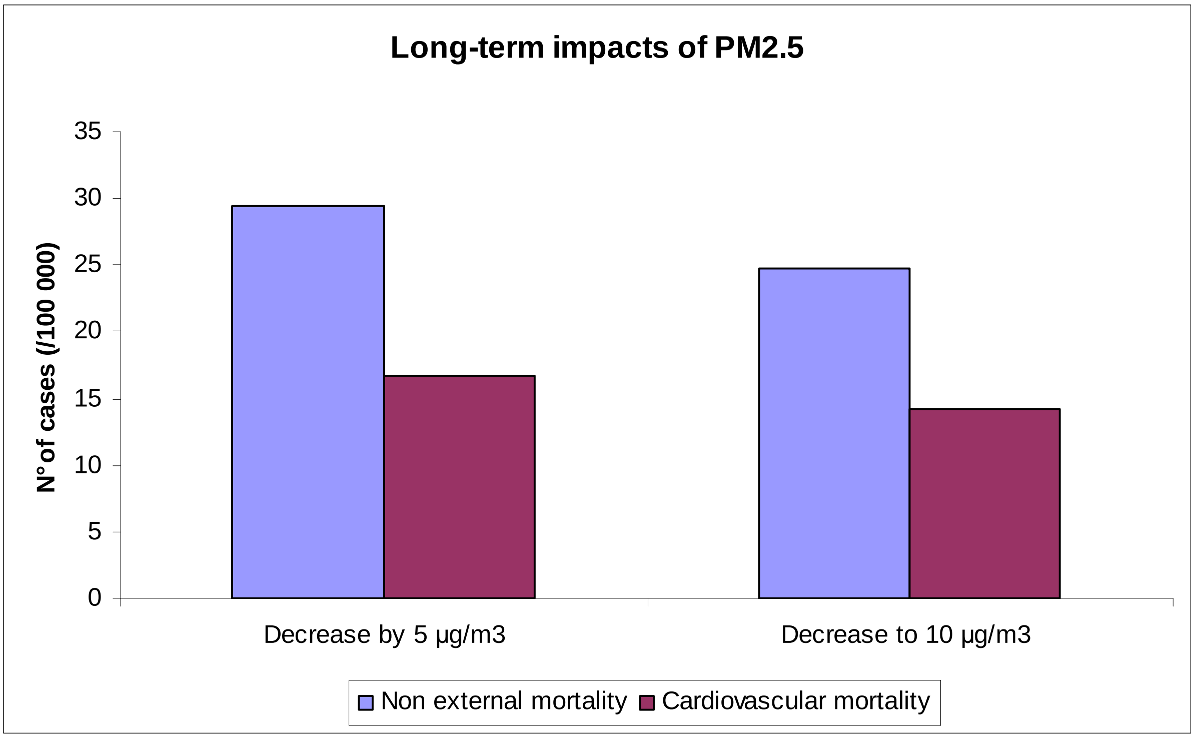


Figure 9 – Potential benefits of reducing annual PM2.5 levels on mortality

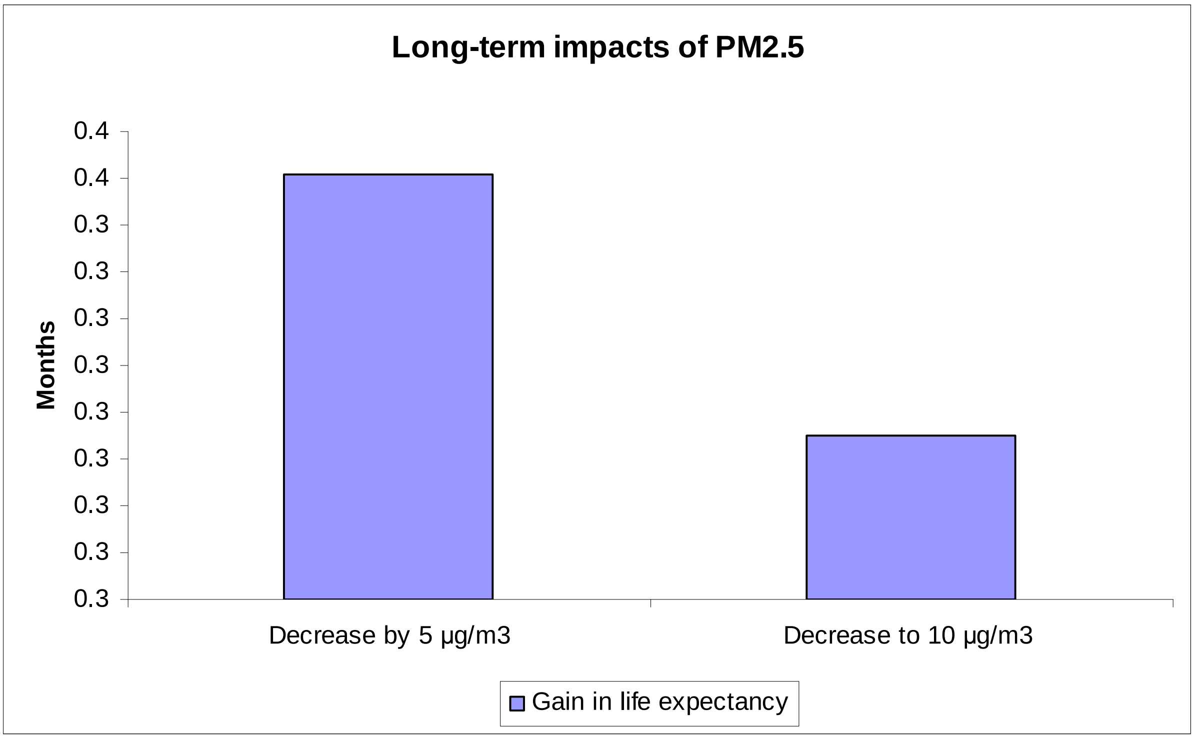


Figure 10 – Potential benefits of reducing annual PM2.5 levels on life expectancy

1.4.4. Economic valuation

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. Indeed, the short- and long-term postponed deaths: differ regarding the size of the gains in life expectancy (see Appendix 2).

In the previous part we presented results (number of deaths and hospitalisations) rounded at the unit level whereas calculations of this part were based on results of the previous part rounded with two decimals.

Mortality

The monetary values chosen to assess mortality benefits are going to differ depending on the short- or long-term nature of the exposure to air pollution (see Appendix 2). For short-term impacts, a monetary value of €86,600 was chosen. Decreasing PM10 concentrations to 20 µg/m3 would then correspond to a saving of €433,000. Decreasing PM10 concentrations by 5µg/m3 would correspond to a saving of €1,039,200. Decreasing ozone concentrations above 100 µg/m3 to 100 µg/m3 would save €346,400.

For long-term impacts, the monetary value of €1,655,000 was chosen. Decreasing PM2.5 concentrations by 5 µg/m3 would then correspond to a saving of €206,875,000. Decreasing PM2.5 concentrations to 10 µg/m3 would correspond to a saving of €174,048,682 . Taking into account the gain in life expectancy would correspond to a saving of €388,349,040 for the first scenario, and €291,261,780 for the second.

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 method is detailed on Appendix 2. Considering that a hospitalisation costs €3,777, the savings would be of €241,728 when reducing PM10 concentrations by 5 µg/m3 and of €90,648 when reducing PM10 concentrations to 20 µg/m3. The gain associated to a reduction of ozone levels exceeding 100 µg/m3 would be of €18,885.

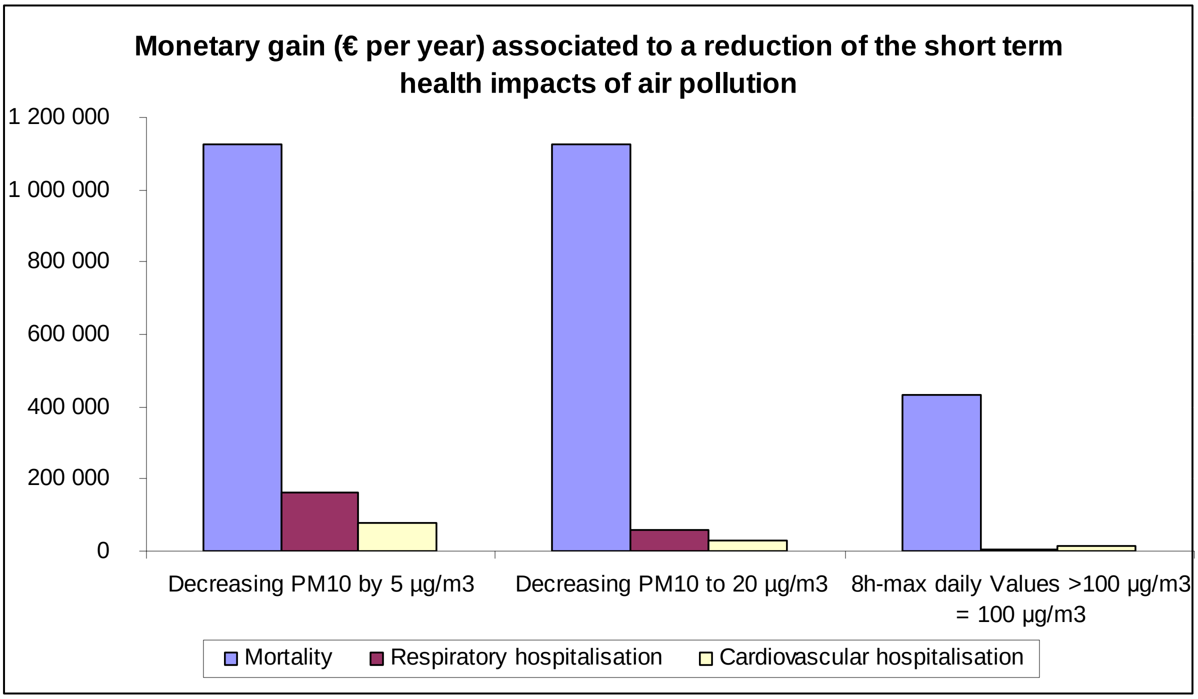


Figure 11 – Potential monetary gains associated to a reduction of PM10 and or ozone levels

1.4.5. Interpretation of findings

In Toulouse, a non-negligible health gain would be achieved by lowering the PM concentrations. The compliance with the WHO-AQG for PM10 (20µg/m3) would induce a moderate benefit on mortality and hospital admissions (5 deaths and 24 hospital admissions avoided per year). The associated monetary gain would be of more than €1 million.

Lowering PM2.5 would have a greater impact. Compliance with the WHO-AQG of 10 µg/m3 would postpone 105 deaths, corresponding to a gain in life expectancy of 0.3 years per inhabitants. Considering the reduced mortality, the associated monetary gain would be more than €170 million. The gain in life expectancy would be valued approximately €290 million.

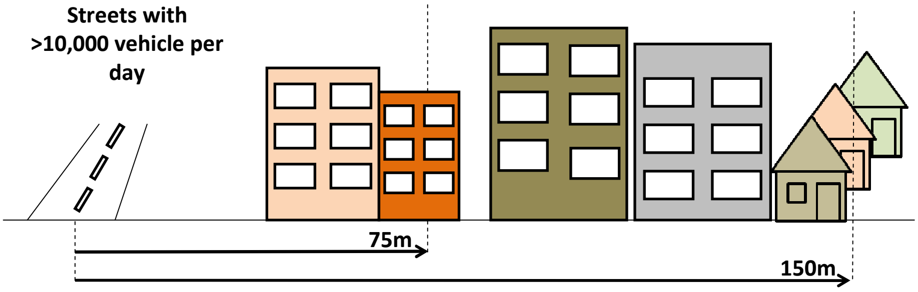
The results from the present HIAs may help promoting local measures aiming at reducing air pollutant emissions, especially from traffic.

Section 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 11 – 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.

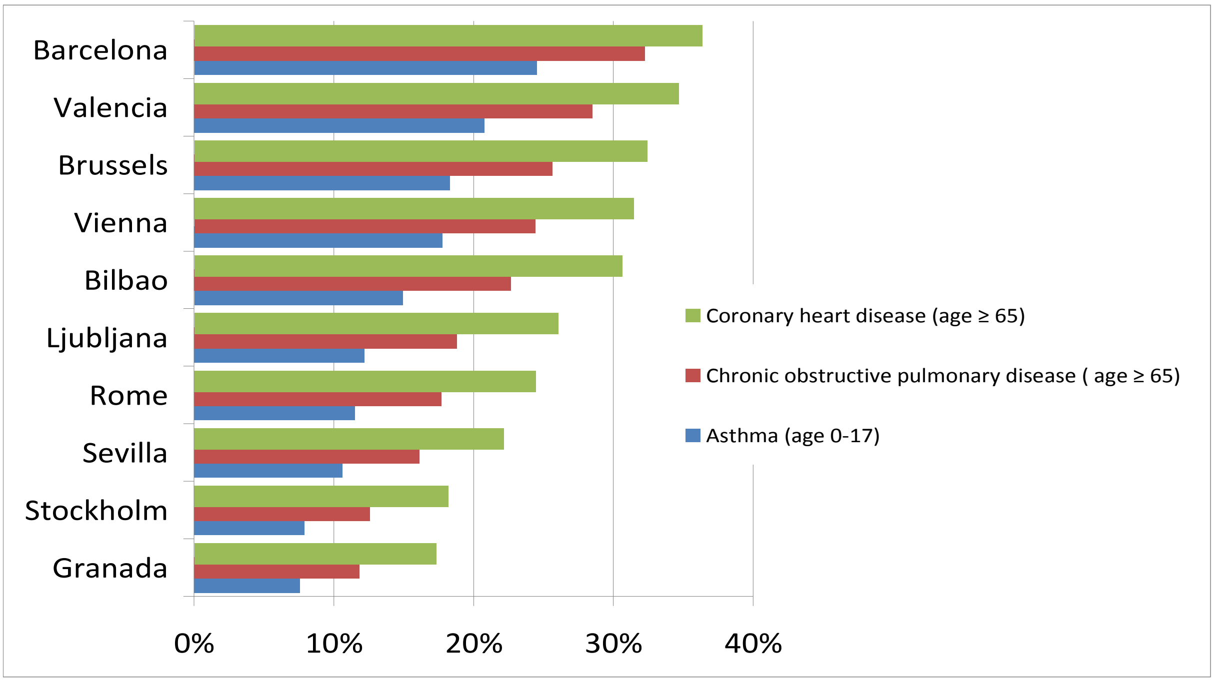


Figure 12 – Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

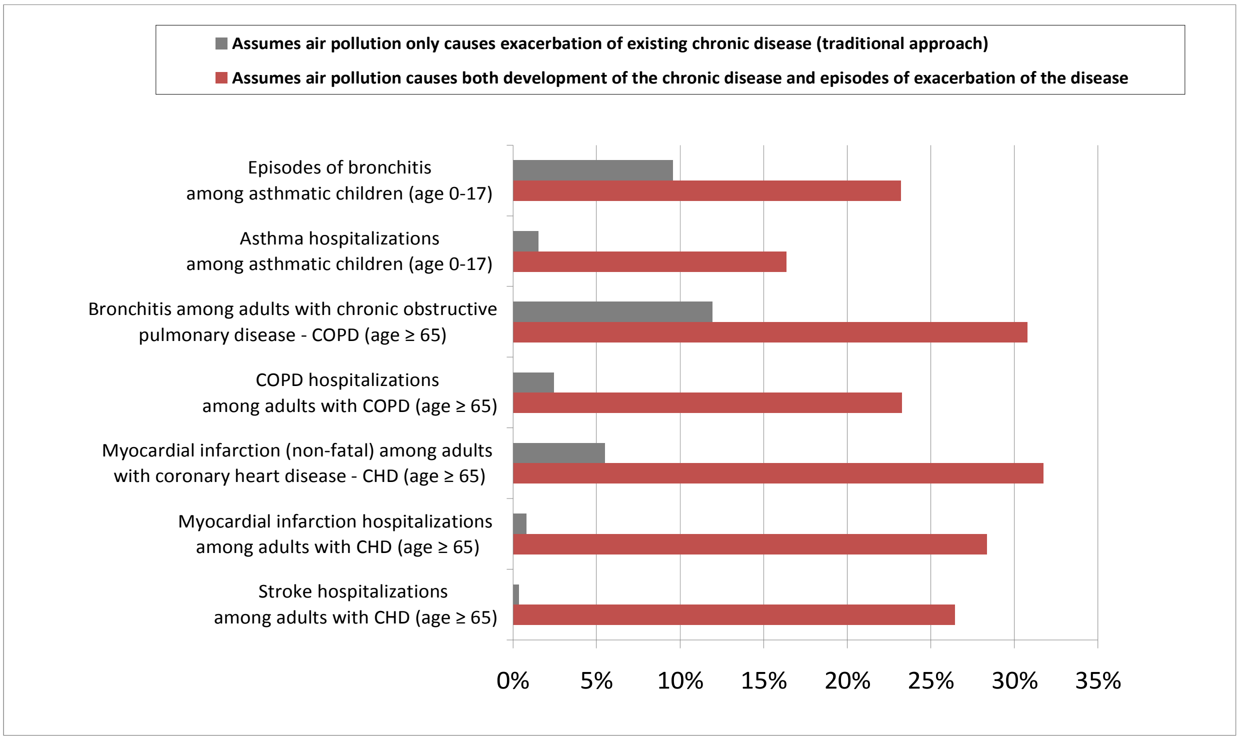


Figure 13 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

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.

Section 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.

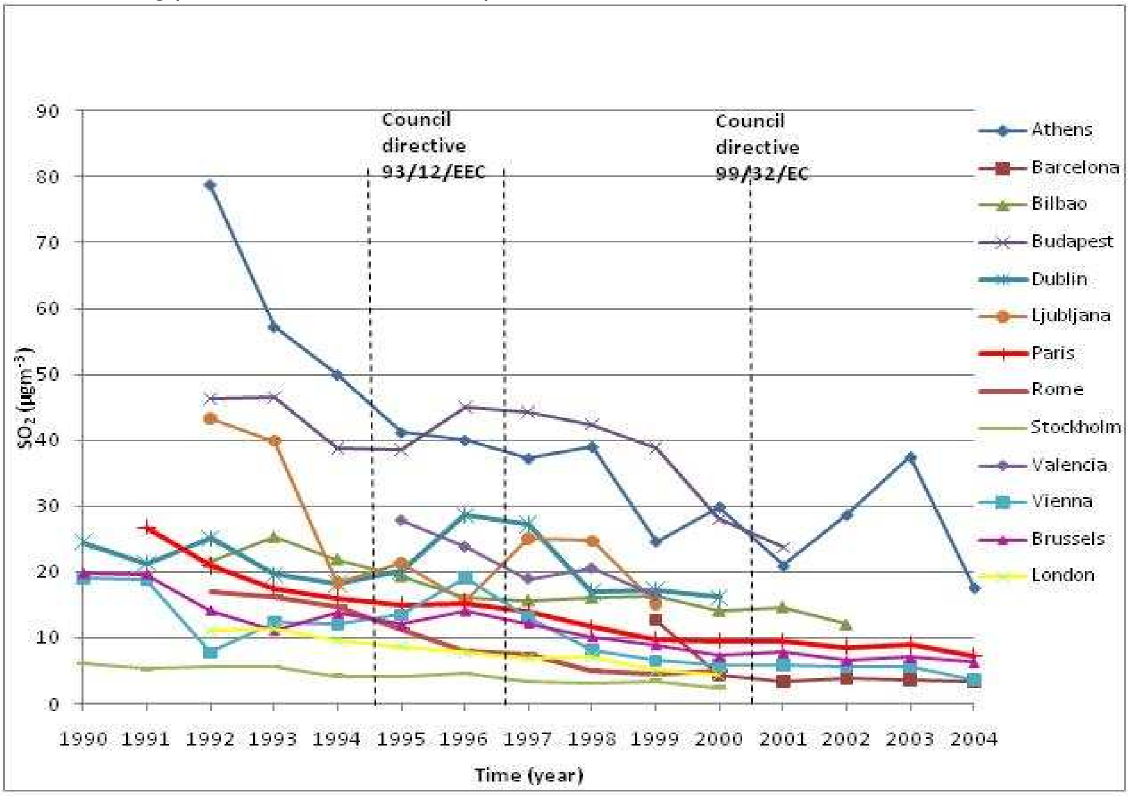


Figure 14 – Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

Figures 15 and Figure 16 show preliminary work done using hourly SO2 data from Vienna, Austria showing seasonal plots for winter (Fig.15) and summer (Fig 16) for a central urban station for the years 1990 to 2000. For example: In Figure 14 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. 15) 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. 16) shows a clear reduction in peak SO2 levels for the aforementioned 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 Figure 15 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.

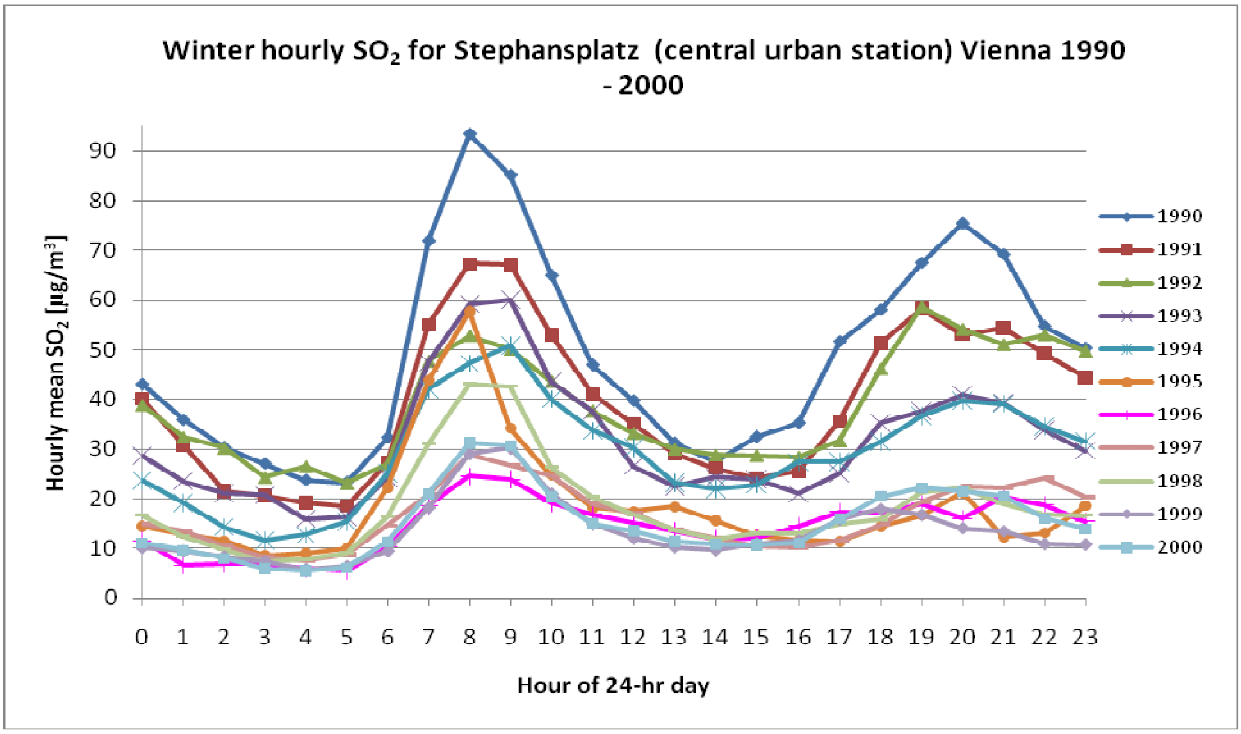


Figure 15 – Diurnal plot of winter hourly SO2 for a central urban station in Vienna 1990-2000

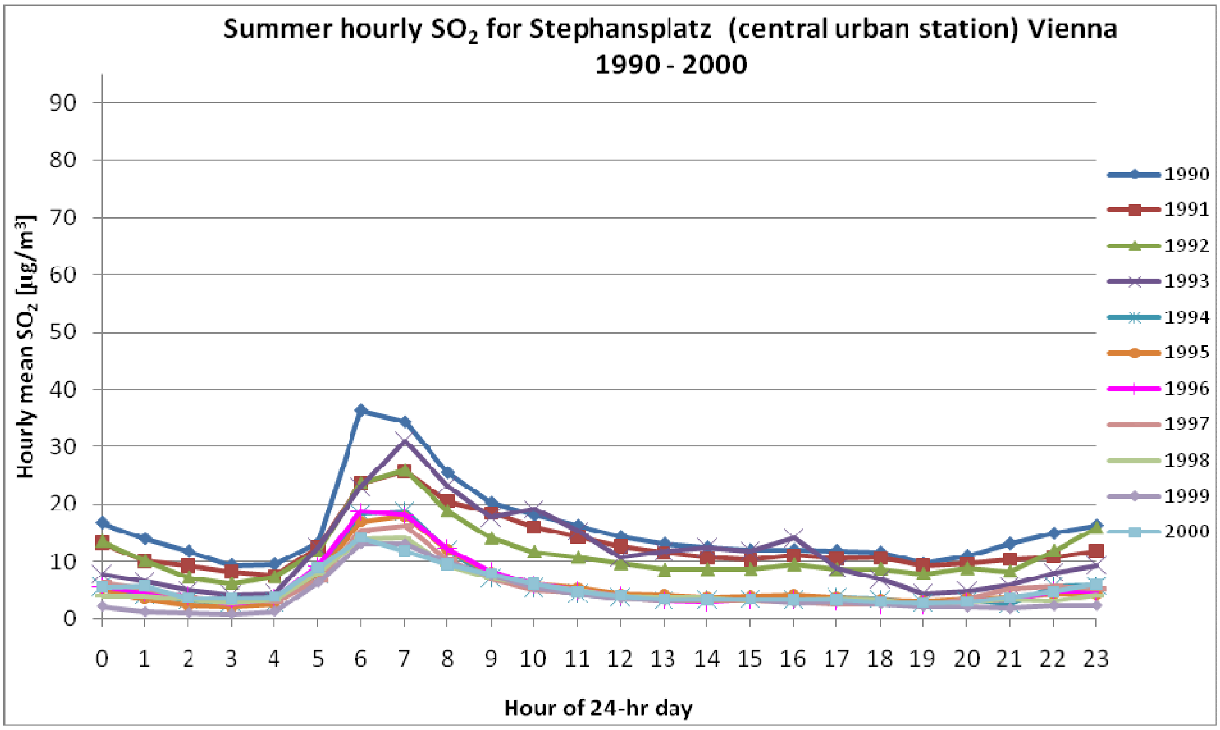


Figure 16 – Diurnal plot of summer hourly SO2 for a central urban station in Vienna 1990-2000

Figure 17 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 Figure 15 for Vienna, where 2 distinct peaks throughout the day for the winter months were observed, here in Figure 17 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.

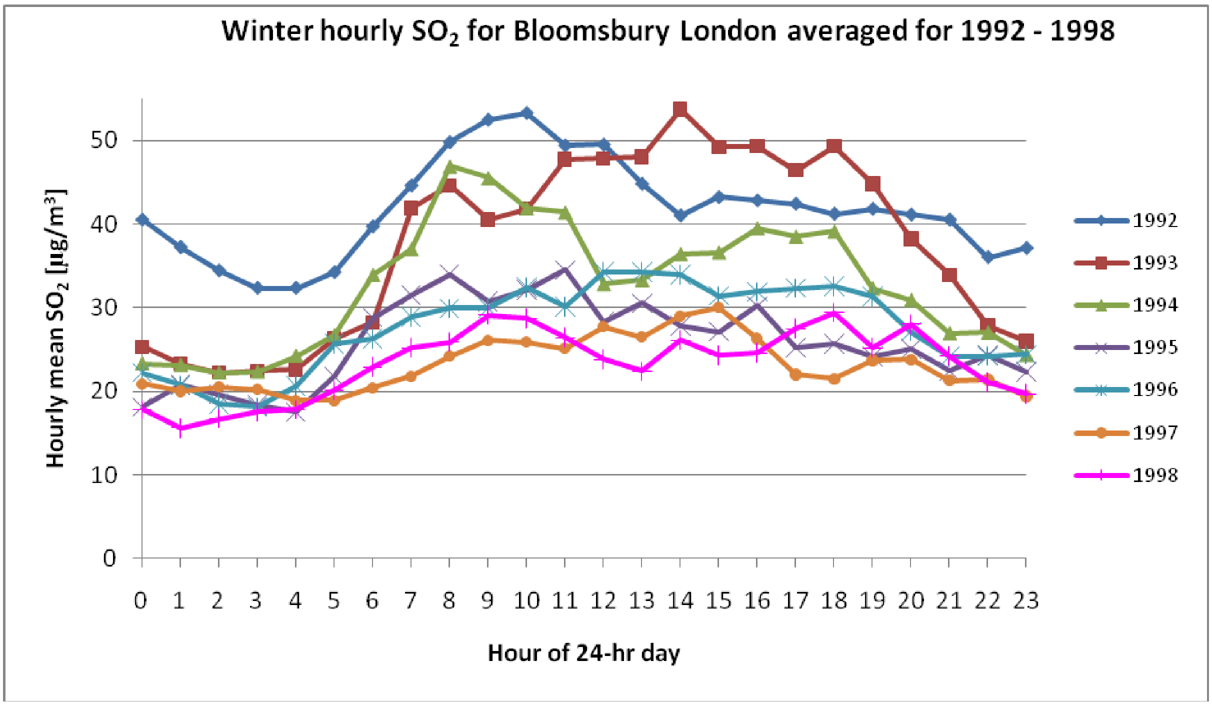


Figure 17 – Diurnal plot of winter hourly SO_2 for an urban background station in London 1992-1998

Section 4. Sharing Knowledge and Uncertainties with Stakeholders

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 involved in developing policy options. 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.

This type of multi-criteria assessment enables highlighting divergences of opinion, focusing discussions on critical points and bridging differences among stakeholders from differing backgrounds. As a result, this process facilitates both communication and decision making.

To test use of the process and tool, Aphekom conducted two case studies in Brussels and in Paris during the development of local air-quality action plans. The case studies demonstrated the ability of the method and tools to structure discussions and highlight differing views, as confirmed by participants' satisfaction with their use.

We also developed an online tool to familiarize users with the deliberation-support process used in the case studies and to enable them to create their own deliberative forums http://aphekom.kertechno.net/.

Section 5. Overview of findings and local recommendations

In Toulouse, a non-negligible health gain would be achieved by lowering the PM concentrations. The compliance with the WHO-AQG for PM10 (20µg/m3) would induce a benefits on mortality and hospital admissions (5 deaths and 24 hospital admissions avoided per year). The associated monetary gain would be of more than €1 million.

Lowering PM2.5 would have a greater impact. Compliance with the WHO-AQG of 10 µg/m3 would postpone 105 deaths, corresponding to a gain in life expectancy of 0.3 years per inhabitants. Considering the reduced mortality, the associated monetary gain would be more than €170 million. The gain in life expectancy would be valued approximately €290 million.

The results from the present HIAs may help promoting measures aiming at reducing air pollutant emissions, especially traffic linked emissions.

In addition, the Aphekom project was able to show that living near streets and roads carrying heavy traffic may have serious health effects, particularly on the development of chronic diseases. An 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) showing in 20 cities 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.

Together these findings show that policies aiming at reducing air pollution would be associated with a significant improvement in the health status and quality of life of European citizens.

Acknowledgements

The authors would like to thank the Oramip air quality network www.oramip.org and specifically Pierre-Yves Robic, which provided the air quality data.

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 11 – 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 hospitalisations	All	1.0114 [1.0062-1.0167]	(5)
	Cardiac hospitalisations	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 hospitalisations	15-64	1.001 [0.991-1.012]	(4)
	Respiratory hospitalisations	>=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).
  Δx = 0 if $[PM10]_{mean}$ <20

Ozone

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

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

The exposure indicator of ozone was the cumulated sum over defined thresholds, calculated using 8hours-daily values.

The corresponding Δx for the two scenarios are;

$$\Delta x = \frac{\sum_{i=1}^{N} O_i}{N}$$

- Scenario 1, if [O3]i≥160 μg/m3, Oi=([O3]i-160)
  if $[O_3]_i$<160 μg/m^3, Oi=0
- Scenario 2, if [O3]i≥100 μg/m3, Oi=([O3]i-100)
  if $[O_3]_i$<100 μg/m^3, Oi=0
- Scenario 3, where the ozone yearly mean is decreased by 5 μg/m^3. Δx = 5 μg/m^3

PM2.5

For PM2.5, we first considered a scenario where the PM2.5 annual mean is decreased by 5 μg/m^3, and then a scenario where the PM2.5 annual mean is decreased to 10 μg/m^3 (WHO annual AQG).
The exposure indicator of PM2.5 was the yearly mean, calculated as the arithmetic mean of the daily concentrations of the selected stations. The corresponding Δx for the two scenarios are;

- Scenario 1, Δx = 5 μg/m^3
- Scenario 2, Δx = ($[PM2.5]_{mean}$ – 10 μg/m^3)
  Δx = 0 if $[PM2.5]_{mean}$ <10

Reference List

1. Medina S, Tertre AL, Saklad M, on behalf of the Apheis Collaborative Network. The Apheis project: Air Pollution and Health?A European Information System. Air Qual Atmos Health 2009;2:185-498.

2. Ballester F, Medina S, Boldo E, Goodman P, Neuberger M, Iñiguez C, et al. Reducing ambient levels of fine particulates could substantially improve health: a mortality impact assessment for 26 European cities. J Epidemiol Community Health 2008;62(2):98-105.

3. Boldo E, Medina S, LeTertre A, Hurley F, Mücke HG, Ballester F, et al. Apheis: Health impact assessment of long-term exposure to PM(2.5) in 23 European cities. Eur J Epidemiol 2006;21(6):449-58.

4. Anderson HR, Atkinson RW, Peacock JL, Marston L, Konstantinou K. Meta-analysis of time-series studies and panel studies of Particulate Matter (PM) and Ozone (O3). Report of a WHO task group. WHO Regional Office for Europe; 2004.

5. Atkinson RW, Anderson HR, Medina S, Iñiguez C, Forsberg B, Segerstedt B, et al. Analysis of all-age respiratory hospital admissions and particulate air pollution within the Apheis programme. APHEIS Air Pollution and Information System. Health Impact Assessment of Air Pollution and Communication Strategy. Third-year Report. Institut de Veille Sanitaire; 2005. p. 127-33.

6. Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J, et al. Acute effects of ozone on mortality from the "air pollution and health: a European approach" project. Am J Respir Crit Care Med 2004;170(10):1080-7.

7. Pope CA, III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Jama 2002;287(9):1132-41.

8. Pope CA, III, Burnett RT, Thurston GD, Thun MJ, Calle EE, Krewski D, et al. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation 2004;109(1):71-7.

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. Indeed, the approach most widely used to value mortality elicits a hypothetical willingness to pay to benefit from a small decrease in mortality risk. Based on this trade-off, it then computes a VSL (used for long-term mortality effects) and/or a VOLY (used for short- and long-term mortality effects).

We chose to rely on values obtained in recent European studies (see final Aphekom report for more details).

The choice of the monetary value to assess mortality benefits associated to a decrease in air pollution level depends on the type of impact.

- **For short-term mortality calculations**, the annual number of deaths postponed per year is used. Because the gains in life expectancy corresponding to each of these postponed deaths can be considered in the range of a few months, certainly lower than one year (Cafe 2005, Vol 2, p. 46), *a VOLY of €86,600 is applied to each deaths postponed to compute annual benefits.*

- **For long-term mortality calculations**, the magnitude of the gain in life expectancy related to the deaths postponed is considered as higher than a year (see Ezzati et al., 2002; Hurley et al. 2005; Watkiss et al. 2005; or Janke et al., 2009). A *VSL of €1,655,000 is applied to each deaths postponed to compute annual benefits.*

- **For long-term life expectancy calculations**, an average gain in life expectancy for persons 30 years of age is also computed using life tables and following a cohort until complete extinction. *The annual corresponding benefits are obtained by multiplying the average gain in life expectancy by the number of 30-year-old individuals in the city, and by the VOLY.* This corresponds to the benefits (in terms of life expectancy) 30 year-old people would gain over their lifetime if exposed to the 10 µg/m^3 average annual level of PM2.5 (WHO's Air Quality Guideline) instead of the current existing air pollution level in the city.

Valuation of hospitalisations benefits

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

The direct medical costs related to cardiac and respiratory hospitalisations are computed as the cost per inpatient day times the average length of stay in hospital. These cost data are taken from CEC (2008) for all twelve countries where the cities analysed in Aphekom are located (see Table 1). The average lengths of stay in days are obtained from the OECD Health Database (2010) for all countries except Romania (which is imputed from the population weighted average lengths of the 11 other countries).

The indirect costs are computed as the average gross loss of production per day times twice the average length of stay in hospital. Since we cannot control whether these days were actual working days, we then compute the daily loss of production as the average gross earnings in industry and services (full employment) obtained from Eurostat (2003) for each country, expressed in 2005 and divided by 365 days.

The total medical costs for cardiac and respiratory hospitalisations are obtained by adding together the direct and indirect components.

Table 12 – 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 12, 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 hospitalisation 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.

References

CAFE (2005b) Methodology for the Cost-Benefit analysis for CAFE: Volume 2 – Health Impact Assessment. http://www.cafe-cba.org . F. Hurley, A. Hunt, H. Cowie, M. Holland, B. Miller, S. Pye and P. Watkiss.

CEC Commission of the European Communities (2008), Commission staff working document accompanying the Proposal for a Council recommendation on patient safety, including the prevention and control of healthcare associated infections – Impact assessment, SEC(2008) 3004 Brussels, December 15, 59 p.

Eurostat (2003), Paternoster A. Annual Gross Earnings: Results from Member States, Acceeding and Candidature Countries, and Switzerland, Theme 3—25/2003, Statistics in Focus, EUROSTAT.

ExternE (1999) DGXII (JOULE Programme) Externalities of Energy, ExternE Project, Report Number 7, Methodology: Update 1998. Holland, M.R. and Forster, D. (eds.).

Ezzati, M., Lopez, A., Rodgers, A., van der Hoorn, S., Murray, C.J.L. and the Comparative Risk Assessment Collaborating Group. (2002), Selected major risk factors and global and regional burden of disease. The Lancet, 360, 1347-1360.

Hurley, F., Cowie, H., Hunt, A., Holland, M., Miller, B., Pye, S. and Watkiss, P. (2005), Methodology for the Cost-Benefit analysis for CAFE, Volume 2: Health Impact Assessment.

Janke K., Propper C., and Henderson J. (2009). Do current levels of air pollution kill? The impact of air pollution on population mortality in England. Health Economics, doi:10.1002/hec.1475.

New-Ext (2004), New Elements for the Assessment of External Costs from Energy Technologies, final report to the European Commission DG Research, Technological Development and Demonstration, (Contract No : ENG1-CT2000-00129), produced by IER (Institute for Energy Economics and the Rational Use of Energy) et al.

OECD Health Data (2010), CD-ROM

Watkiss, P., S. Pye and Holland M. (2005), CAFE CBA: Baseline Analysis 2000 to 2020 Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE). Programme AEAT/ED51014/Baseline Scenarios, issue 5, AEA Technology, April, 122 p.

The Aphekom collaborative network

The authors would like to thank the Aphekom collaborative network for its invaluable contribution to the project, in particular:

▪ FRENCH INSTITUTE FOR PUBLIC HEALTH SURVEILLANCE, InVS, Saint-Maurice, France – Sylvia Medina, Kanwal Eshai, Christophe Declercq, Agnès Lefranc, Myriam Blanchard, Sophie Larrieu, Tek-Ang Lim, Alain Le Tertre, Laurence Pascal, Mathilde Pascal, Magali Corso, Aymeric Ung.

▪ UMEÅ UNIVERSITY, Umeå, Sweden – Bertil Forsberg, Lars Modig, Kadri Meister, Hans Orru

▪ MEDICAL UNIVERSITY OF VIENNA, Austria – Hanns Moshammer, Manfred Neuberger, Daniela Haluza, Hans-Peter Hutter

▪ BARCELONA PUBLIC HEALTH AGENCY, Spain – Manuel Nebot, Anna Perez, Natalia Valero

▪ CENTRE FOR RESEARCH IN ENVIRONMENTAL EPIDEMIOLOGY, CREAL, Barcelona, Spain, SWISS TROPICAL AND PUBLIC HEALTH INSTITUTE and UNIVERSITY OF BASEL, Basel, Switzerland – Nino Künzli, Laura Perez-Grau, Xavier Basagaña, David Agis Cherta

▪ DUBLIN INSTITUTE OF TECHNOLOGY, Ireland – Patrick Goodman, Susann Henschel

▪ ST. GEORGE'S, UNIVERSITY OF LONDON, United Kingdom – Richard Atkinson

▪ DEPARTMENT OF HYGIENE, EPIDEMIOLOGY AND MEDICAL STATISTICS, MEDICAL SCHOOL, UNIVERSITY OF ATHENS, Greece – Klea Katsouyanni, Antonis Analitis, Konstantina Dimakopoulou, Alexandros Gryparis, Eva Kougea, Xanthi Pedeli

▪ CENTRE OF ECONOMICS AND ETHICS FOR THE ENVIRONMENT AND DEVELOPMENT, C3ED, UNIVERSITY OF VERSAILLES SAINT-QUENTIN-EN-YVELINES, UVSQ, France – Yorghos Remvikos, Delphine Delalande, Jeroen Van der Sluijs, Martin O'Connor

▪ VALENCIAN SCHOOL FOR HEALTH STUDIES, EVES, AND CENTRE FOR RESEARCH ON PUBLIC HEALTH, CSISP, Valencia, Spain – Ferran Ballester, Carmen Iñiguez, Marisa Estarlich

▪ BRUSSELS INSTITUTE FOR THE MANAGEMENT OF THE ENVIRONMENT, Belgium – Catherine Bouland

▪ BASQUE FOUNDATION FOR HEALTH INNOVATION AND RESEARCH, Vitoria-Gasteiz, Spain – Teresa Martínez-Rueda, Koldo Cambra, Eva Alonso, Sausan Malla, Francisco Cirarda

▪ ANDALUSIAN SCHOOL OF PUBLIC HEALTH, EASP, Granada, Spain – Antonio Daponte, Piedad Martin-Olmedo, Alejandro Lopez-Ruiz, Marina Lacasaña, Pablo Sánchez-Villegas

▪ NATIONAL INSTITUTE OF PUBLIC HEALTH, Bucharest, Romania – Emilia Maria Niciu, Bogdan Constantin Stolica, Ioana Pertache

▪ INSTITUTE OF PUBLIC HEALTH OF THE REPUBLIC OF SLOVENIA, Ljubljana, Slovenia – Peter Otorepec, Katarina Bitenc, Ana Hojs

▪ NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH, Budapest, Hungary – Anna Páldy, János Bobvos, Gizella Nador

▪ ROME E HEALTH AUTHORITY, Italy – Francesco Forastiere, Giulia Cesaroni, Chiara Badaloni

The Aphekom Scientific Committee

▪ UNIVERSITY OF BATH, United Kingdom – Alistair Hunt

▪ INSTITUTE OF OCCUPATIONAL MEDICINE, Edinburgh, United Kingdom – Brian Miller, Fintan Hurley

▪ WHO EUROPEAN CENTRE FOR ENVIRONMENT & HEALTH, Bonn, Germany – Michal Krzyzanowski

▪ WHO EUROPEAN CENTRE FOR ENVIRONMENT & HEALTH, Rome, Italy – Martin Krayer Von Krauss

▪ EUROPEAN COMMISSION DG JOINT RESEARCH CENTRE, Ispra, Italy – Peter Pärt

▪ SPANISH NATIONAL RESEARCH COUNCIL, CSIC, Barcelona, Spain – Xavier Querol

▪ MAILMAN SCHOOL OF PUBLIC HEALTH, COLUMBIA UNIVERSITY, New York, United States of America – Patrick Kinney

Other Aphekom contributors

- Brunel University, London, United Kingdom – Ariana Zeka
- National Center for Scientific Research, GREQAM and IDEP, Marseille, France – Olivier Chanel
- Regional Health Observatory of the Paris Ile-de-France Region, ORS, Paris, France – Sabine Host, Edouard Chatignoux
- Saklad Consultants for communications strategy, Paris & New York – Michael Saklad
- Stockholm Environment Administration – Christer Johansson and Boel Lövenheim
- WWAM Writers Ltd., Birmingham, United Kingdom – Geoff Davies

Coordination

- French Institute for Public Health Surveillance, InVS, France - Sylvia Medina
- Umea University, Sweden - Bertil Forsberg

Funding and support

The Aphekom project has been co-funded by the European Commission's Programme on Community Action in the Field of Public Health (2003-2008) under Grant Agreement No. 2007105, and by the many national and local institutions that have dedicated resources to the fulfilment of this project.

To learn more

www.aphekom.org