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

Local city report

Lille

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

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

[2]Regional Office of InVS, Lille, France

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

Summary

In the framework of the Aphekom project, the burden of exposure to particulate matter and ozone on mortality and hospitalisations in 2004-2006 period in Lille has been assessed, by comparing the 2004-2006 situation with what it could have been if the particulate matter and ozone had been decreased to the Word Health Organization (WHO) Air Quality Guidelines (AQG).
A decrease of the average $PM_{2.5}$ levels to the WHO AQG (10 µg/m^3), *i.e.* a 6 .6 µg/m^3 decrease would have lead to an average gain of 5.8 months in life expectancy at 30. This is equivalent to a burden of $PM_{2.5}$ on mortality of more than 300 annual deaths, from which more than 150 are caused by cardiovascular diseases. This is also equivalent to an annual gain of more than 7864 life-years. The associated economic benefit would have exceeded €500 million (2005) by year.
A decrease of the annual level of PM_{10} to the WHO AQG (20 µg/m^3), *i.e.* a 7.6 µg/m^3 decrease, would have allowed to avoid 117 respiratory hospitalisations and 56 cardiac hospitalisations per annum, which would have resulted in a €654,000 (2005) economic benefit.
A decrease of all daily 8h-maximum levels of ozone below the WHO AQG (100 µg/m^3) would have lead to avoid 6 respiratory hospitalisations per annum (€17,000) and to postpone 6 deaths per annum (€517,000).
In addition, with an innovative approach tested in 10 Aphekom cities (but not in Lille), the Aphekom project was able to show that living near streets and roads carrying heavy traffic may have a significant impact on prevalence and exacerbations of chronic respiratory diseases and ischemic heart diseases.
The Aphekom project also investigated the impact of the EU legislation to reduce the sulphur content of fuels (mainly diesel fuels used by diesel engines, shipping and home heating) in 20 Aphekom cities. This showed a sustained decrease in SO_2 levels but also the resulting postponing of some 2,200 premature deaths per year from year 2000 onwards (implementation of the 3rd stage of implementation. In Lille, it has been estimated that 93 premature deaths had been postponed annually.
Together these findings show that public policies aiming at improving air quality would be associated with a significant improvement in the health status and quality of life of European citizens. The Aphekom results should help promoting measures aiming at reducing air pollutant emissions, especially traffic-related emissions, as the estimated health and economic benefits are really significant.

Acronyms

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

AQG: Air Quality Guidelines

HIA: health impact assessment

O_3: ozone

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

$PM_{2.5}$: particulate matter with an aerodynamic diameter <2.5 µm

WHO: World Health Organization

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 a subject 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.

This work shows that a decrease to 10 micrograms/cubic metre of long-term exposure to $PM_{2.5}$ fine particles (WHO's annual air-quality guideline) could add up to 22 months of life expectancy at 30, 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.

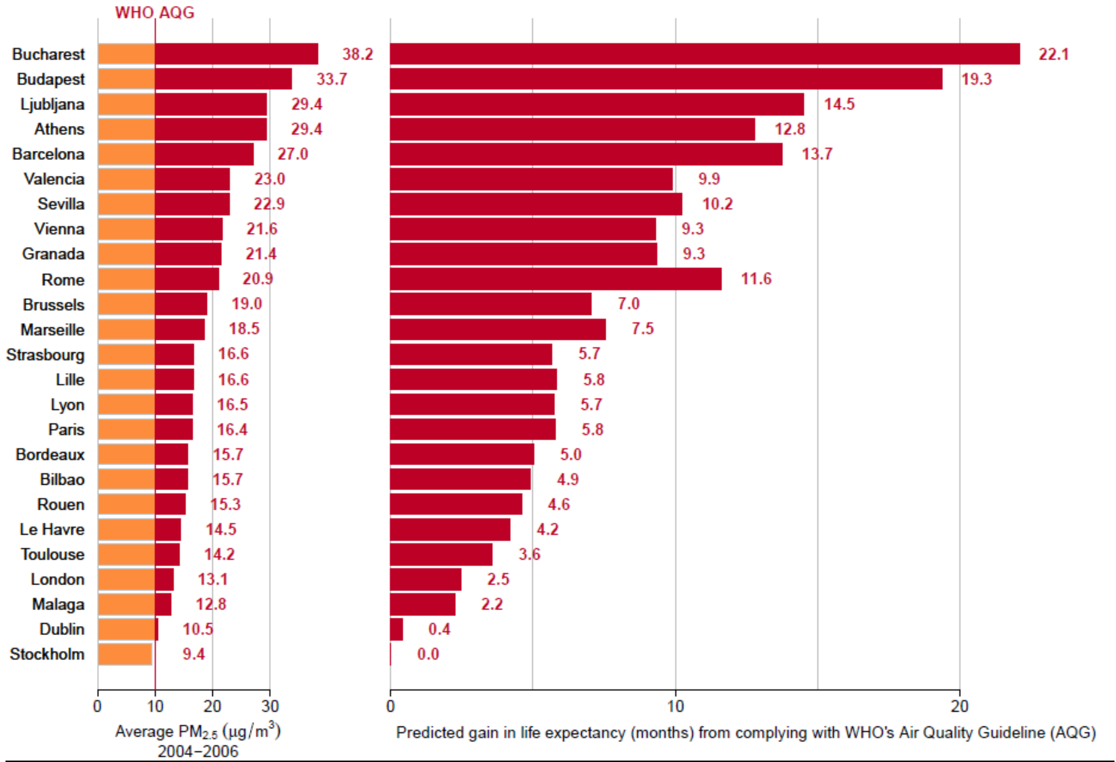


Figure 1 – **Predicted average gain in life expectancy (months) for persons 30 years of age in 25 Aphekom cities for a decrease in average annual level of PM2.5 to 10 µg/m^3 (WHO's Air Quality Guideline)**

1.1. Description of the Lille study area

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.

For the Lille area, it corresponds to the Lille-Métropole Communauté Urbaine area. It had a population of 1,107,861 at the 2006 census, living in 85 cities on an area of 612 km^2 in size. The main acitvity centres are the cities of Lille, Roubaix, Tourcoing and Villeneuve d'Ascq (see figure 2).

The study area of Lille is flat, widely swept by prevailing winds from the west. It has moderate climate under the influence of the sea, with a relatively wide range of temperatures.

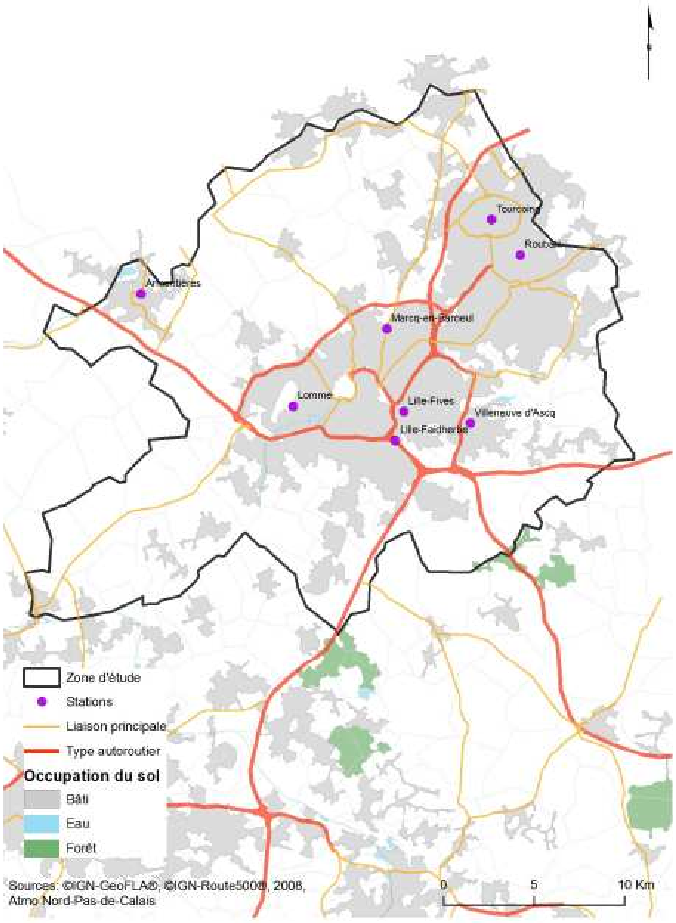


Figure 2 – Map of the study area

1.2. Sources of air pollution and exposure data

Sources

Situated in the heart of Europe, the traffic in the metropolitan area of Lille is very heavy, mainly on national and international traffic (A1, A22, A23, A25). There is also a heavy traffic between the suburbs and the town centres. Road traffic and residential/tertiary emissions are the main sources of particulate matter, NOx and volatile organic compounds (table 1).

Table 1 – Main sources of air pollution (tons/year) in Lille

Pollutant	Road Transport	Residential/ Tertiary	Manufacturing Industry/Energy Transformation
SO_2	216	1,446	5,762
NO_x	7,383	1,741	2,636
Primary Total Suspended Particles	519	2,506	489
Volatile Organic Compounds	4,206	6,554	8,288

Source: Cadastre des émissions de polluants atmopshériques dans le Nord-Pas-de-Calais, ATMO Nord-Pas-de-Calais, 2006

Exposure data

We used data provided by the ATMO Nord-Pas-de-Calais air quality monitoring network: 5 urban monitoring stations for PM_{10}, 2 urban stations for PM2.5 and 5 urban and 2 suburban stations for ozone. PM_{10} and $PM_{2.5}$ were measured with TEOM (we applied the same local correction factor than in the APHEIS project: +18% in summer and +27% in winter). Ozone was measured by UV absorption (table 2).

Table 2 – Mean levels of air pollutants (2004-2006)

Pollutant	Indicator	
PM_{10}*	Average of the daily values (µg/m^3)	27.6
$PM_{2.5}$*	Average of the daily values (µg/m^3)	16.6
Ozone (daily average)**	Average of the daily 8h-maximum values (µg/m^3) whole year	61.1
	% of valid days where the daily 8h-maximum value is over 100 µg/m^3	9.6

***: Corrected TEOM[1]**
****: UV absorption**

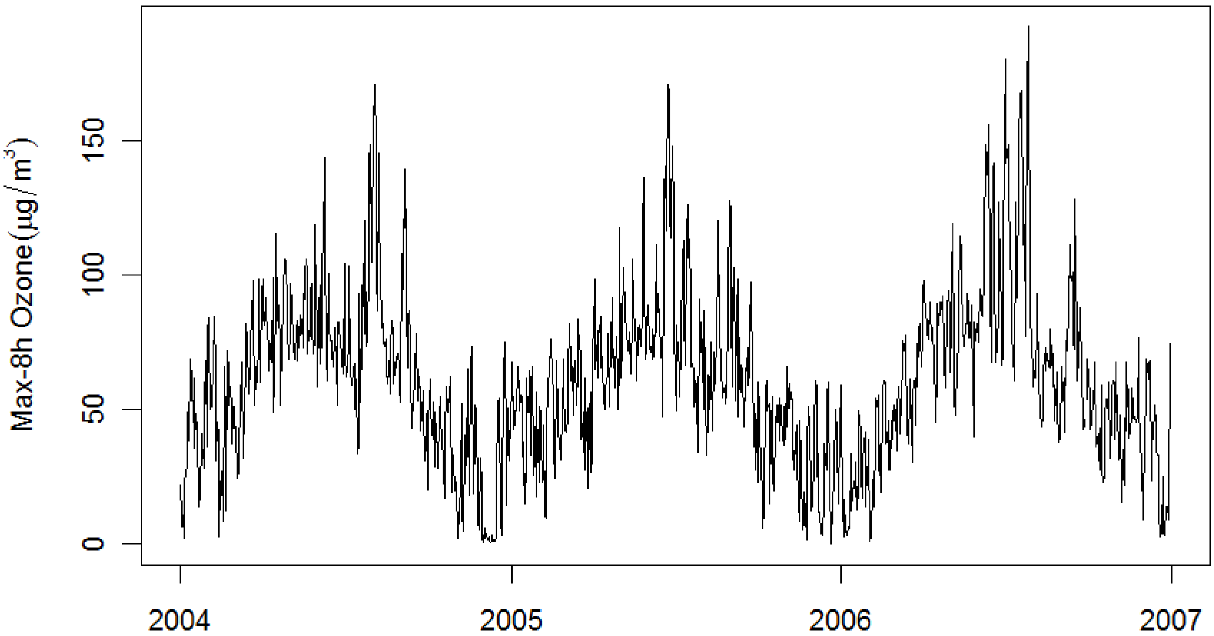


Figure 3 – Daily 8h-max. levels of Ozone (µg/m^3) concentration in Lille (2004-2006)

1 We applied fixed seasonal (winter and summer) correction factors estimated from field surveys comparing TEOM and gravimetric measurements in the Lille area in 2001-2002 (Houdret JL, Mathé F, Dybiak R, Angotzi C. *Métrologie des particules. Programme national de surveillance des particules $PM_{2.5}$ and PM_{10}*. Douai: École des mines de Douai, 2002.

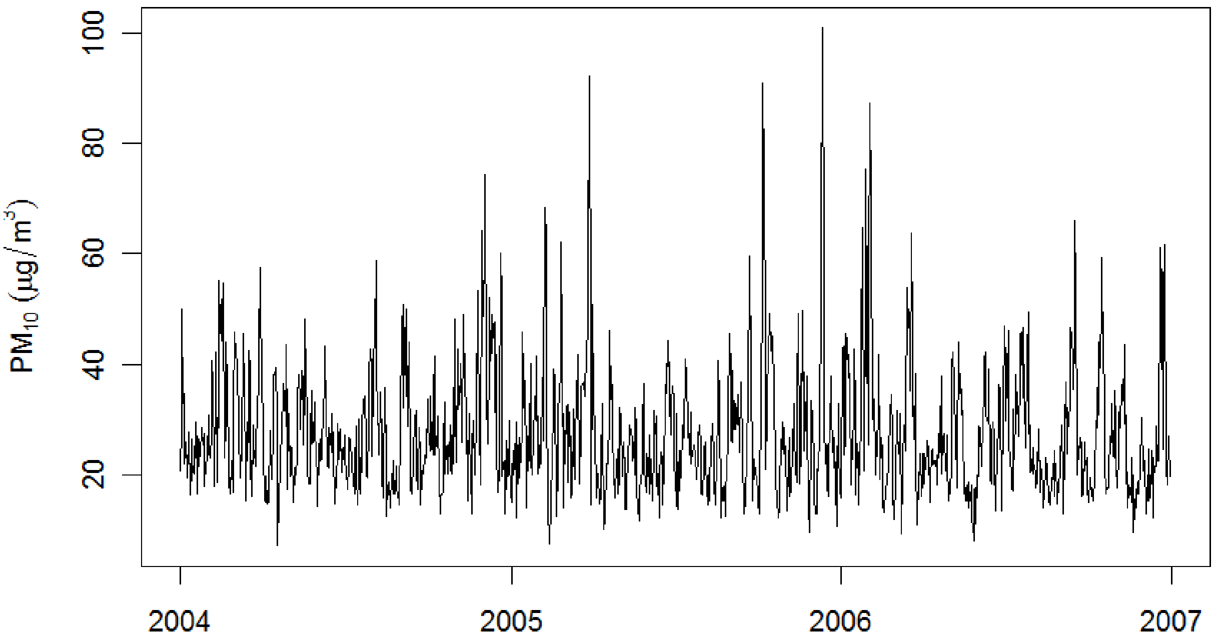


Figure 4 – Daily corrected levels of PM_{10} (µg/m^3) in Lille (2004-2006)

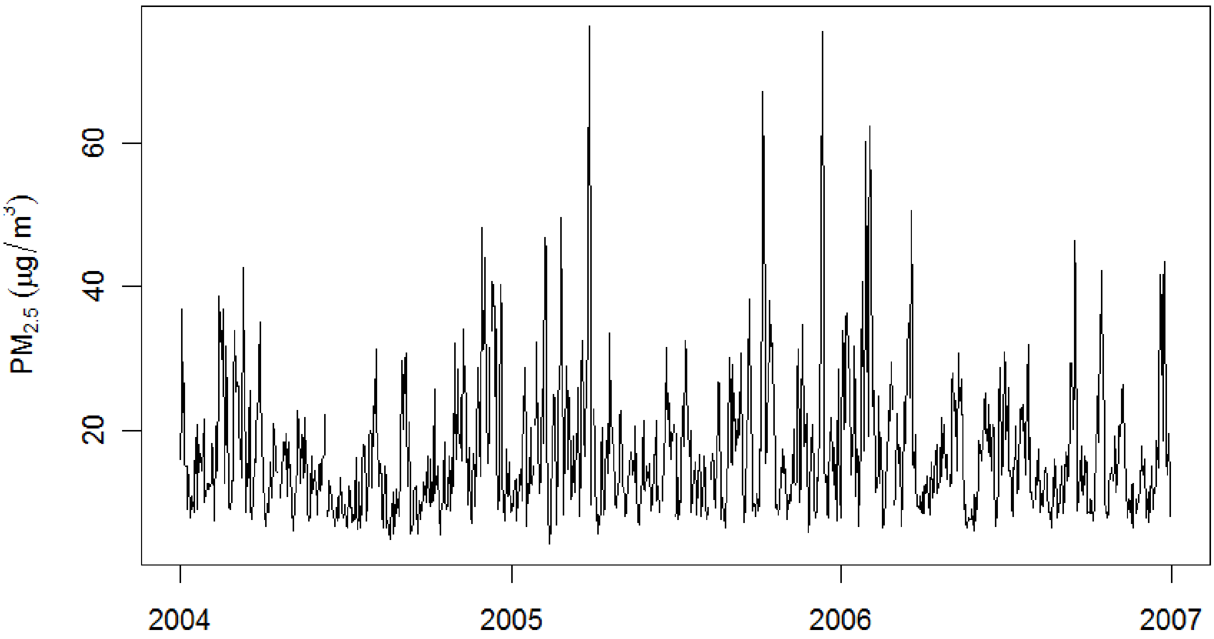


Figure 5 – Daily corrected levels of PM2.5 (µg/m3) in Lille (2004-2006)

1.3. Health data

We used mortality data from INSERM/CepiDC and hospital data (main diagnosis at discharge) provided by the hospital information technical agency (ATIH)). These are PMSI (*programme de médicalisation des systèmes d'information)* data from 17 hospitals and private clinics that provide health care to the inhabitants of the study area (table 3).

Table 3 – Annual mean number and annual rate per 100 000 of deaths and hospitalizations in Lille (2004-2006)

Health outcome	ICD9	ICD10	Age	Annual mean number	Annual rate per 100 000
Total (excluding external*) mortality	< 800	A00-R99	All	7,599	686
Total (including external*) mortality	001-999	A00-Y98	> 30	7,970	1073**
Cardiovascular mortality	390-429	I00-I52	> 30	2,131	265**
Cardiac hospitalisations	390-429	I00-I52	All	12,427	1,122
Respiratory hospitalisations	460-519	J00-J99	All	13,607	1,228

*External mortality: violent deaths such as injuries, suicides, homicides, or accidents.

**Standardized rate (WHO European standard population)

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 online HIAs tool are provided in http://si.easp.es/aphekom

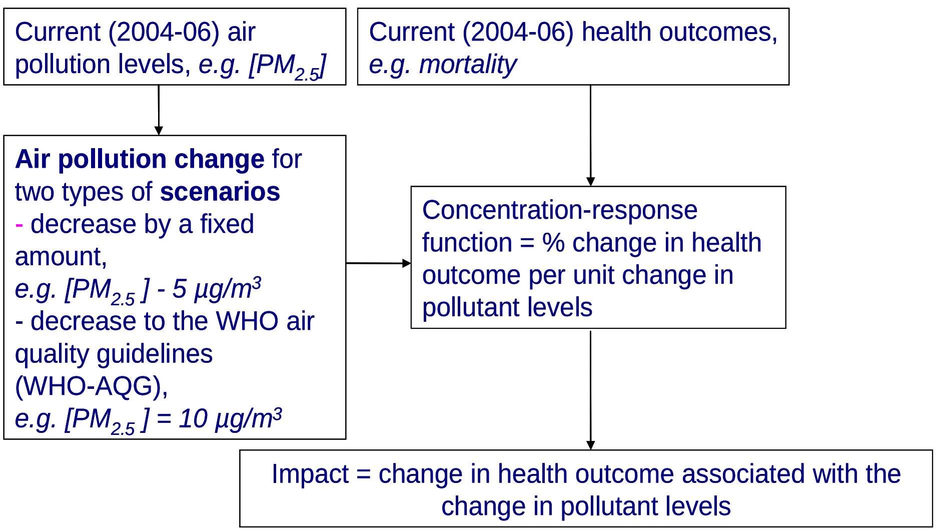


Figure 6 – Principles of local health impact assessment (HIA)

1.4.1. Short-term impacts of PM10

For PM_{10}, we first considered a scenario where the annual mean of PM_{10} is decreased by 5 µg/m^3. In this scenario, 23 deaths would have been postponed, and 77 respiratory hospitalisations and 37 cardiac hospitalisations would have been avoided in Lille each year. We then considered a scenario where the PM_{10} annual mean is decreased to 20 µg/m^3, the WHO annual air quality guideline (WHO-AQG): 35 deaths would have been postponed, and 117 respiratory hospitalisations and 56 cardiac hospitalisations would have been avoided each year.

Table 4 – Potential benefits of reducing annual PM_{10} levels on short-term total non-external* mortality

Scenarios	Total annual number of postponed non-external deaths	Annual rate of postponed non-external deaths (per 100,000)
Decrease by 5 µg/m^3	23	2
Decrease to 20 µg/m^3	35	3

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

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

	Respiratory hospitalisations		Cardiac hospitalisations	
Scenarios	**Total annual number of avoided hospitalisations**	**Annual rate of avoided hospitalisations (per 100,000)**	**Total annual number of avoided hospitalisations (per 100,000)**	**Annual rate of avoided hospitalisations (per 100,000)**
Decrease by 5 µg/m^3	77	7	37	3
Decrease to 20 µg/m^3	117	11	56	5

1.4.2. Short-term impacts of ozone

For ozone, WHO set two guideline values for the daily 8h-maximum value. The interim target value (WHO-IT) 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 100 µg/m^3 were reduced to WHO-AQG (100 µg/m^3): in this scenario, there would have been each year in Lille 6 non-external deaths postponed and 5 respiratory hospitalisations in 65 year and over people avoided. We also considered a scenario where there is a decrease by 5 µg/m^3 in the annual mean of daily 8h-maximum values: in this scenario, there would have been 12 deaths postponed and 12 respiratory hospitalisations avoided (2 for 15-64 year and 10 for 65 year and over)

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

Scenarios	Total annual number of postponed non-external deaths	Annual rate of postponed non-external deaths (per 100,000)
8h max daily values >100 µg/m^3 = 100 µg/m^3	5,7	0,5
Decrease by 5 µg/m^3	11,8	1,1

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

Table 7 ─ Potential benefits of reducing daily ozone levels on respiratory hospitalisations

	Respiratory hospitalisations (15-64 year)		Respiratory hospitalisations (>64 year)	
Scenarios	**Total annual number of avoided hospitalisations**	**Annual rate of avoided hospitalisations (per 100,000)**	**Total annual number of avoided hospitalisations**	**Annual rate of avoided hospitalisations (per 100,000)**
8h max daily values >100 µg/m^3 = 100 µg/m^3	1,0	0,1	4,6	3,3
Decrease by 5 µg/m^3	2,0	0,3	9,5	6,8

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

For the long-term effects of chronic exposure to $PM_{2.5}$, we first considered a scenario where the $PM_{2.5}$ annual mean is decreased by 5 µg/m^3: this would have resulted in an average increase by 4.4 months in the life expectancy at 30, which amounts to a total burden of nearly 6000 life-years per year. This is equivalent to a burden of 229 deaths par year, among which 117 are caused by cardiovascular diseases.

We then considered a scenario where the $PM_{2.5}$ annual mean is decreased to 10 µg/m^3 (WHO AQG). This would have allowed an average gain of 5.8 months of life expectancy at 30, which amounts to a total of more than 7800 life years per year. This is equivalent to a burden of 302 deaths per year, among which 154 are caused by cardiovascular diseases.

Table 8 – Potential benefits of reducing annual $PM_{2.5}$ levels on long-term total mortality and life expectancy

Scenarios	Annual number of postponed all cause deaths (30 years and over)	Annual number of postponed cardiovascular deaths (30 years and over)	Average gain in life expectancy at 30 (months)	Total life years per annum (30 years and over)
Decrease by 5 µg/m^3	229	37	4.4	5916,9
Decrease to 10 µg/m^3	302	49	5.8	7865,9

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. The monetary values chosen to assess mortality benefits are going to differ depending on the short- or long-term nature of the exposure to air pollution (see Appendix 2). For short-term impacts, the monetary value of €86,600 per premature death was applied to the total annual number of deaths postponed. For long-term impacts, the monetary value of €1,655,000 per premature death was applied to the total annual number of deaths postponed. The way gain in life expectancy was estimated is detailed in Appendix 2.

The standard cost of illness approach is used for short-term hospitalisations, and consists in applying unit economic values to each case, including direct and indirect costs. The unit economic values will differ across cities, based on specific local market prices for medical resources and wages (see Appendix 2). The economic benefits related to a reduction in air pollution exposure are then computed by multiplying the number of hospitalisations by the corresponding unit economic value.

Economic valuation of HIA results in Lille are largely dominated by the potential benefits of a decrease in $PM_{2.5}$ levels and the resulting impact on long-term mortality. A decrease to the WHO AQG (10 $\mu g/m^3$) could lead to a benefit of €681,000,00 annually if the economic valuation is applied to gains in life expectancy (€500,224,000 if applied to number of postponed deaths).
A decrease in PM_{10} levels to WHO AQG (annual average of 20 $\mu g/m^3$) and the short-term impact on cardiac and respiratory hospitalisations could lead to a benefit of €654,000 annually .
A decrease of all daily 8h-maximum levels of ozone below the WHO AQG (100 $\mu g/m^3$) would have lead to a gain of €17,000 for respiratory hospitalizations and of €517,000 due to postponed deaths annually.

1.4.5. Interpretation of findings

Mortality data are highly reliable, and therefore do not represent a major source of uncertainty for the results of the present HIAs. On the contrary, hospital admission data present a major source of uncertainty because they include both emergency hospital admissions and planned hospital admissions that are certainly not temporally linked with the levels of air pollution. In consequence, the numbers of attributable hospital admissions are certainly over-estimated.

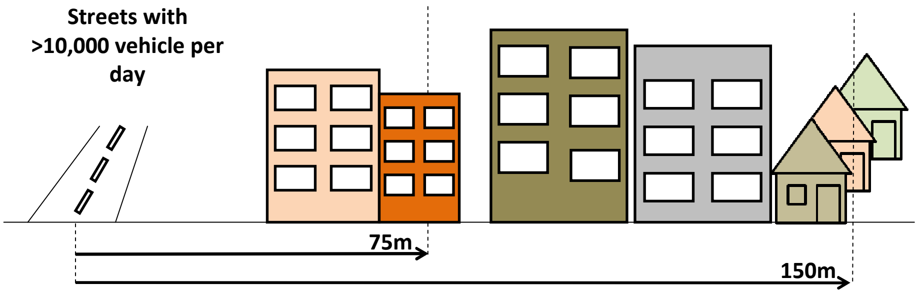
The results from the present HIAs may help promoting measures aiming at reducing air pollutant emissions, especially traffic linked emissions, as health benefits are a powerful way of motivating changes in individuals comportments.

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 7 – 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.

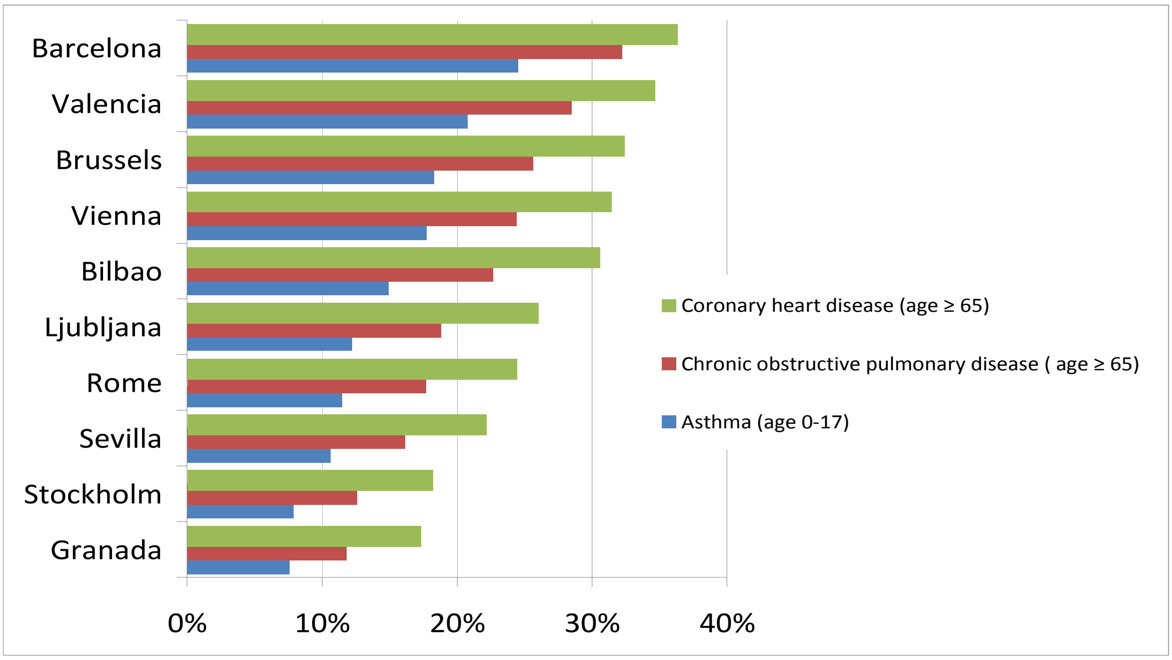


Figure 8 – Percentage of population with chronic diseases whose disease is attributable to living near busy streets and roads in 10 Aphekom cities

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.

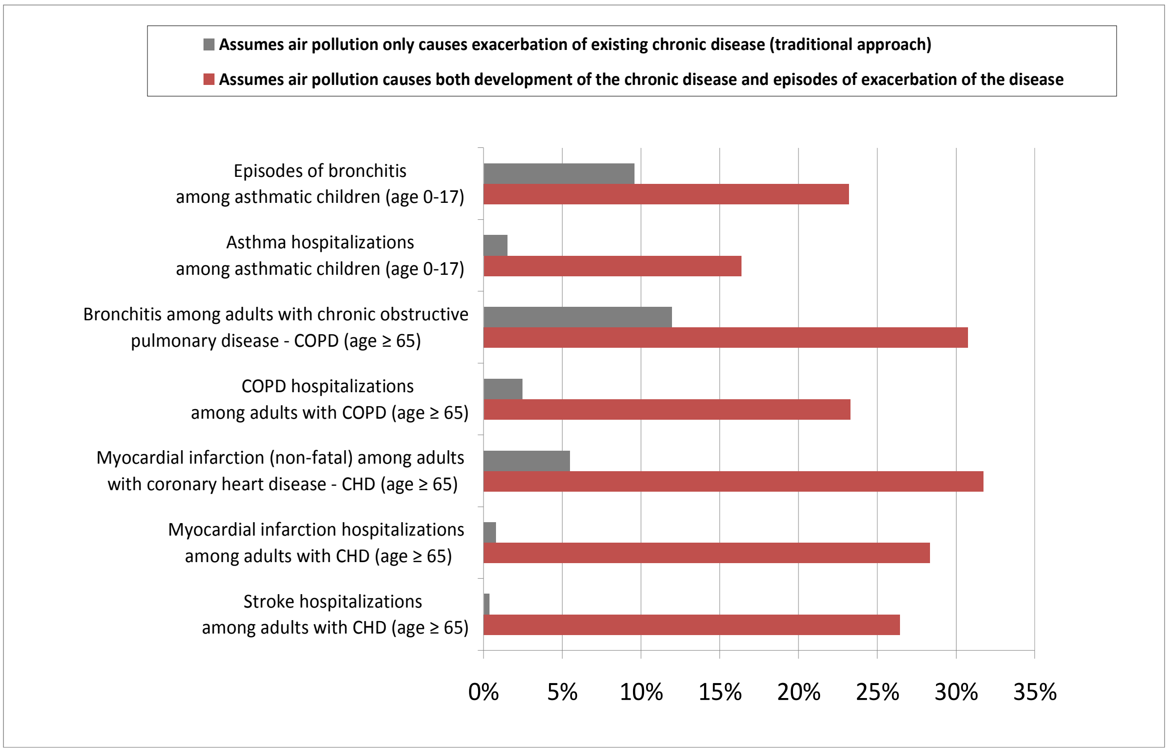


Figure 9 – Comparison of impact of air pollution on chronic diseases calculated using two different HIA approaches in Aphekom

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

As part of the work of the Aphekom WP6 an extensive review of the scientific literature on interventions, both legislative and coincidental which have resulted in reductions in air pollution, was conducted.
This review shows that air pollution interventions have been successful at reducing air pollution levels. It has also shown that there is consistent (significant) published evidence that most of these interventions have been associated with health benefits, mostly by way of reduced cardiovascular or respiratory mortality and or morbidity. Throughout the majority of reviewed interventions the found decrease in mortality exceeded by far the expected predicted figures based on European multicity studies. This provides an informed scientific basis for decision and policy makers.

In addition to that, Aphekom WP6 investigated the effects of EU legislation to reduce the sulphur content of fuels (mainly diesel oil used by diesel vehicles, shipping and home heating). In detail the effect on air pollution levels of the implementation of the Council Directive 93/12/EEC and its amended version Council Directive 1999/32/EC including marine oils were analysed. The implementation of the two Council Directives encompassed three stages of implementation gradually reducing the sulphur content in certain fuels in the EU member states with stage (I) being implemented as laid down in the directive on 1st Oct. 1994, stage (II) on 1st Oct. 1996 and stage (III) on 1st July 2000.

This analysis showed not only a marked, sustained reduction in ambient SO_2 levels, but also a saving of 2212 lives from all-cause mortality, 153 lives from respiratory-cause and 1312 lives from cardiovascular-cause mortality per year attributable to reduced ambient SO_2 for 20 European cities including Lille, spread all across Europe, from the year 2000 onwards compared to the baseline period with no directive being implemented.

Air quality analysis

The general decreasing trend in daily urban background (UB) SO_2 concentrations that has been observed across all centres over the time period of the study is illustrated in Figure 12 (French centres others than Paris are not represented). Overall there was no clear step change in SO_2 concentrations after implementation of the Directives; rather a gradual decline in SO_2 levels was observed.

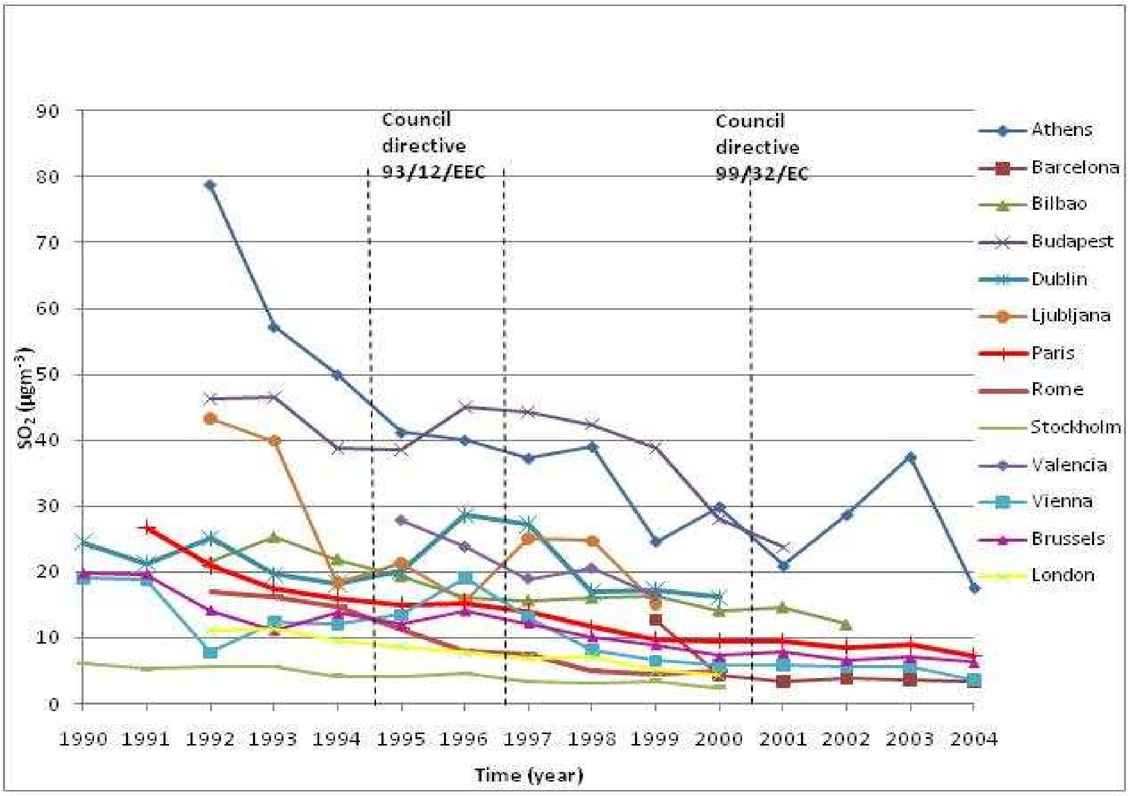


Figure 10 – Yearly urban background SO_2 averages for 13 Aphekom cities from 1990 to 2004

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. Peaks also occur now and then during the studied period in SO_2 levels for individual centres, but he 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.

In Lille (Fig 11), slight peaks were observed in the 1995-1996 and 1996-1997 winters.

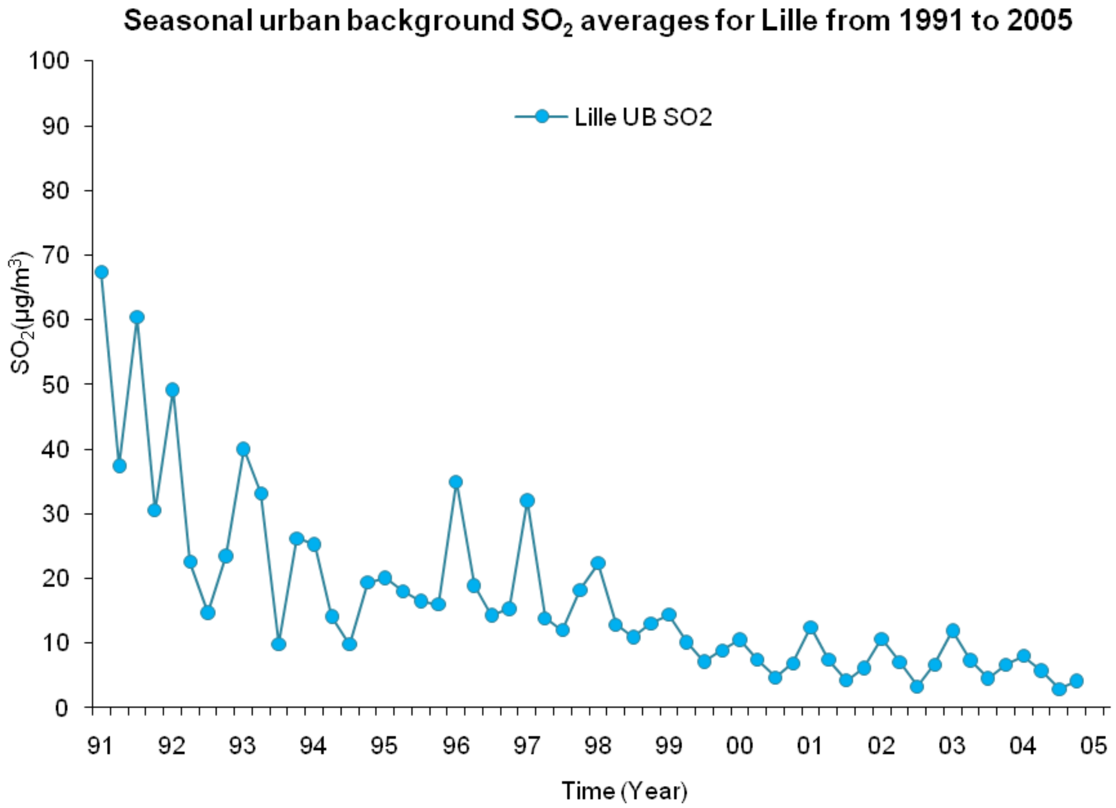


Figure 11: Plot of seasonal urban background SO_2 averages for Lille from 1991 – 2005

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.

Time-series analysis

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

The health data analysis showed no evidence of change of slope in the dose-response curve after implementation of the legislations and hence observed effects were related to level changes. The implementation of the first stage in 1994 reduced annual deaths by 639 deaths from all causes, by 47 deaths from respiratory and by 361 deaths from cardiovascular causes compared to the baseline period prior to October 1994 with no directive being implemented. The implementation of the 2nd stage in 1996 reduced annual deaths by 1093 deaths from all causes, by 83 deaths from respiratory and by 610 deaths from cardiovascular causes compared to the baseline period with no directive being implemented. The implementation of the 3rd stage in 2000 reduced annual deaths by 1616 deaths from all causes, by 127 deaths from respiratory and by 889 deaths from cardiovascular causes compared to the baseline period with no directive being implemented.

Local results in the Lille area are presented in table 12. Results are a gradual augmentation of saving of lives from stage 1 to stage 3 with finally a saving of 93 lives from all-cause mortality, 8 lives from respiratory-cause and 44 lives from cardiovascular-cause mortality per year attributable to reduced ambient SO_2 from the year 2000 onwards compared to the baseline period with no directive being implemented.

Table 9: Impact of the EU legislation on the sulphur content of fuels on mortality in Lille by implementation stage

Time Period	Annual number of postponed deaths (95% Confidence interval)	Annual number of postponed respiratory deaths (95% Confidence interval)	Annual number of postponed cardiovascular deaths (95% Confidence interval)
Stage 1 (1/10/1994-1/10/1996)	36 (13 to 59	3 (-1 to 7)	16 (5 to 28)
Stage 2 (1/10/1996-1/07/2000)	62 (22 to 102)	5 (-1 to 12)	28 (8 to 49)
Stage 3 (From 1/07/2000)	96 (34 to 159)	8 (-2 to 18)	44 (13 to 76)

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

The local estimates are not sufficiently robust at the city level to allow a local HIA so it has been decided to use the meta results for the local economic valuation. The legislation has two potential effects on mortality: short-term and long-term. It has been decided that, to take a conservative standpoint, mortality effects will be considered as short-term effects.

Consequently, a VSL (Value of Statistical Life) of €86,600 was applied to each premature deaths to compute the benefits for short-term mortality of the EU legislation to reduce the sulphur content of fuels at the city level. The economic evaluation thus constitutes a lower bound of the mortality benefits of the legislation.

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

Overall, the Aphekom project has shown that a decrease in concentrations of some pollutants to WHO guidelines, would lead to health improvement and cost benefits.
In particular, a decrease to 10 µg/m3 (WHO's annual AQG) of long-term exposure to PM2.5 could add up to 22 months of life expectancy at 30, depending on the city and its average level of PM2.5. This is equivalent to a burden of 19 000 deaths annually (15 000 of them from cardiovascular diseases) and a cost of €31,5 billion annually. In french cities, life expectancy at 30 could increase of 3 to 6 months. Locally, in Lille, a 5.8 months gain in life expectancy at 30 could be expected if PM2.5 was reduced to 10 µg/m3, placing Lille in the second place of French cities in term of long-term impact of PM2.5 on life expectancy (after Marseille and at the same level as Paris).
Aphekom also highlighted the health impact of living near traffic roads. Living near busy streets could be responsible for about 15% of asthma in children. The positive impact of SO2 legislation was also assessed.

In Nord-pas-de-Calais region, and in Lille area in particular, PM10 are globally decreasing from 2005. Yet, PM10 pollution episodes are frequent and WHO guidelines are often exceeded (and by the way France is in infraction with European legislation). PM2.5 represents 65% of PM10. Causes of high PM10 levels are among other things a high demographic density and a high density of traffic roads (Lille is at the center of a convergent highway system). After years of increase, we observe a decrease of mobility also characterized by a decrease of car use (but still 54% of transfers and 74% of covered distances) and an increase of public transports use (LMCU survey 2006). Actually, traffic is not really decreasing since covered distances are increasing. Moreover, periurban territories are highly dependant of car and public transports are mainly concentrated in the heart of the agglomeration.
Ozone is also a subject of concern since concentrations are slightly increasing since 2000 with guidelines exceedings. In this context, a reflexion on Ozone and climate change has to be engaged.

Aphekom results highlighted the fact, that despite some ameliorations of air quality and a general good air quality index (ATMO), a local strategy has to be elaborated to lower emissions, and especially PM emissions, also in application of the national "Plan particules" (particulates plan). In particular, PM2.5 will have to decrease of 30% until 2015. Local measures include the PDU (Plan de Déplacements Urbains) 2010-2020. Ambitious objectives include for example the reduction of the part of car use in mobility from 54% to 35%, in particular with a better agreement between land use and public transport network. As a cross-border territory, Lille also has to work in agreement with Belgian actions, within the framework of the Metropolitan Area of Lille (AML). Finally, since all Nord-pas-de-Calais is concerned by a vulnerability to PM emissions, the SRCAE (Schema Regional Climat Air Energie) will have to integer strong measures in favour of a reduction of PM10 and PM2.5 levels.

Acknowledgements

We would like to acknowledge the help and support of ATMO Nord-Pas-de-Calais, the air quality monitoring network in the Nord-Pas-de-Calais region.

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 9 – Health outcome and relative risks used in the HIA

HIA	Health outcome	Ages	RR per 10 µg/m^3	Ref
Short-term impacts of PM10	Non-external mortality	All	1.006 [1.004-1.008]	(4)
	Respiratory hospitalizations	All	1.0114 [1.0062-1.0167]	(5)
	Cardiac hospitalizations	All	1.006 [1.003-1.009]	(5)
Short-term impacts of O_3	Non-external mortality	All	1.0031 [1.0017-1.0052]	(6)
	Respiratory hospitalizations	15-64	1.001 [0.991-1.012]	(4)
	Respiratory hospitalizations	>=65	1.005 [0.998-1.012]	(4)
Long-term impacts of PM2.5	Total (including 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 $[PM2.5]_{mean} < 10$

References

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 mortality risk. Based on this trade-off, it then computes a VSL (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 $\mu g/m^3$ average annual level of PM2.5 (WHO's Air Quality Guideline) instead of the current existing air pollution level in the city.

Valuation of hospitalisations benefits

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

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

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

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

Table 1 Average lengths of stay, daily hospitalisation costs and work loss, and total hospitalisations cost per patient.

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

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

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

8.5 days x € 373= € 3,171

and the corresponding indirect cost related to work loss is:

2 x 8.5 days x € 73= € 1,241.

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

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

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

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

References

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.

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