APHEIS
Air Pollution and Health : A European Information System

Health Impact Assessment of Air Pollution In 26 European Cities

Second-year Report
2000-2001

Ajuntament de Barcelona
Institut Municipal de Salut Pública

Institut de Veille Sanitaire

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GLOSSARY

AIRNET: a thematic network on air pollution and health
APHEA: Air pollution and health: a European approach
APHEIS: Air pollution and health: a European information system
BS: black smoke particles
CAFE: Clean Air For Europe programme
CI: Confidence intervals / **CO:** carbonmonoxide / **CO_2:** carbon dioxide
DIM: French department of medical information in hospitals
DRIRE: French regional office of industry, research and infrastructure
EMECAS: Spanish study on the effects of air pollution on health in 14 Spanish Cities
ERPURS: Paris surveillance system of the effects of air pollution on health
E-R functions: Exposure-Response functions
EUROHEIS: A European Health and Environment System for Disease and Exposure Mapping and Risk Assessment
HIA: Health Impact Assessment
IARC: International Agency for Research on Cancer
ICD: International classification of diseases
INSERM: French National Institute of health and medical research
InVS: French national institute for Public Health Surveillance
NEHAPS: National Environment and Health Action Plans
NO: nitrogen oxide
NO_2: nitrogen dioxide
NO_x: nitrogen oxides
O_3: ozone
P10: 10^{th} percentile of the distribution of the pollutant
P90: 90^{th} percentile of the distribution of the pollutant
PACA: Provence Alpes Côte d'Azur
Pb: lead
PDU: French plans for urban transportation
PM_{10}: particulate matter less than 10 micrometers of diameter
$PM_{2.5}$: particulate matter less than 2.5 micrometers of diameter
PMSI: French hospital information system
PPA: French plans for the protection of the atmosphere
PRQA: French regional plans for air quality
PSAS-9: French national programme on the surveillance of the effects of air pollution on health in nine French cities
SD: Standard deviation
SO_2: sulfur dioxide
TSP: total suspended particulates
VOCs: Volatil Organic Compounds
WHO: World Health Organisation

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Air pollution continues to threaten public health across Europe despite tighter emission standards, closer monitoring of air pollution and decreasing levels of certain types of air pollutants.

This situation led to creation of the Apheis programme in 1999 to provide European decision and policy makers, environmental and health professionals, the media and the general public with an up-to-date and easy-to-use information resource on air pollution and public health, with the objective of helping them make better-informed decisions about the political, professional and personal issues they face in this area.

To develop this information resource, Apheis assembled a network that brings together environmental and public-health professionals on the city, regional and national levels across Europe. This network performs epidemiological surveillance through a system that provides information on an ongoing basis for HIA (health-impact assessment) of air pollution in Europe.

During its first year (1999-2000), Apheis achieved two key objectives: it defined the best indicators for epidemiological surveillance and HIA of air pollution in Europe; and it identified those entities best able to implement the surveillance system in the 26 cities in 12 European countries participating in the programme.

This report covers the work of the second year of the Apheis programme, which ended in April 2002. In specific, it presents the HIA findings for all the cities, first together and then city by city, and thus constitutes the initial step in meeting the information and decision-making needs of the programme's different target audiences.

What makes Apheis different?

The Apheis programme has produced the first broad-based European HIA of air pollution, since it comprises more cities in more countries than previous HIAs conducted in Europe.

The Apheis programme also differs from previous programmes by providing information on both the local and European levels simultaneously. In specific, the Apheis programme is the first to conduct individual HIA studies in each city in the programme, and also compile the findings from those studies in a single European HIA that comprises all the cities.

This multilevel approach provides two main benefits: the local HIAs supply each city with local data that can be used for local decision making, such as urban and transport planning and the devising of steps to reduce air-pollution levels; European authorities gain a global view and a tool for making decisions concerning air pollution and public health on the European level.

What did we learn?

We chose different HIA scenarios in order to provide decision makers at the local, national and European levels with a range of possible benefits from reducing particulate air pollution for short- and long-term perspectives. These scenarios took into account Council Directive 1999/30/EC of 22 April 1999 relating to limit values for particulate matter and other pollutants that should not be exceeded in 2005 and 2010.

Since some countries already showed low levels of PM_{10} and BS, we also proposed a scenario for smaller reductions such as 5 µg/m^3.

For this last scenario, in the 19 cities measuring PM_{10} and totalling almost 32 million European inhabitants, our HIA found 5 547 deaths (with a range of 3 368 to 7 744) deaths that could be prevented annually if long-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3. At least fifteen percent of these deaths can be attributed to a reduction of 5 µg/m^3 in short-term exposure to PM_{10}.

If instead of considering PM_{10} we consider black smoke in the 15 cities that measure it and total almost 25 million inhabitants, our HIA found 577 annual deaths (with a range of 337 to 818) that could be reduced if short-term exposure to outdoor concentrations of BS were reduced by 5 µg/m^3. We considered only the acute effects, since no exposure-response functions were available for the chronic effects of black smoke.

As these numbers show, while health risks from environmental factors, such as air pollution, are smaller than health risks from other causes, such as infectious diseases, cigarette smoking, and obesity, the small size of the risk from air pollution should not be underestimated in terms of its impact on public health.

Indeed, such relatively smaller risks deserve attention from a public-health perspective because air pollution is omnipresent and thus exposes the entire population to this health-risk factor.

As a result, we concluded that even very small and achievable reductions in air-pollution levels have an impact on public health, and that this impact justifies taking preventive measures, even in cities with low levels of air pollution.

The Apheis programme also obtained HIA findings that are consistent with those of other organisations that have conducted HIAs in the area of air pollution. Our findings thus add one more brick in the wall of evidence that air pollution continues to have an impact on public health.

How to interpret the findings?

To ensure that findings are comparable across all 26 participating cities, our network uses common methodology built on WHO and Apheis guidelines, and applies it consistently in all the cities.

Because uncertainties are inherent in HIA calculations, we used a conservative approach with reasonable assumptions. In specific, for mortality we did not consider the effects on newborns or infants separately. Indeed, even if the number of attributable cases may be small in the younger age groups, the impact on years of life lost, and therefore the economic costs, could be considerable.

We also did not consider many other health outcomes listed by WHO and potentially relevant for HIA.

We also limited our analysis to PM_{10} and BS among the air pollutants that could be considered. For example, we did not evaluate the independent effect of ozone.

Lastly, because the reference level used for the exposure to particulate air pollution strongly influences the impact estimates, in our HIA we used a range of reference levels in different scenarios to provide a set of realistic, conservative pictures of the potential health benefits of reducing air pollution.

One other concern was that, like every HIA, we faced uncertainties that include, among others, the transferability of exposure-response functions. For short-term exposure to air pollution, this problem did not arise since we used exposure-response functions newly developed by the APHEA 2 study, whose cities are almost the same as those in the Apheis programme.

However, for long-term exposure to air pollution, in the absence of European studies on chronic mortality and air pollution, we selected the exposure-response function used in the HIA done in Austria, France and Switzerland based on two American cohort studies and reanalysed by the Health Effects Institute. At the same time, we are aware that the transferability of estimates between the U.S. and Europe remains an open question, since the particulate composition and populations can differ substantially between the two continents.

What are the next steps?

By translating epidemiological findings into a decision-making tool, the Apheis programme seeks to bridge the gap between data and action.

During our second year, the programme conducted an HIA that provides a conservative but accurate and detailed picture of the impact of air pollution on health in 26 European cities, and shows that air pollution continues to threaten public health in Europe.

To keep the information we produce and disseminate as up-to-date and accurate as possible, during the third year of the Apheis programme, which started in April 2002, we will produce new exposure-response functions on the short-term effects of air pollution using our epidemiological surveillance system. And we will calculate years of life lost or reduction in life expectancy, in addition to the absolute number of attributable cases, in order to estimate the health impacts of long-term exposure to air pollution.

To fulfil our mission of ultimately making our learnings available to the broadest possible audiences for decision making on air-quality management, public policy, health care and personal behaviour, during the third year and for the first time we will also explore and understand how best to meet, in terms of content and form, the information needs of government decision and policy makers concerned with the impact of air pollution on public health.

In a future phase of the Apheis programme, as another new step we plan to collaborate with economists in order to calculate the costs to society of the health effects of air pollution in the cities participating in the programme.

We also hope to involve the Apheis programme more closely in local, regional, national and European programmes like NEHAPs (National Environmental Health Action Plans), the European network AIRNET, the WHO programme on air pollution and health, the CAFE (Clean Air for Europe) programme and the EUROHEIS programme, and share with them our latest findings.

As a reminder, Apheis is a multiyear, multiphase proactive programme dedicated to answering key questions on air pollution and public health in Europe. Each phase of the programme builds on the learnings of the previous phase like a set of building blocks.

To be truly effective in meeting on a continuing basis the information needs of the audiences it serves, the Apheis programme requires the ongoing commitment and financial support of the European Commission and its member states.

This report and further information on the Apheis programme and its participants can be found at www.apheis.org

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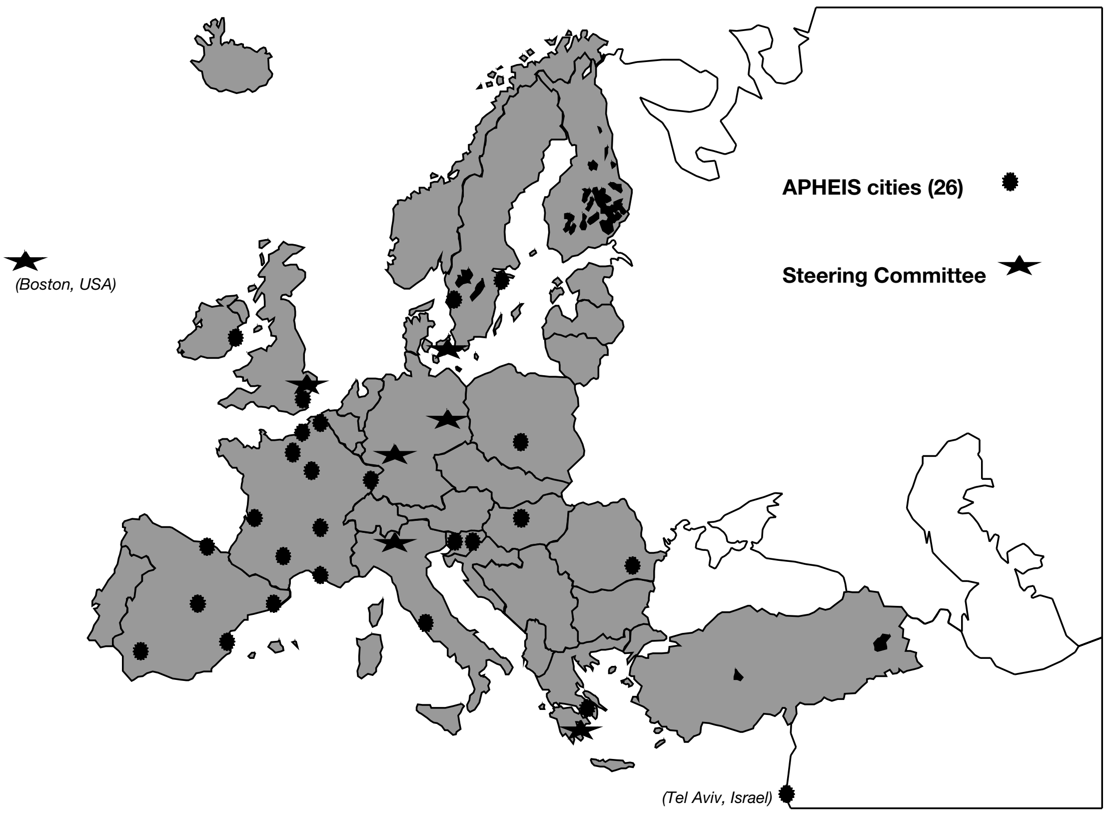
www.apheis.org

APHEIS Centres



INTRODUCING APHEIS

Air pollution continues to threaten public health across Europe despite tighter emission standards, closer monitoring of air pollution, and decreasing levels of certain types of air pollutants.

Because of this situation, the Apheis programme was created in 1999 to provide European decision makers, environmental and health professionals, the media and the general public with a comprehensive, up-to-date and easy-to-use information resource on air pollution and public health with the objective of helping them make better-informed decisions about the political, professional and personal issues they face in this area.

To develop the information resource, the Apheis programme has created an epidemiological surveillance system that generates information on an ongoing basis for HIA (health-impact assessment) of air pollution in Europe.

During its first year (1999-2000), Apheis achieved two key objectives: it defined the best indicators for epidemiological surveillance and HIA of the effects of air pollution on public health in Europe; and it identified those entities best able to implement the surveillance system in the 26 cities in 12 European countries participating in the programme[1].

This report covers the work of the second year of the Apheis programme, which ended in April 2002, and constitutes the first step in meeting the information needs of the programme's different target audiences.

To gather this information, Apheis created a European network of environmental and public-health professionals who perform epidemiological surveillance and HIA of air pollution in 26 European cities. The epidemiological surveillance and HIA generate data that Apheis analyses and presents in the form of reports, such as this one, to meet the information needs described above.

To meet the information needs of its different audiences, in this report government or policy decision makers should find scientific data and analysis that will enable them to make better-informed decisions about air pollution and public health.

Environmental professionals should find information enabling them to include the public-health perspective when developing new strategies for measuring air quality.

Health and public-health professionals should find scientific information enabling them to be better informed about the effects of air pollution on health so they can better advise patients and decision-makers on this topic.

The media should find information that will help them better understand the consequences of exposure to air pollution for our health and give them the latest available scientific data and findings in this area.

And the general public should find information to understand better the impact of air pollution on public health and to make decisions about their personal behaviour.

How this report is organised

In this report we first describe briefly how the Apheis network is organised, and how we conducted the HIA.

We then present and compare the characteristics and the HIA of the participating cities.

The next section describes how to interpret the findings, followed by the main conclusions and future steps.

The last section comprises the 26 city-specific reports, and is followed by the appendices.

References

1. Medina S, Plasència A, Artazcoz L, Quénel P, Katsouyanni K, Mücke HG, De Saeger E, Krzyzanowsky M, Schwartz J, and the contributing members of the Apheis group. APHEIS: Monitoring the Effects of Air Pollution on Public Health in Europe. Scientific report, 1999-2000. Institut de Veille Sanitaire, Saint-Maurice, March 2001; 136 pages *(www.apheis.org).*

METHODS USED BY APHEIS

How is Apheis organised

The Apheis programme comprises 16 centres totalling 26 participating cities in 12 European countries (Figure A). Each Apheis centre is part of a local, regional or national institution active in the field of environmental health.

During the first year of the Apheis programme, a survey determined that, in institutional and operational terms, most of the Apheis centres could create an organisation able to generate and use standardised periodic reports on the effects of air pollution on health[1].

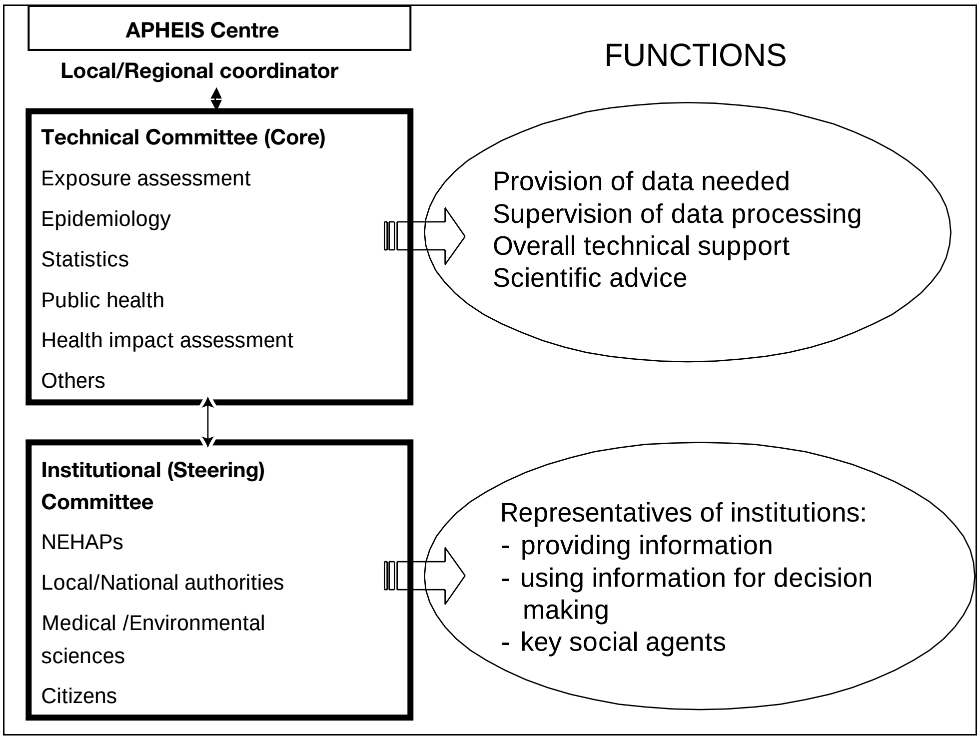
The survey also determined that the degrees of institutional involvement at each centre produced different organisational models. These models range from a basic model, essentially comprising environmental and public-health professionals and scientists from other fields, to a more-comprehensive, better-structured model having a broader spectrum of scientific and technical participants and greater institutional involvement in decision making through the presence of an institutional committee (Figure B).

During the second year of the Apheis programme, the different participating centres created organisations to collect and process data on exposure to air pollution and on health outcomes, as well as on climate, geographical and demographic aspects. This information gathering and processing enables periodic preparation of standardised reports, like this one, on the health impact assessment of air pollution in each city.

Figure A. **APHEIS centres by country**

Country	Centres	Cities
France	France (PSAS-9 Programme)	Bordeaux Le Havre Lille Lyon Marseille Paris Rouen Strasbourg Toulouse
Greece	Athens	Athens
Hungary	Budapest	Budapest
Ireland	Dublin	Dublin
Israel	Tel Aviv	Tel Aviv
Italy	Rome	Rome
Poland	Cracow	Cracow
Romania	Bucharest	Bucharest
Slovenia	Slovenia	Celje Ljubljana
Spain	Barcelona Bilbao Madrid Seville Valencia	Barcelona Bilbao Madrid Seville Valencia
Sweden	Sweden	Gothenburg Stockholm
United Kingdom	London	London

Figure B. APHEIS general organisational model and functions



Tables 1 and 2 describe the type of experts and the level of institutional involvement in each Apheis centre. The programme currently involves over 200 professionals in 26 cities who largely come from the health sector (58%), but also from the environmental sector (24%) and other fields (5%). This gives a mean of eight professionals per centre and a range of two to 23 (Table 1). The survey also determined that all centres have appointed a formal coordinator who, in most cases, belongs to a public-health institute.

Most centres show some level of institutional involvement, either local (85%), regional (58%) or national (31%) (Table 2). In 31% of the centres, there is also some level of involvement from academic or grass-roots organisations. Such participation has been formally established at the technical and scientific levels in most cities, with explicit involvement at the decision-making level in Barcelona, the nine cities in France and the two cities in Sweden.

In conclusion, the organisational models that support the development of Apheis are ample and diverse in terms of technical and scientific areas of expertise. Similarly local, regional and national experts from the fields of health and environment are present in most centres. On the other hand, although the necessary organisations are in the early phase of being created, it seems desirable to involve decision makers more deeply in the organisational models needed to support Apheis activities in the future.

Table 1. **Number of experts active in each Apheis centre by field and city**

City	Coordinator	Field of expertise		
		Air Quality	Health	Other
Athens	1	–	–	1
Barcelona	1	4	7	2
Bilbao	1	1	4	–
Bordeaux	1	2	8	–
Bucharest	1	4	4	–
Budapest	1	1	1	–
Celje	2	1	1	–
Cracow	1	2	4	–
Dublin	1	–	1	–
Gothenburg	1	4	6	1
Le Havre	1	2	3	–
Lille	2	3	8	–
Ljubljana	1	1	2	–
London	1	–	1	–
Lyon	1	2	9	–
Madrid	1	4	4	–
Marseille	1	5	17	–
Paris	1	3	3	3
Rome	1	(*)	1	–
Rouen	1	4	5	–
Seville	1	–	3	–
Stockholm	1	4	6	1
Strasbourg	1	2	6	–
Tel Aviv	1	2	2	2
Toulouse	1	1	7	–
Valencia	1	2	9	–

(*) some degree of involvement, but not further specified

Table 2. **Levels of institutional involvement in each Apheis centre**

City	Level of institutional involvement			
	Local	Regional	National	Other
Athens	–	–	–	X
Barcelona	X	X	–	X
Bilbao	–	X	–	–
Bordeaux	X	X	–	–
Bucharest	X	–	X	–
Budapest	X	–	X	–
Celje	X	–	X	–
Cracow	X	–	X	X
Dublin	–	–	–	X
Gothenburg	X		X	X
Le Havre	X	X	–	
Lille	X	X	–	X
Ljubljana	X	–	X	–
London	X	X	–	–
Lyon	X	X	–	–
Madrid	X	X	–	–
Marseille	X	X	–	–
Paris	X	X	–	–
Rome	X	X	–	–
Rouen	X	X	–	–
Seville	–	–	–	X
Stockholm	X		X	X
Strasbourg	X	X	–	–
Tel Aviv	X		X	
Toulouse	X	X	–	–
Valencia	X	X	–	–

Data collection and analysis

The methods used to gather and analyse data on air pollution and its impact on health in the 26 European cities are described in the Apheis first-year report. Apheis members drafted the guidelines needed to create and implement the epidemiological surveillance system. And they drafted guidelines for developing a standardised protocol for data collection and analysis to be used in the health impact assessment[1].

Health impact assessment

In the field of air pollution, an HIA can play a role in evaluating different policy scenarios for reducing air-pollution levels; in assessing new air-quality directives; or in calculating the external monetary costs of air pollution or the benefits of preventive actions.

An HIA in this field provides the number of health events attributable to air pollution in the target population.

For the purpose of its work, Apheis adopted WHO guidelines for assessing and using epidemiological evidence for environmental-health risk assessment[a], and also developed its own statistical and HIA guidelines[1].

When conducting our HIA, the main steps we used included:

a. Specify exposure

b. Define the appropriate health outcomes

c. Specify the exposure-response relationships or effect estimates

d. Derive population baseline frequency measures for the health outcomes under consideration

e. Calculate the number of attributable cases in the target population.

Acute effects of particles

For its first HIA, Apheis has analysed the acute effects of inhalable particles (PM_{10} and BS) on premature mortality and hospital admissions.

During this phase of our work, we used the effect estimates newly developed by the APHEA 2 study[b] for the following health outcomes:

- Acute effects of air pollution on premature mortality, excluding accidents and violent deaths (ICD9<800)
- Acute effects on hospital admissions for respiratory diseases in the over-65 age group (ICD9 460-519)
- Acute effects on hospital admissions for cardiac diseases in people of all ages (ICD9 410-414, 427, 428)

For future phases of the project, Apheis will develop new estimates for acute effects of air pollution, and will increase the number of health indicators studied.

The estimates of acute impacts of short-term changes in air pollution, based on time-series studies, represent a lower bound of the total impacts, which will also include effects of long-term exposures.

[a] See a more detailed description of WHO guidelines in Appendix 1.

[b] See selected Exposure-Response functions in Appendix 2.

Chronic effects of particles

The conclusions of the WHO Working Group meeting in November 2001[2] state that the most complete estimates of the impact on health of exposure to air pollution are those based on cohort studies. Therefore, we also estimated the impacts on premature mortality of long-term exposure to particles. For this purpose, we used the exposure-response function employed in the HIA conducted in Austria, France and Switzerland and based on two American cohort studies[b].

For this and future phases, Apheis will use the most up-to-date exposure-response functions available for the chronic effects of air pollution.

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1. Medina S, Plasència A, Artazcoz L, Quénel P, Katsouyanni K, Mücke HG, De Saeger E, Krzyzanowsky M, Schwartz J, and the contributing members of the APHEIS: group. APHEIS: Monitoring the Effects of Air Pollution on Public Health in Europe. Scientific report, 1999-2000. Institut de Veille Sanitaire, Saint-Maurice, March 2001; 136 pages (www.apheis.org).
2. Quantification of health effects of exposure to air pollution. WHO, Regional Office for Europe, Copenhagen, 2001 (E74256).

COMPILATION OF FINDINGS

Descriptive statistics

The following tables and figures show the demographic characteristics of the Apheis cities; the levels of particulate air pollution observed; and the health measurements used to evaluate the impact of air pollution.

Demographic characteristics

The total population covered in this phase by Apheis includes almost 39 million inhabitants of Western and Eastern Europe. The proportion of people over 65 years of age is around 15% of the population, with the highest proportion being in Barcelona and the lowest in London.

Table 3. **Demographic characteristics of 26 cities**

City	Year	Population	Population over 65 years
		Number	Percent
Athens	1996	3 072 922	13.0
Barcelona	1999	1 505 581	20.7
Bilbao	1996	647 761	16.4
Bordeaux	1999	584 164	15.8
Bucharest	1999	2 028 000	13.0
Budapest	1999	1 775 587	17.5
Celje	1999	50 121	14.0
Cracow	1999	738 150	13.4
Dublin	1998	510 139	13.1
Gothenburg	2000	462 470	16.4
Le Havre	1999	254 585	15.1
Lille	1999	1 091 156	12.8
Ljubljana	1999	267 763	14.8
London	1999	7 285 100	12.6
Lyon	1999	782 828	15.7
Madrid	1998	2 881 506	17.8
Marseille	1999	856 165	18.7
Paris	1999	6 164 418	13.8
Rome	1995	2 685 890	17.2
Rouen	1999	434 924	15.2
Seville	1996	697 485	13.5
Stockholm	1999	1 163 015	15.6
Strasbourg	1999	451 133	13.3
Tel Aviv	1996	1 139 700	14.2
Toulouse	1999	690 162	13.5
Valencia	1996	746 683	16.1

Air-pollution levels

In this HIA we used the most recent years for which air-pollution measurements are available for each city. And we only used measurements in areas representative of the exposure of the population at large. Most of the time, this choice limits the measurement stations to urban background locations. In Appendix 4 appears a full description of the air-quality network in each city, including the total number and type of monitoring stations and the number used for our purpose.

Black smoke measurements were provided by 15 cities: Athens, Barcelona, Bilbao, Bordeaux, Celje, Cracow, Dublin, Le Havre, Lille, Ljubljana, London, Marseille, Paris, Rouen and Valencia.

PM_{10} measurements were provided by 19 cities: Bordeaux, Bucharest, Budapest, Celje, Cracow, Gothenburg, Lille, Ljubljana, London, Lyon, Madrid, Marseille, Paris, Rome, Seville, Stockholm, Strasbourg, Tel Aviv and Toulouse. Bilbao had data on PM_{10} from only one monitoring station that may not accurately represent the average exposure of the residents in the Bilbao area. As a result, PM_{10} data for Bilbao is not shown in the core report.

Some cities provided both PM_{10} and black smoke measurements.

According to the Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (Official Journal L 163, 29/06/1999 P. 0041 – 0060)[1], a PM_{10} 24-hour limit value of 50 µg/m^3 should not be exceeded more than 35 times per year by 1 January 2005 and no more than seven times per year by 1 January 2010 in the Member States. Also, a PM_{10} annual limit value should not exceed 40 µg/m^3 by 1 January 2005 and 20 µg/m^3 by 1 January 2010.

Table 4 and Figures 1 and 2 give an indication of current levels of particulate pollution in the cities (mean levels, standard deviation [SD], 10th and 90th percentiles of the distribution of the pollutant in each city).

When reading these tables and figures, we should remember that it is difficult to compare air-pollution levels between different cities in Europe due to the use of different years and possible different sources of variability in the measurements (see section “How to Interpret the Findings” and Appendix 4).

Table 4. **PM_{10} and BS levels in 26 cities**

City	Year	PM_{10}				BS			
		Mean	SD[1]	P10[2]	P90[3]	Mean	SD	P10	P90
Athens	1996					65.9	29.6	32.6	108.0
Barcelona	1999					32.9	13.5	19.2	48.4
Bilbao	1998					18.4	10.7	7.8	32.9
Bordeaux	2000	20.1	10.1	10.3	32.4	15.3	10.2	5.5	30.6
Bucharest*	1999	73.0*	13.0*	58.9*	86.1*				
Budapest	1999	29.5	11,3	16.2	45.2				
Celje	1999	36.0	19.3	14.8	58.7	15.6	14.1	4.0	32.0
Cracow	1999	45.4	31.6	20.5	79.0	36.5	40.0	10.5	75.0
Dublin	1998					11.2	6.5	5.0	19.9
Gothenburg	2000	14.0	7.0	6.8	22.3				
Le Havre	1998					9.3	9.2	2.8	20.5
Lille**	1999-2000**	19.5	7.9	11.0	30.0	8.1	6.8	2.0	18.0
Ljubljana	1999	35.7	19.5	15.7	61.7	18.3	15.5	6.0	36.7
London	1999	21.8	8.2	14.0	32.0	9.5	6.0	4.0	16.0
Lyon	2000	23.0	12.0	11.8	37.3				
Madrid	1998	36.9	16.4	19.8	56.1				
Marseille	2000	24.4	9.2	13.5	33.5	16.9	15.8	4.0	41.6
Paris	1998	24.0	13.6	12.0	38.9	19.0	16.8	7.4	34.8
Rome	1999	43.3	17.4	25.6	66.6				
Rouen	1998					9.8	14.0	2.5	19.2
Seville	1999	44.4	10.7	32.1	58.9				
Stockholm	2000	14.0	5.3	7.4	24.0				
Strasbourg	1999	22.3	10.9	10.4	36.0				
Tel Aviv	1996	56.4	97.8	24.0	78.0				
Toulouse	2000	17.9	8.3	9.0	29.0				
Valencia	1999					23.5	15.6	10.5	44.9

1. SD: Standard deviation
2. P10: 10th percentile of the distribution of the pollutant
3. P90: 90th percentile of the distribution of the pollutant

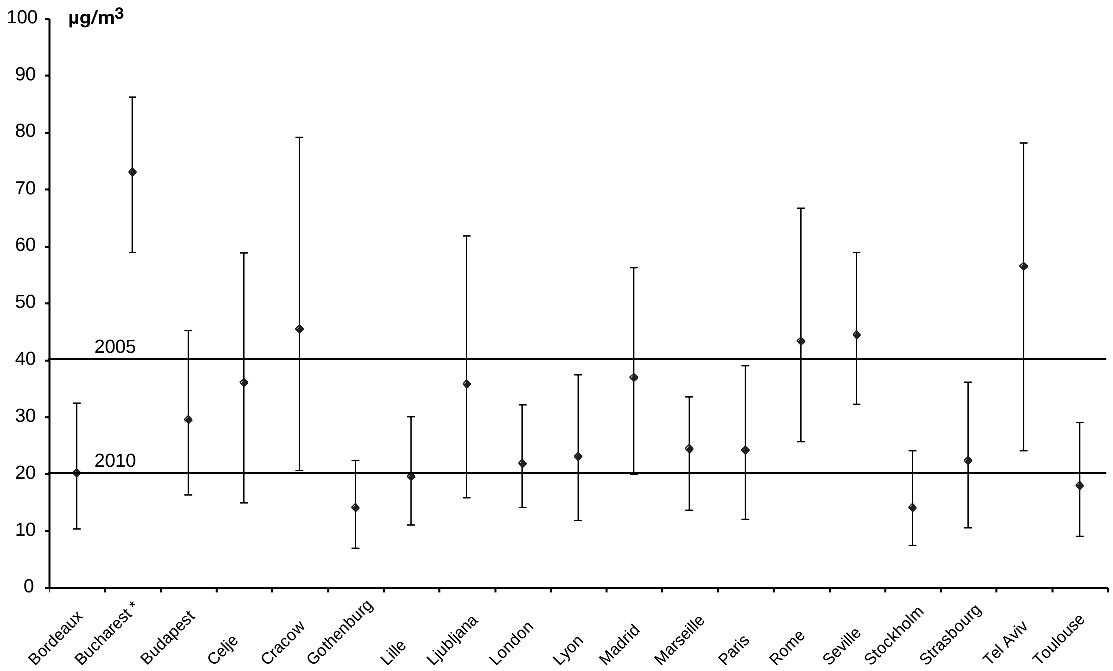
* For Bucharest, measurements only available for four weekdays (Monday to Thursday)

** For Lille: PM_{10} measurements available for 2000, BS measurements available for 1999

[1] See Appendix 3.

In Figure 1, horizontal lines indicate the EC annual mean cut-offs of 40 µg/m³ and 20 µg/m³ to be reached respectively in 2005 and 2010.

Figure 1. **Annual mean levels and 10th and 90th percentiles of the distribution of PM_{10}**



* Bucharest shows the highest PM_{10} levels, but in this city measurements were only available for four weekdays (Monday to Thursday); this may explain the high levels observed.

Tel Aviv also shows high values of PM_{10} levels, partly influenced by wind-blown sand from the desert. Cracow, Rome and Seville show PM_{10} levels higher than 40 µg/m³.

Mean values of most of the cities are in the range between 40 and 20 µg/m³. Gothenburg, Lille, Stockholm and Toulouse show levels below 20 µg/m³.

For each city measuring PM_{10}, Figure 2 uses different grey scales to show the number of days per year when PM_{10} exceeded 24-hour values of 20 and 50 µg/m^3.

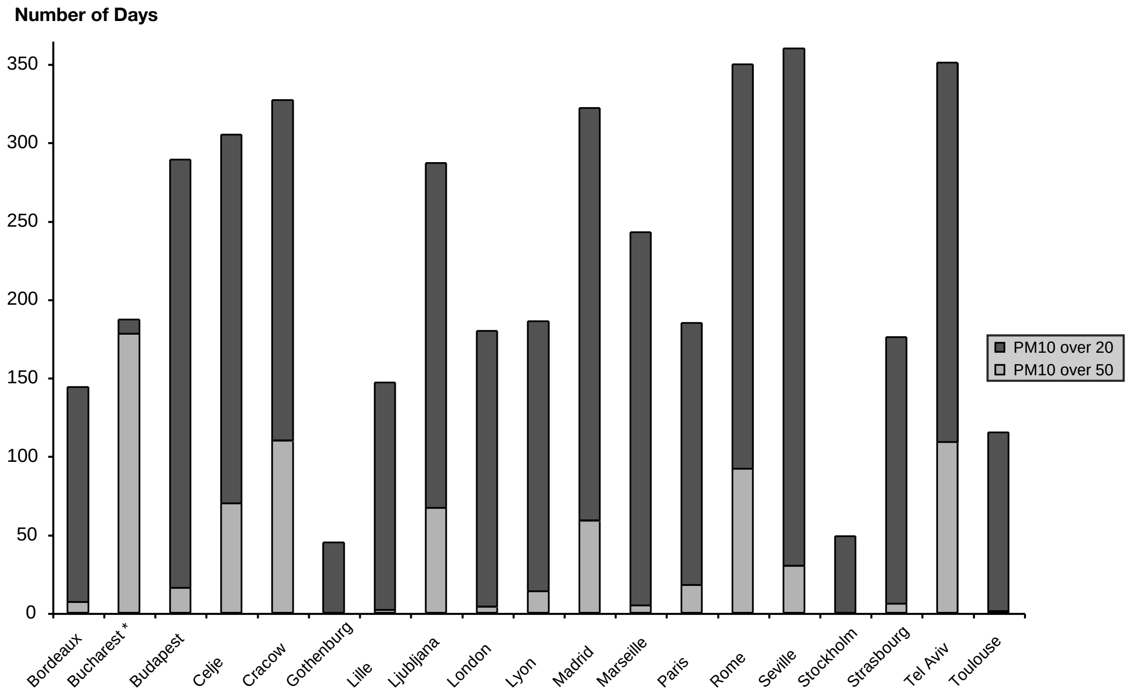
The PM_{10} 24-hour value of 20 µg/m^3 is exceeded frequently.

During a 1-year period, PM_{10} 24-hours value exceeded 20 µg/m^3 on 300 days or more in Celje, Cracow, Madrid, Rome, Seville and Tel Aviv. If we exclude Bucharest, the 24-hour value of 20 µg/m^3 was exceeded on 150 or more days in a 1-year period in Budapest, Ljubljana, London, Lyon, Marseille, Paris and Strasbourg.

The number of days in the year when the PM_{10} 24-hour value of 50 µg/m^3 is exceeded is the highest in Cracow (110), Rome (92) and Tel Aviv (109), if we exclude Bucharest. These cities are followed by Celje (70), Ljubljana (67), and Madrid (59).

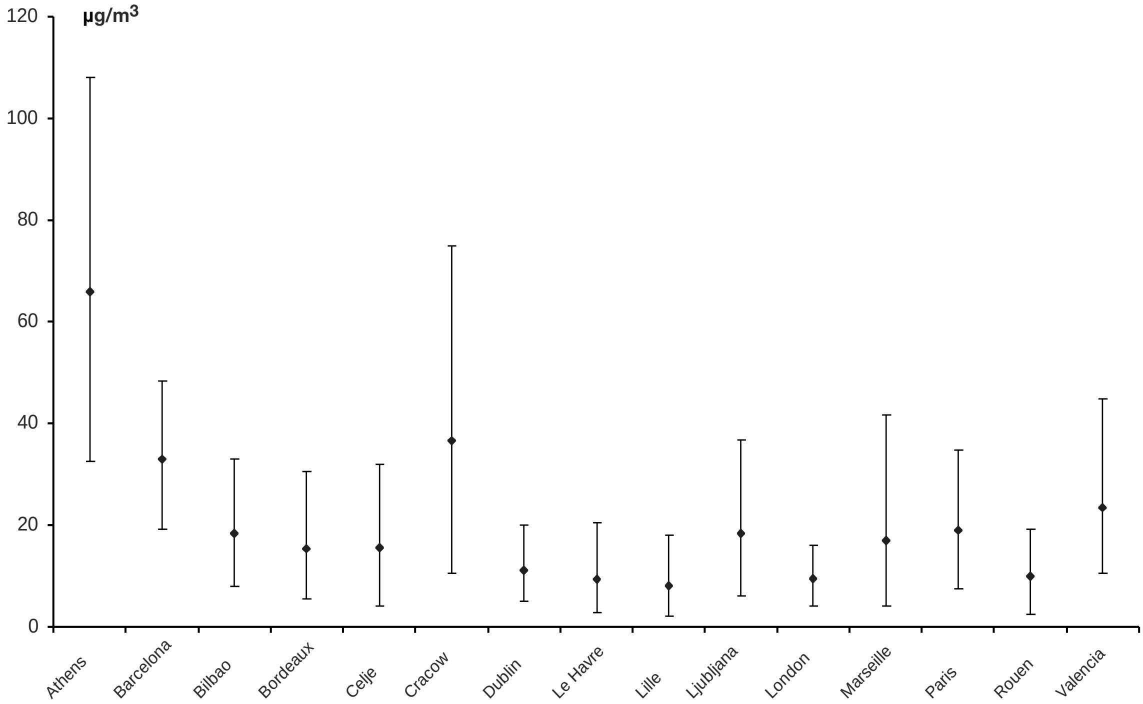
The rest of the cities exceeded 50 µg/m^3 during a few days, thereby already complying with the PM_{10} 24-hour limit values to be met in 2005 and not to be exceeded more than 35 times per year.

Figure 2. **Number of days per year when PM_{10} exceeded 24-hour values of 20 and 50 µg/m^3**



** For Bucharest, measurements were only available for four weekdays (Monday to Thursday).*

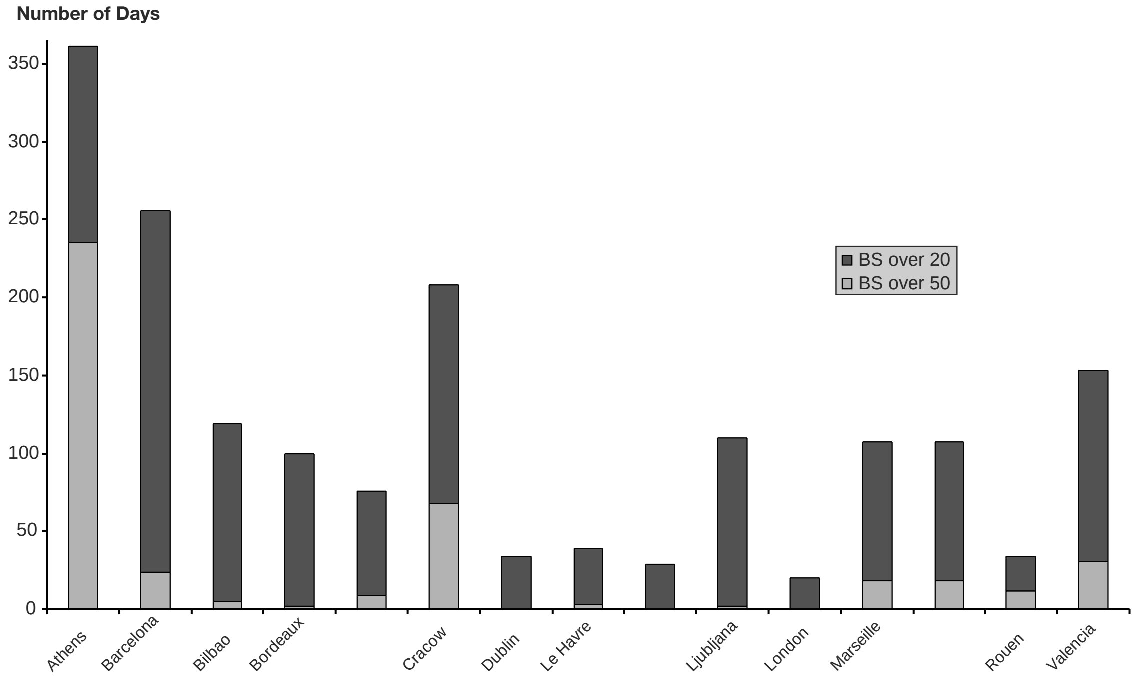
Figure 3. **Annual mean levels and 10^{th} and 90^{th} percentiles of the distribution of black smoke**



Regarding BS (Figure 3), Athens shows by far the highest mean levels. One of the reasons for these high levels may be that the two selected stations measuring BS are in the centre of Athens and could be characterized as traffic stations.

Barcelona, Cracow and Valencia follow with levels higher than 20 µg/m^3. The lowest BS levels (below 10 µg/m^3) are seen in Le Havre, Lille, London and Rouen.

Figure 4. **Number of days per year when black smoke exceeded 24-hour values of 20 and 50 µg/m³**



The number of days when BS 24-hour values of 50 and 20 µg/m³ were exceeded is the highest in Athens. In this city, mean levels of BS exceeded 50 µg/m³ on 235 days during a 1-year period and 20 µg/m³ during 361 days during a 1-year period. These high levels are probably influenced by the proximity of traffic (Figure 4).

In Barcelona, the number of days when BS 24-hour values exceeded 20 µg/m³ is 256, in Bilbao it is 119, in Bordeaux 100, in Cracow 208, in Ljubljana 110, in Marseille and Paris 107 and in Valencia 153.

In Barcelona, Cracow and Valencia the number of days when BS 24-hour values exceeded 50 µg/m³ is 24, 68 and 31 respectively.

Health indicators

Appendix 5 gives a full description of the health indicators used, the type of sources, the coverage, the existence of a quality-control programme, the type of coding used, the completeness of the data, and conclusions about the comparability of the data.

Mortality

After checking the different items presented in Appendix 5, the mortality data for the 26 cities can be compared reliably.

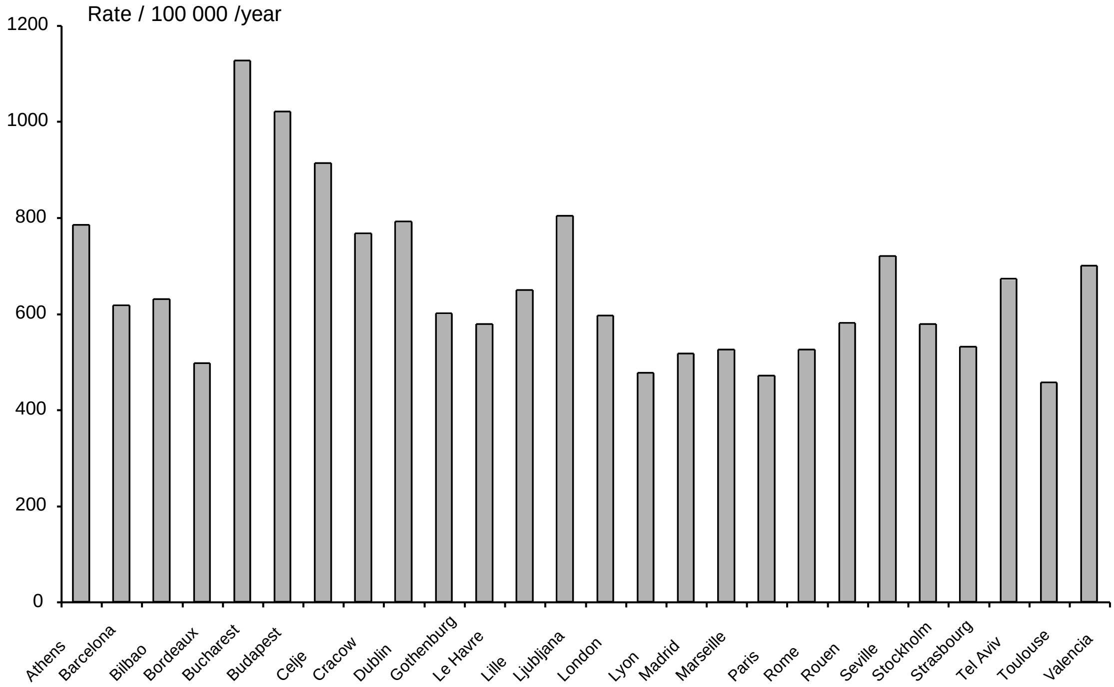
Table 5 shows the daily mean number of deaths excluding violent deaths and the age-standardised mortality rates for all causes, including violent deaths, in the 26 Apheis cities, using the European population for reference (IARC 1982).

Table 5. **Daily mean (standard deviation) number of deaths and age-standardised mortality rates in the 26 cities**

City	Year	Total mortality* Daily mean (standard deviation)		Age standardised** Mortality rate
Athens	1996	74.5	(14.0)	784.4
Barcelona	1999	41.2	(10.1)	616.4
Bilbao	1998	13.8	(4.1)	630.0
Bordeaux	1999	12.1	(3.9)	497.0
Bucharest	1999	59.2	(13.1)	1127.0
Budapest	1999	73.6	(10.7)	1020.6
Celje	1999	1.7	(0.4)	913.0
Cracow	1999	18.3	(4.8)	766.5
Dublin	1998	12.4	(3.6)	791.0
Gothenburg	1999	13.1	(3.8)	600.0
Le Havre	1998	5.4	(2.3)	578.0
Lille	1998	21.9	(4.8)	648.5
Ljubljana	1999	7.7	(1.6)	803.5
London	1999	157	(35.0)	595.6
Lyon	1998	15.2	(4.3)	476.9
Madrid	1998	61.7	(12)	516.8
Marseille	1998	20.9	(4.9)	524.8
Paris	1998	115.6	(14.8)	470.2
Rome	1999	59.0	(13)	524.9
Rouen	1998	9.6	(3.5)	580.0
Seville	1999	15.4	(4.7)	719.0
Stockholm	1999	30.3	(6.4)	578.0
Strasbourg	1998	8.2	(2.8)	530.6
Tel Aviv	1996	27.2	(5.5)	672.0
Toulouse	1998	11.4	(3.5)	456.0
Valencia	1999	17.3	(5.9)	699.8

** ICD9<800*
*** Age-standardised mortality rate per 100 000 including violent deaths, using the European population (IARC 1982)*

Figure 5. **Standardised mortality rates for all causes of deaths in the 26 cities**



The standardised mortality rates for all causes of death, including violent causes (Figure 5), are the highest for Bucharest, Budapest and Celje, and range from 1 127 per 100 000 in Bucharest to 450-500 per 100 000 in Bordeaux, Lyon, Paris and Toulouse.

Hospital admissions

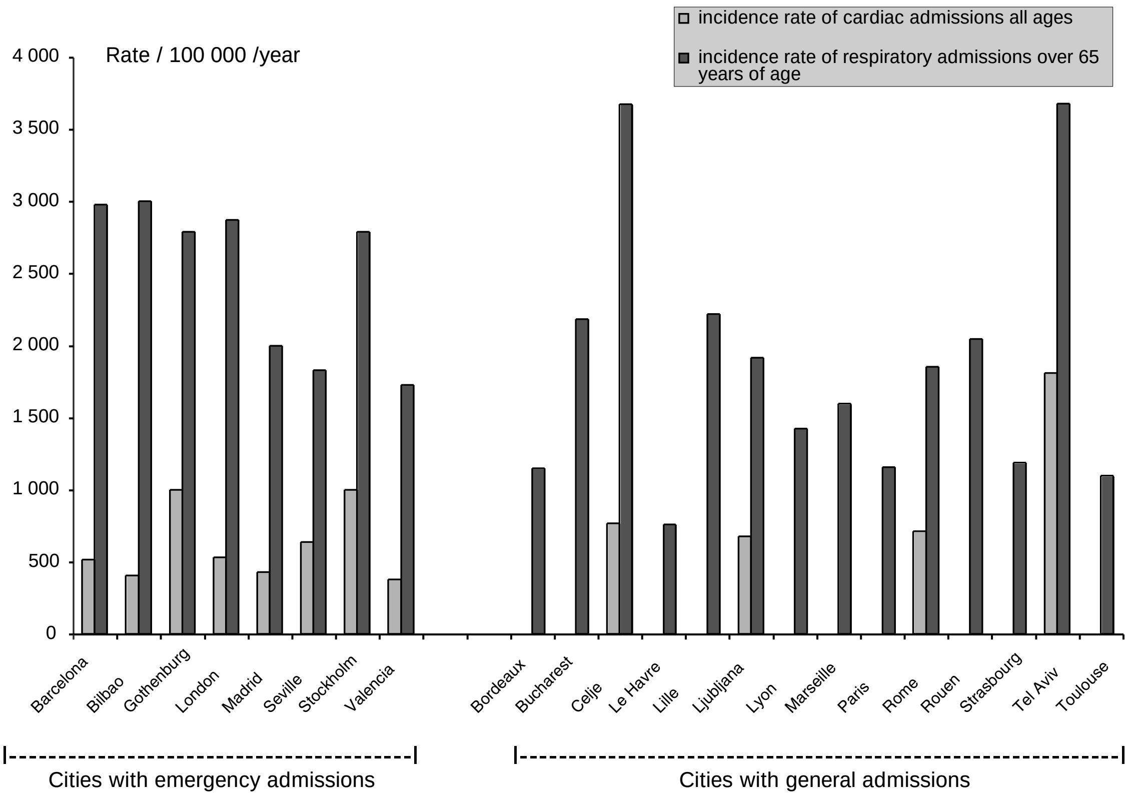
Twenty-two cities had data on hospital admissions. Although most of the cities have data from registers with a quality-control programme, there are limitations in the comparability of the data between cities.

The main problem for comparability is the difference in the type of hospital admissions available (total versus emergency); therefore, comparisons for hospital admissions presented in Figure 6 are separated into two groups: those cities providing emergency hospital admissions (Barcelona, Bilbao, Gothenburg, London, Madrid, Seville, Stockholm and Valencia); and those who could not distinguish between emergency and non-emergency admissions (Bordeaux, Celje, Le Havre, Lille, Ljubljana, Lyon, Marseille, Paris, Rome, Rouen, Strasbourg, Tel Aviv and Toulouse).

French cities could not provide data for cardiac admissions all ages.

An individual description of hospital admissions in each city and the corresponding health impact assessments appear later in this report.

Figure 6. **Incidence rates for hospital admissions in 22 cities (eight with emergency admissions, 14 with general admissions)**



In the eight cities where emergency-admissions data was available, incidence rates for cardiac admissions for all ages were the highest for Gothenburg and Stockholm (999 per 100 000). Incidence rates for respiratory admissions over 65 years of age were the highest for Barcelona, Bilbao, London and the Swedish cities (almost 3 000 per 100 000).

The fact that in the other cities the distinction between emergency and non-emergency admissions could not be made complicates making comparisons (see Appendix 5).

Benefits of reducing PM_{10} and black smoke levels for different scenarios

The HIA findings presented below consider the effects of short- and long-term exposure to particles on mortality alone. Because of the difficulties in comparability discussed above, we only show the HIA on hospital admissions city by city.

PM_{10} scenarios

In accordance with Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (Official Journal L 163, 29/06/1999 P. 0041 – 0060)[1] described earlier, and to take account of the fact that some countries already present low levels of PM_{10}, we propose our HIA for the following scenarios to reduce PM_{10} levels.

Acute effects scenarios

We used three scenarios to estimate the acute effects of short-term exposure to particulate air pollution on mortality over a 1-year period:

– reduction of PM_{10} levels to a 24-hour value of 50 µg/m^3 (2005 and 2010 limit values for PM_{10}) on all days exceeding this value
– reduction of PM_{10} levels to a 24-hour value of 20 µg/m^3 (to allow for cities with low levels of PM_{10}) on all days exceeding this value
– reduction by 5 µg/m^3 of all the 24-hour daily values of PM_{10} (to allow for cities with low levels of PM_{10}).

Chronic effects scenarios

We used four scenarios to estimate the chronic effects of long-term exposure to particulate air pollution on mortality over a 1-year period:

– reduction of the annual mean value of PM_{10} to a level of 40 µg/m^3 (2005 limit values for PM_{10})
– reduction of the annual mean value of PM_{10} to a level of 20 µg/m^3 (2010 limit values for PM_{10})
– reduction of the annual mean value of PM_{10} to a level of 10 µg/m^3 (to allow for cities with low levels of PM_{10})
– reduction by 5 µg/m^3 of the annual mean value of PM_{10} (to allow for cities with low levels of PM_{10}).

The case of Bucharest

In order to allow comparisons with the HIA findings in the other Apheis cities, we had to replace the values of PM_{10} that were missing in Bucharest (only four weekday measurements were available).

According to the PEACE project[2], PM_{10} levels generally vary little between weekdays and weekends, on the order of -5% to -7%. But during PM_{10} European measurement campaigns, experts consider that the PM_{10} concentration on weekends (Saturdays and Sundays) is 30% lower than from Mondays to Fridays. For Bucharest the annual mean for 1999 is 73.0 µg/m^3 (measurements from Monday to Thursday). Because Fridays should also be considered (due to industrial and pre-weekend traffic activities on Fridays), the “weekend reduction” should be smaller, around 20% to 25%, which means that the missing values should be replaced by 55 µg/m^3. Instead, we replaced PM_{10} missing values by an average value of 40 µg/m^3, applying an “at least” approach.

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[1] See Appendix 3.
[2] Hoek G, Forsberg B, Borowska M, Hlawiczka S, Vaskövi H, Welinder H, Branis M, Benes I, Kotesovec F, Hagen LO, Cyrus J, Jantunen M, Roemer W, Brunekreef B. Wintertime PM_{10} and Black smoke concentrations across Europe: results from the PEACE study *Atmospheric Environment* 1997; 31: 3609-3622.

Replacing all missing values by an average value of 40 µg/m^3, the air-pollution levels during a 1-year period in Bucharest become the following:

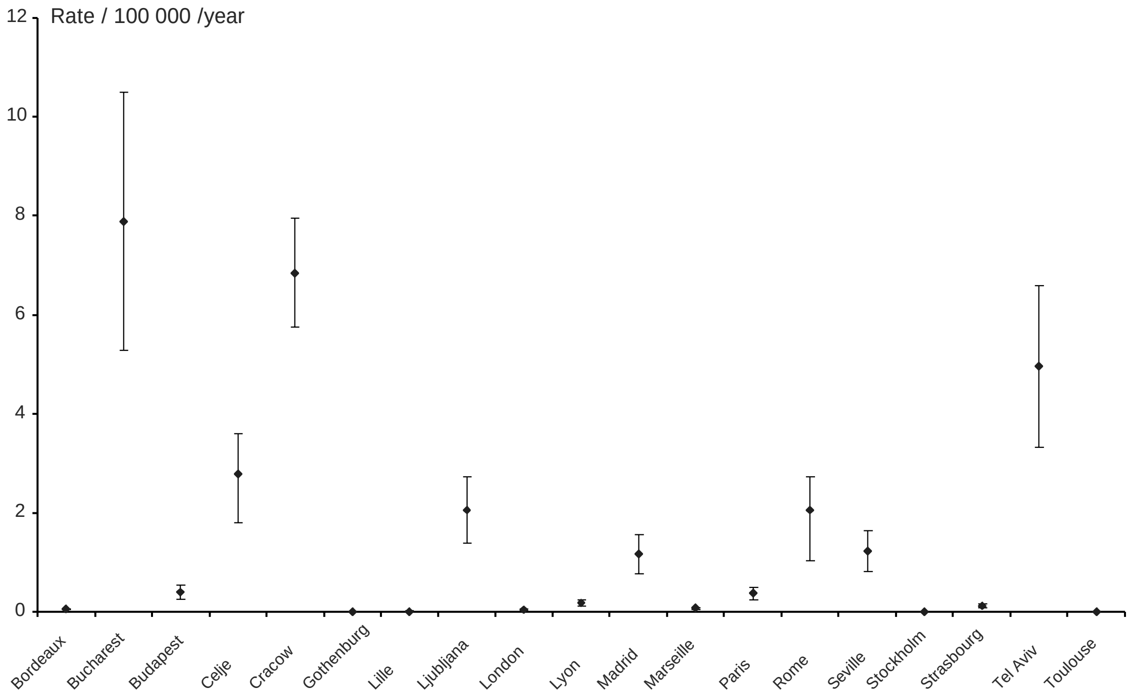
– daily mean levels of PM_{10} would be 56.9 µg/m^3 (SD: 18.9)
– the levels of PM_{10} hypothetically reached on the days with the lowest (10th percentile) and the highest (90th percentile) levels would be respectively 40 µg/m^3 and 82 µg/m^3
– the number of days when PM_{10} would exceed 20 µg/m^3 would be 364 days
– the number of days when PM_{10} would exceed 50 µg/m^3 would be 178 days.

PM_{10} findings

Acute effects

Figure 7 shows the potential benefits of reducing PM_{10} levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value. The potential health benefits are expressed as mortality rates per 100 000 inhabitants.

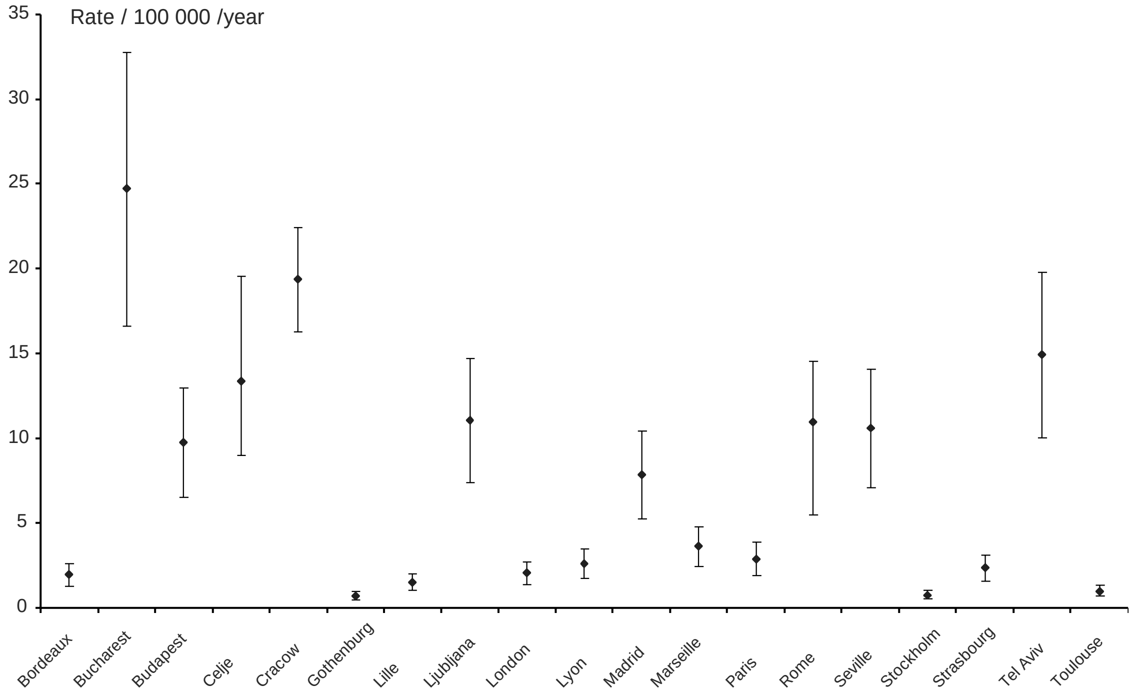
Figure 7. **Potential benefits of reducing PM_{10} levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}**



Among those cities measuring PM_{10}, if PM_{10} levels for all days when they exceeded a 24-hour value of 50 µg/m^3 were reduced to 50 µg/m^3, Bucharest, Cracow and Tel Aviv would show reductions higher than 5 deaths per 100 000 inhabitants; Celje, Ljubljana, Madrid, Rome and Seville would show smaller reductions in the mortality rates.

As Bordeaux, Gothenburg, Lille, London, Marseille, Stockholm and Toulouse already show levels of PM_{10} below 50 µg/m^3, these cities do not show any health benefit in this scenario.

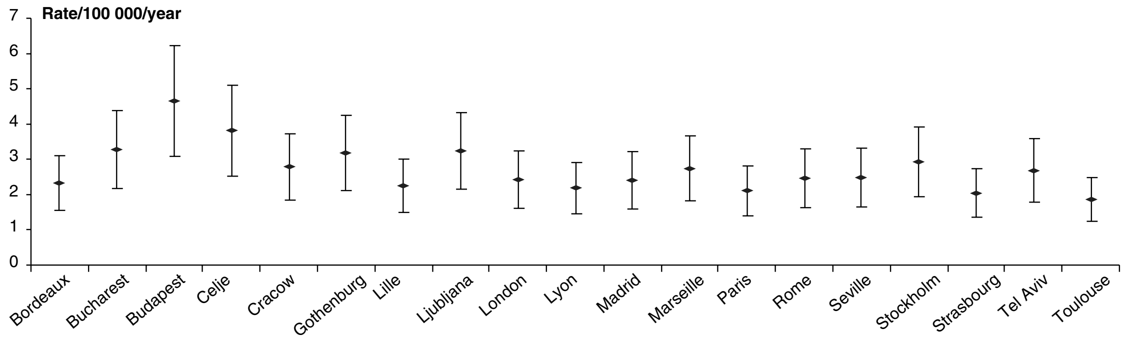
Figure 8. **Potential benefits of reducing PM_{10} levels to a 24-hour value of 20 µg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}**

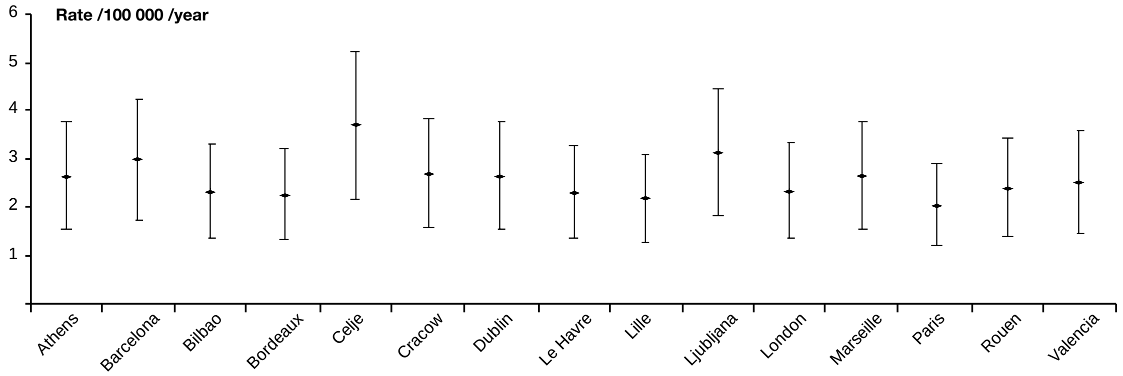


If PM_{10} levels for all days when they exceeded a 24-hour value of 20 µg/m^3 were reduced to 20 µg/m^3 (Figure 8), the health benefits would be greater and would concern more cities.

The corresponding decrease in the number of deaths per 100 000 inhabitants would range from 25 in Bucharest, 19 in Cracow, 15 in Tel Aviv, 13 in Celje and 11 in Ljubljana, Rome and Seville to 1-3 in Bordeaux, Gothenburg, Lille, London, Lyon, Marseille, Paris, Stockholm, Strasbourg and Toulouse.

Figure 9. **Potential benefits of reducing daily PM_{10} levels by 5 µg/m^3 - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}**





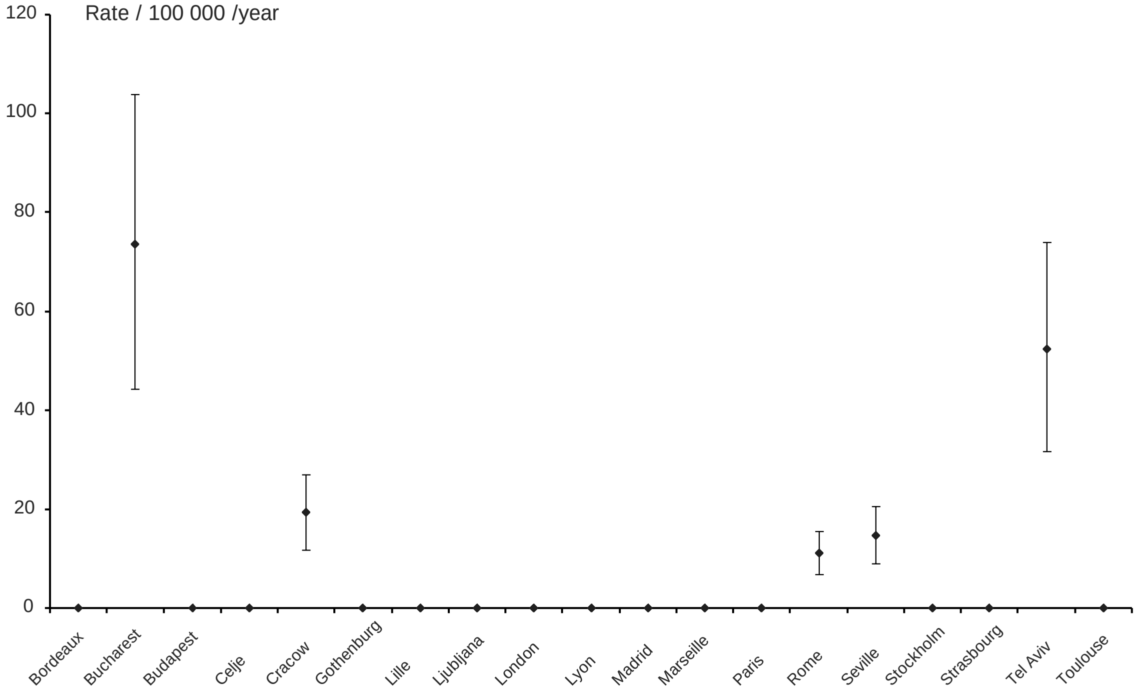
If daily PM_{10} levels were reduced by 5 µg/m^3 in all the cities (Figure 9), the consequent reduction in the number of deaths per 100 000 inhabitants would range between 2 in Toulouse and 5 in Budapest (depending on the number of deaths observed in each city) and would average 3 (2 to 4) deaths per 100 000 inhabitants for the 19 cities measuring PM_{10}.

In these cities, totalling 31 794 813 European inhabitants, our HIA found 820 deaths (with a range of 544 to 1 096) that could be prevented if short-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3.

Chronic effects

The following figures present the potential health benefits of reducing long-term exposure to PM_{10}. Note that most, but not all, the potential benefits of reducing short-term exposure to PM_{10} are included in the benefits of reducing long-term exposure.

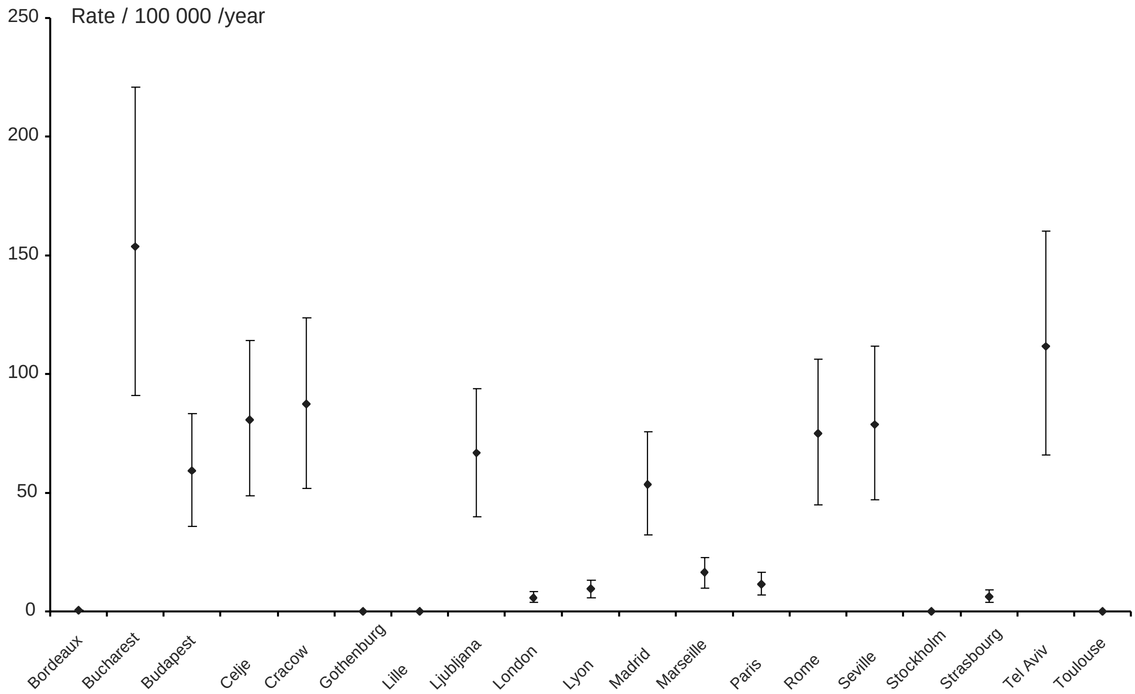
Figure 10. **Potential benefits of reducing annual mean values of PM_{10} to a level of 40 µg/m³ (2005 limit values for PM_{10}) - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}**



Among the cities where PM_{10} is measured, the reduction of the annual mean value to 40 µg/m³ (2005 limit values for PM_{10}) would reduce the number of deaths per 100 000 inhabitants by 74 in Bucharest (including 11 related to short-term exposure to PM_{10}), 19 in Cracow (including 3 related to short-term exposure to PM_{10}), 11 in Rome (including 2 related to short-term exposure to PM_{10}), 15 in Seville (including 2 related to short-term exposure to PM_{10}) and 53 in Tel Aviv (including 8 related to short-term exposure to PM_{10}).

The rest of the cities already comply with this scenario (Figure 10).

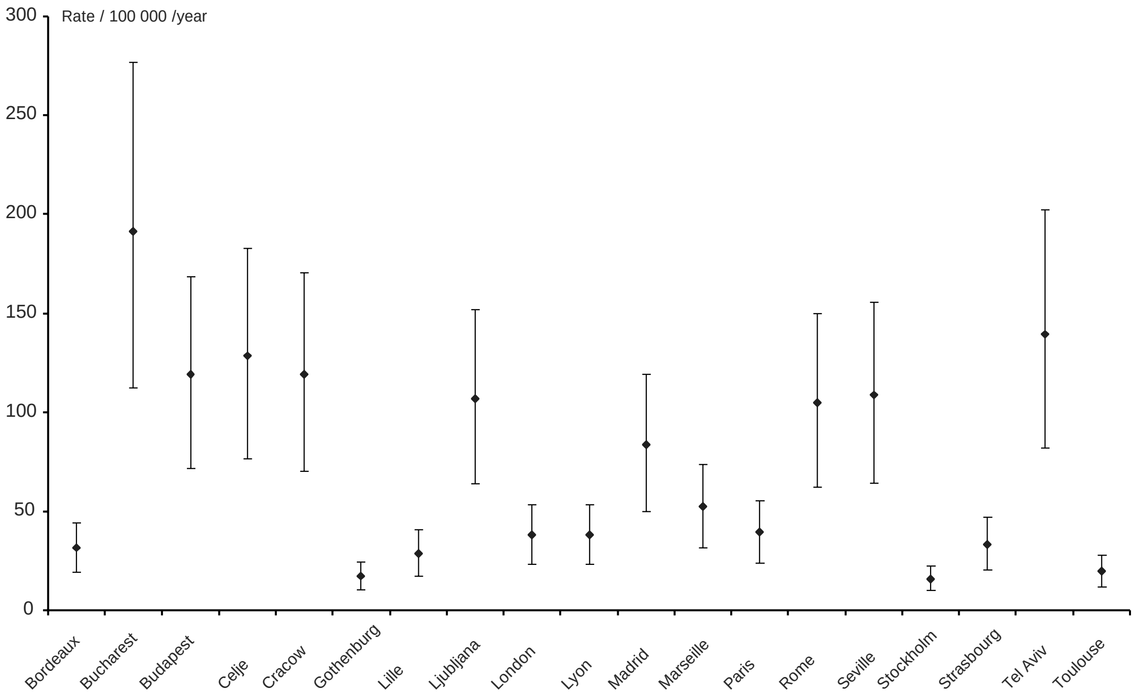
Figure 11. Potential benefits of reducing annual mean values of PM_{10} to a level of 20 µg/m^3 (2010 limit values for PM_{10}) - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}



If we now consider a reduction in annual mean values of PM_{10} to 20 µg/m^3 (2010 limit values for PM_{10}), all cities would benefit from this reduction in air-pollution levels except Bordeaux, Gothenburg, Lille, Stockholm and Toulouse, which already comply with this level of air pollution.

The corresponding reductions in the number of deaths per 100 000 inhabitants would range from 154 in Bucharest (including 24 related to short-term exposure to PM_{10}) to 6 deaths in London and Strasbourg, including one related to short-term exposure to PM_{10} (Figure 11).

Figure 12. Potential benefits of reducing annual mean values of PM_{10} to a level of 10 µg/m^3 – Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}

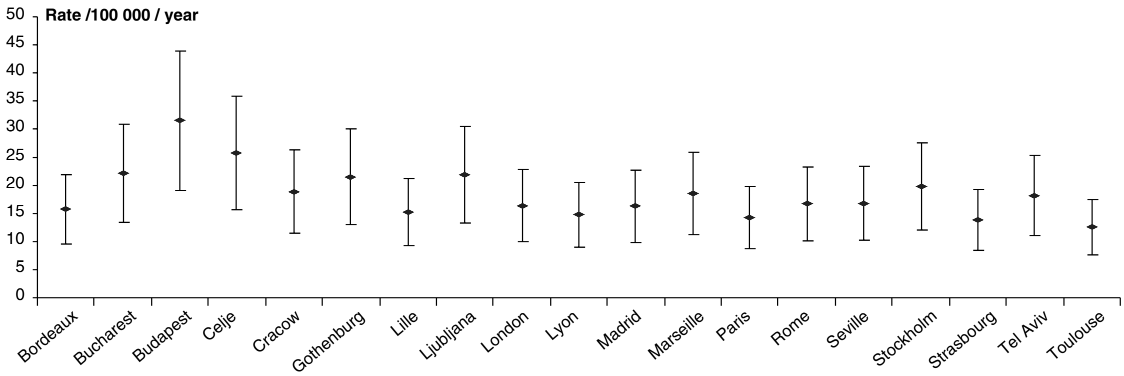


This scenario (Figure 12) considers a reduction in annual mean values to 10 µg/m^3. Even if this scenario is idealistic for many cities, it would allow cities with very low levels of air pollution, like those in Sweden, London and a few in France, to benefit from the improvement in air quality, since even their low levels are associated with health risks. All the other cities would obviously benefit more from these reductions.

The health benefits would be greater for Bucharest, Budapest, Celje, Cracow, Ljubljana, Madrid, Rome, Seville and Tel Aviv, ranging from a decrease in the number of deaths per 100 000 inhabitants of 191 in Bucharest (including 31 related to short-term exposure to PM_{10}) to 84 in Madrid (including 13 related to short-term exposure to PM_{10}).

For Bordeaux, Gothenburg, Lille, London, Lyon, Marseille, Paris, Stockholm, Strasbourg and Toulouse, these decreases would range between 52 in Marseille (including 8 related to short-term exposure to PM_{10}) to 16 in Stockholm (including 2 related to short-term exposure to PM_{10}).

Figure 13. Potential benefits of reducing annual mean values of PM_{10} by 5 µg/m^3 – Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}



If annual mean values of PM_{10} were reduced by 5 µg/m^3 in all the cities (Figure 13), the consequent reduction in the number of deaths per 100 000 inhabitants would range between 32 in Budapest and 13 in Toulouse (depending on the number of deaths observed in each city) and would average 19 (11 to 25) deaths per 100 000 inhabitants for the 19 cities measuring PM_{10}.

For all these cities, the HIA estimated that 5 547 deaths (with a range of 3 368 to 7 744) could be prevented annually if long-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3 in each city.

Black smoke scenarios

No EU Directive is planned for black smoke by 2005 or by 2010. Nevertheless, this pollution indicator has been measured for many years in most European cities and represents small black particles (less than 4 µm) with measurable health effects. Therefore, we consider the application of PM_{10} scenarios to BS beneficial, even if the objective is not to compare PM_{10} and BS findings.

We considered only the short-term exposure or acute-effects scenarios, since no exposure-response functions are currently available for the long-term effects of black smoke.

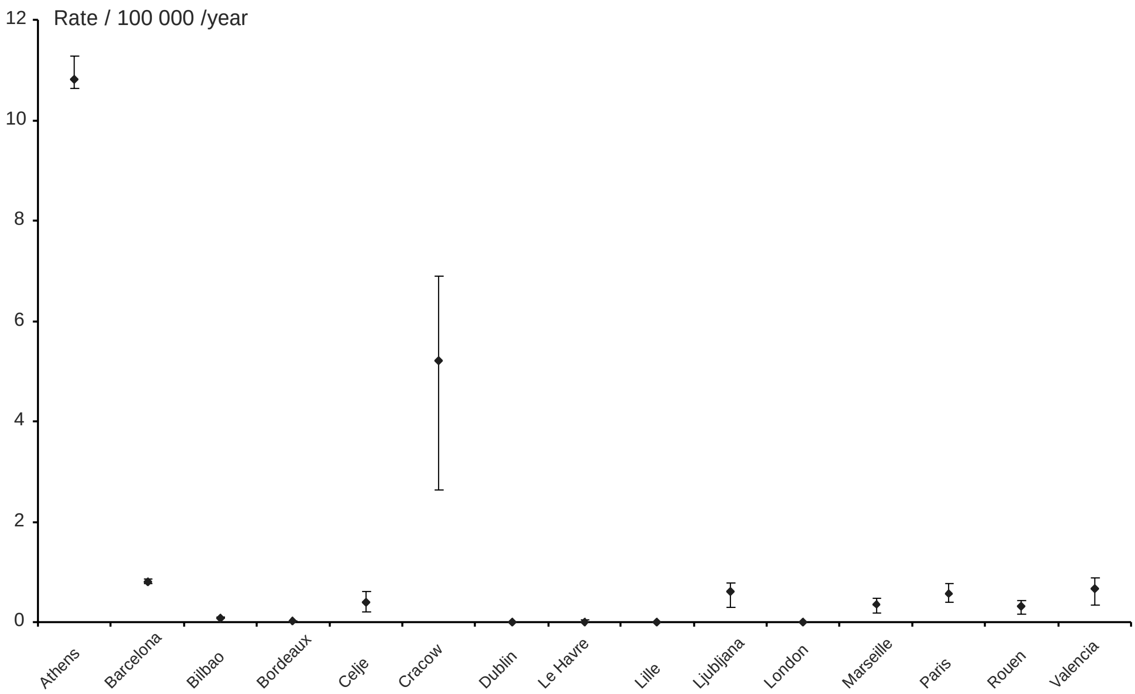
Acute effects scenarios

We used three scenarios to estimate the acute effects of short-term exposure to BS on mortality over a 1-year period:
– reduction of BS levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value
– reduction of BS levels to a 24-hour value of 20 µg/m^3 on all days exceeding this value
– reduction by 5 µg/m^3 of all the 24-hour daily values of BS.

Black smoke findings

Acute effects

Figure 14. **Potential benefits of reducing black smoke levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of black smoke**

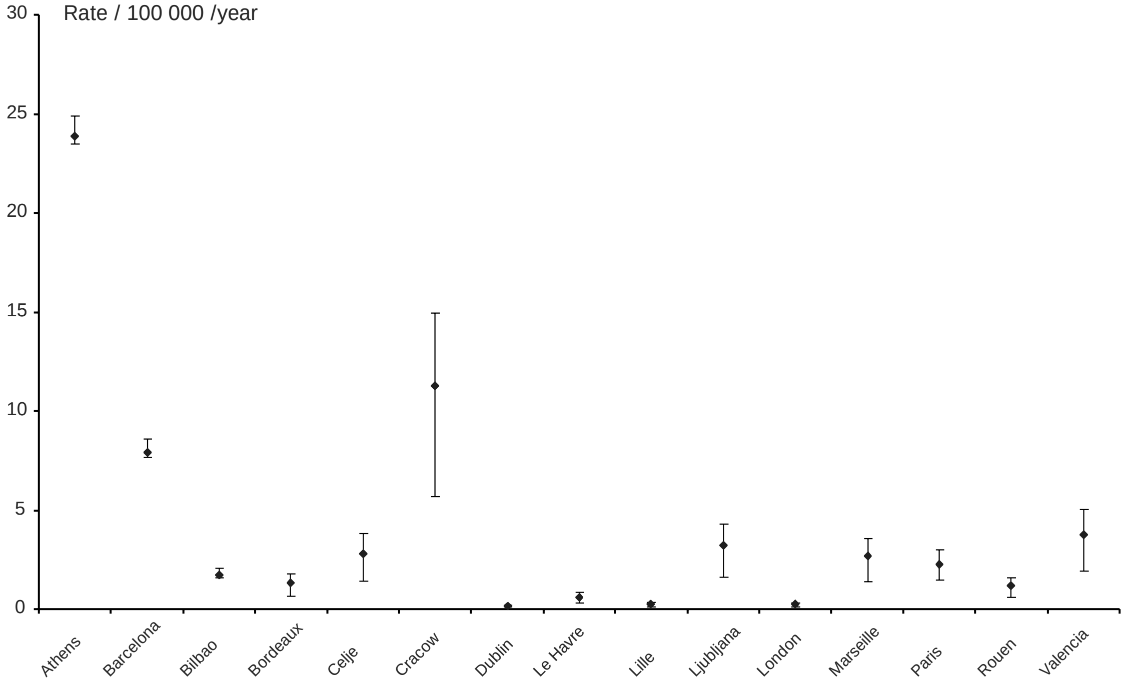


Among the 15 cities measuring BS, Athens would show by far the highest decrease in the number of deaths per 100 000 inhabitants (11) if BS levels for all days exceeding a 24-hour value of 50 µg/m^3 were reduced to 50 µg/m^3, remembering that Athens shows the highest BS levels, probably because of the direct influence of traffic.

Cracow shows the widest range of the 95% confidence interval in the attributable number of deaths per 100 000 (from 3 to 7).

The health benefits of this scenario for the other cities are quite low (Figure 14).

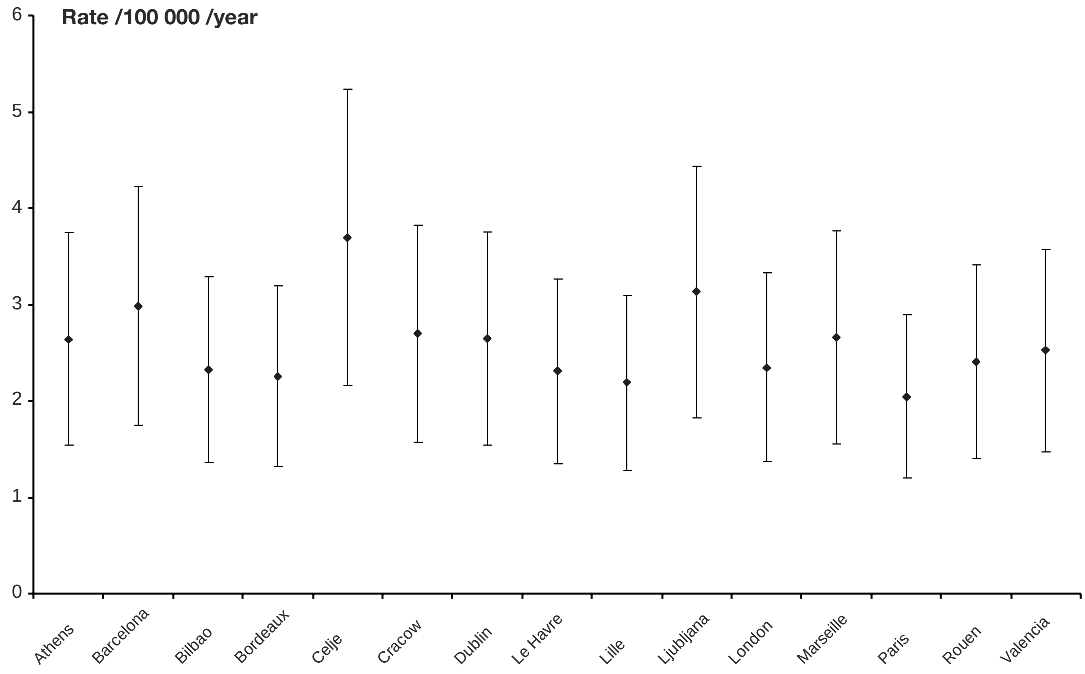
Figure 15. **Potential benefits of reducing black smoke levels to a 24-hour value of 20 µg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of black smoke**



If BS levels for all days when they exceeded a 24-hour value of 20 µg/m^3 were reduced to 20 µg/m^3, more cities would see a decrease in the number of deaths (Figure 15).

These decreases would range from 24 per 100 000 inhabitants in Athens, 11 in Cracow and 8 in Barcelona to 1-4 in Bilbao, Bordeaux, Celje, Ljubljana, Marseille, Paris, Rouen and Valencia.

Figure 16. **Potential benefits of reducing daily black smoke levels by 5 µg/m³ - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of black smoke**



If daily BS levels were reduced by 5 µg/m³ in all the cities measuring this air-pollution indicator, the consequent reduction in the number of deaths per 100 000 inhabitants would range between two and four (depending on the number of deaths observed in each city) and would average 3 deaths per 100 000 inhabitants (2 to 4) for the 15 cities measuring BS (Figure 16).

In these cities, totalling 24 209 632 European inhabitants, our HIA found 577 deaths (with a range of 337 to 817) that could be prevented if short-term exposure to outdoor concentrations of BS were reduced by 5 µg/m³.

HOW TO INTERPRET THE FINDINGS

Introduction

Our HIA sought to quantify the public-health impact of the exposure of almost 39 million European citizens to particulate air pollution.

An HIA in the field of air pollution provides the number of health events attributable to air pollution in the target population assuming that air pollution actually causes the observed health effects. The scientific basis for this hypothesis has been widely discussed in the literature[1-7]. However, since causality is a necessary requirement for an HIA, we will review the evidence for causality in air-pollution studies using the criteria for causality in epidemiological studies proposed by Bradford Hill in 1965[8].

Does air pollution cause the observed effects?

Strength of the association

Health risks from environmental factors, such as air pollution, are smaller than health risks from other causes, such as infectious diseases, cigarette smoking and obesity. But the small size of the risks from air pollution should not be underestimated in terms of its impact on public health.

Indeed, such relatively smaller risks deserve attention from a public-health perspective because air pollution is omnipresent and thus exposes the entire population to this health-risk factor. Such ubiquitous exposure means that even small shifts in the distribution of physiologic measurements can have a substantial impact on public health[9].

It should be noted that, while certain groups, such as smokers, can control their exposure to tobacco smoke, the general population cannot exert control over its exposure to air pollution, which is unavoidable.

Finally, within the risk for the general population, we can identify higher risks in four ways: by using more precise exposure measurements[10]; by considering having an increased range of exposure; by considering more-sensitive population groups[11-13]; or by using more-detailed diagnoses[14,15].

Specificity of the effects

Most diseases are multifactorial[8], in other words multiple factors can lead to a particular disease. Cardiovascular and respiratory diseases can result from air pollution as well as from other risk factors, such as respiratory infectious agents, diet, etc. Because all these factors can interact[16], when studying a particular diagnosis that may be related to air pollution, we need to quantify the contribution of air pollution while controlling for other potential risk factors.

Lack of temporal ambiguity

For exposure in general to be considered the cause of an observed effect, exposure must precede the effect in question. Studies that relate air pollution and health prove that this requirement is met. In addition, when these studies seek to identify a paradoxal effect, they don't find any[17].

Related to the issue of temporality is the so-called "harvesting effect," which asks the question of the extent to which short-term exposure to air pollution simply displaces health events (mortality and hospital admissions) by a few days. Recent analyses[18-22] show that short-term effects of air pollution on mortality can last for several days or weeks, even up to 40 days. They also show that risks increase with longer exposure, particularly when studying cardiovascular mortality. The harvesting effect is also minor for hospital admissions, and the size of the effects doubles for longer periods[23].

Dose response

In general, the dose-response curve that relates particulate air pollution and mortality is linear. As a result, small reductions in air-pollution levels, like the 5 µg/m^3 scenario used in our HIA, have the same consequences for health effects independent of the starting point on the curve. While individuals may have different thresholds regarding their sensitivity to air pollution, this linear relationship means that for the general population there is no threshold below which air pollution has no impact on health [24-25].

Since there is no minimum threshold, preventive action aimed at reducing air-pollution levels should not focus solely on air-pollution peaks (a few days with very high levels of air pollution), because such focus would only prevent a small number of health events. More-effective preventive action would seek to reduce lower air-pollution levels both every day and over the long term.

Consistency of the findings

Epidemiological findings that relate air pollution and health are consistent independent of where the study is conducted and of the statistical methods used[26-30]. In addition, our HIA findings are consistent with recent studies conducted in Europe, South America and North America [31-34].

Coherence of the evidence

The effects of air pollution on health should be coherent with the biology and natural history of the observed effect.

Increased risks have been observed for a coherent chain of effects of varying degrees of severity, such as absenteeism at work, symptoms, doctors' visits, emergency-room visits, hospital admissions and death, that together show a coherent pattern, given the broad distribution of susceptibility within populations.

Health risks are higher for asthma, COPD, myocardial infarction or cardiac failure than for respiratory or cardiovascular diseases considered globally. Risks are also higher when considering the elderly, infants or sensitive patients, as opposed to the population as a whole [12, 35-36]. Risks are also higher for long-term exposure to air pollution than for short-term exposure [35, 37-38].

Biological plausibility

Biological plausibility is related to the scientific knowledge of the biological mechanisms by which air pollution causes the effects suggested by the epidemiological studies. Many studies analyse the mechanisms by which particles act on circulatory and respiratory systems[39-63], as well as those mechanisms that explain the interactions with allergens[64-73].

"Quasi-experimental" evidence

When the exposure factor in general is reduced or eliminated, there is a consequent decrease in the number of health events. In the field of air pollution, some studies show that the number of deaths, hospital admissions and other health events diminishes[74-77] when air-pollution levels decrease.

We reviewed the main causal criteria applied to air-pollution epidemiology in light of scientific knowledge currently available. As Traven[78] said, however, "causality is a continuum and not an all-or-nothing issue". Our understanding of causality continues to evolve, and it is interesting to observe that the strength of evidence has been increasing steadily over the last years.

Although not all of Hill's criteria carry the same weight in our work, they all support the causal nature of the relationship between air pollution and health, and thus justify making HIA calculations.

Are our HIA findings reliable?

When interpreting the findings, in addition to causality another key question concerns the reliability of our HIA findings. The following points should be considered in this light.

Estimates provided by our HIA

As a reminder, our HIA provides the number of events (deaths or hospital admissions) that can be attributed to exposure to particulate air pollution in a specific city. These numbers can be expressed in absolute terms directly related to the size of the population studied, or as rates per 100 000 inhabitants. The absolute numbers describe the local situation in a given city, while the rates allow comparisons between cities.

For cities where PM_{10} and BS are measured, their effects on health must not be added together, because these two pollutants are highly correlated. Therefore, we made two separate HIA calculations.

In the 19 cities measuring PM_{10} and totalling almost 32 million European inhabitants, our HIA found 5 547 deaths (with a range of 3 368 to 7 744) that could be prevented annually if long-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3. In other words, if annual mean values of PM_{10} were reduced by 5 µg/m^3 in all these cities, the consequent reduction in the number of deaths per 100 000 inhabitants would be 19 with a range between 11 and 26. Fifteen percent of these deaths can be attributed to a reduction of 5 µg/m^3 in short-term exposure to PM_{10}.

In this first HIA we conducted, to simplify the centres' work we only expressed our findings on the long-term effects of particles on mortality as attributable deaths per year. Because the concepts of attributable deaths and life expectancy are related, in its future phases Apheis will also calculate the gain in life expectancy attributable to long-term exposure to particles. Gain in life expectancy, which is based on a dynamic approach, is already used in other studies[79-81]. This concept is particularly valuable when assessing the economic costs and benefits of health policies[82].

In addition to PM_{10}, we considered the 15 cities that measure black smoke and total almost 25 million European inhabitants; this HIA found 577 annual deaths (with a range of 337 to 818) that could be reduced if short-term exposure to outdoor concentrations of BS were reduced by 5 µg/m^3. In other words, if daily BS levels were reduced by 5 µg/m^3 in all the cities measuring this air-pollution indicator, the consequent reduction in the number of deaths per 100 000 inhabitants would be 3 ranging between two and four. We considered only the acute effects, since no exposure-response functions were available for the chronic effects of black smoke.

Factors that influence the reliability of our HIA findings

The reliability of our HIA findings depends mainly on the quality of the studies selected for our exposure-response functions, on the statistical methods used for the calculations, and on the quality of the exposure and health data used in each city.

Regarding the exposure-response functions, we used the effect estimates newly developed by the APHEA 2 study[83-85] for short-term exposure to air pollution, since the cities in the Apheis programme are almost the same as those in APHEA 2 that used a common standardised protocol for analysis.

For long-term exposure to air pollution, in the absence of European studies on chronic mortality and air pollution, we selected the exposure-response function used in the HIA done in Austria, France and Switzerland[86] based on two American cohort studies[87-88] and reanalysed by the Health Effects Institute[89].

For long-term exposure, the question of transferability of estimates between the U.S. and Europe could be raised, since the particulate composition and populations can differ substantially between the two continents. Until now, European findings on short-term exposure to particulate air pollution have been consistent with those in the U.S., but we have no way of knowing if this consistency applies for long-term exposure. Also, an update of one of the U.S. studies, the ACS study[90] covering 1.2 million adults in 50 states, doubled the follow-up time to more than 16 years, controlled for more confounding factors and used recent advances in statistical modelling. This study's findings confirm the associations observed in their previous study, which we used, and show a tripling in the number of deaths.

European cohort studies on chronic mortality and air pollution have begun, and first results of the Netherlands cancer study confirm significant associations between long-term exposure to ambient air pollution and longevity (Hoek et al, *The Lancet,* in press). These studies should provide European long-term estimates that will be used in future phases of Apheis.

For our HIA's statistical method, we used WHO guidelines[91] as a starting point and also developed our own standardised statistical and HIA guidelines[92].

Regarding exposure data, our HIA findings depend directly on the levels of particulate pollution measured. These levels vary widely as a function of the number and location of the monitoring sites, the analytical methods used, and the sites selected for our HIA. This explains the importance of using the Apheis guidelines to ensure comparability of the data. Appendix 4 provides a full description of the type of data and methods used and concludes that, although they could be improved, results for the exposure to be used in the HIA were reliable.

Regarding health indicators, Appendix 5 describes in detail the data provided and concludes that, for local use in each city, the selected data is reliable. When comparing findings between cities, the data is fully comparable for the selected categories of mortality. Nevertheless, even if most of the cities have hospital data from registries that use a quality-control programme, the data for hospital admissions is not strictly comparable, because some cities used emergency admissions, while others that lacked this information used non-emergency admissions. Our study stresses the need to promote the use of more-uniform hospital admissions data in Europe.

Regarding health-outcome frequencies, for mortality we calculated standardised mortality rates using the European population as the reference population, allowing us to compare mortality rates between cities. Such comparability was limited, however, for the incidence of hospital admissions. Consequently, we only present data for hospital admissions and the consequent HIA in the city-by-city reports.

Also concerning reliability, the APHEA European study reported substantial regional heterogeneity in the estimated short-term effects of ambient particles[93] used for our short-term HIA. This study subsequently investigated determinants of this heterogeneity and found that the PM_{10}/mortality effect is positively modified by the long-term NO_2 concentration, by the proportion of NO_2/ PM_{10}, by the average temperature and by the proportion of the elderly in the population[83]. For respiratory hospital admissions the study found the effects are modified by the long-term ozone concentrations[84]. The very recent evidence on effect modification has potential implications for HIA, and different ways to account for effect modification may be proposed. We have decided to initiate a discussion within Apheis on whether and how to integrate this information in future HIA calculations, the results of which will be reflected in the next report.

How did we deal with the uncertainties in our HIA calculations?

Inherent uncertainties must be taken into account in the different steps in the HIA calculations. For this reason, as for our HIA in Austria, France and Switzerland[86], we adopted the principle of an "at least," or conservative, approach.

For each step, we chose methodological approaches in order to get an impact that can be expected to be "at least" attributable to air pollution, and we expressed the findings in a way to take into account the uncertainties in the effect estimates.

A conservative approach

We chose a conservative approach to deal with the uncertainties when determining the number of cases attributable to air pollution.

In this approach, regarding the health outcomes described as associated with air pollution, we included only total mortality and hospital admissions for two conditions: cardiac all ages; and respiratory 65 years and over.

For mortality, we did not consider separately the effects on newborns or infants [94,95]. Even if the number of attributable cases may be small in the younger age groups, the impact on years of life lost, and therefore the economic costs, could be considerable.

For hospital admissions, we only used the most conservative HIA scenarios based on effects of days above 50 and 20 $\mu g/m^3$.

We did not consider many other health outcomes potentially relevant for HIA as proposed by WHO[91], again underestimating the impact.

Also in this conservative approach, regarding the air pollutants that could be considered, we limited our analysis to PM_{10} and BS. Although air pollutants are correlated, the independent effect of ozone, for example, was not evaluated.

The choice of the reference level in the exposure to particulate air pollution strongly influences the impact estimates. Our HIA proposes a range of reference levels used in different scenarios that can be considered as a sensitivity analysis, giving a realistic and conservative picture of the possible impacts of air pollution on health.

In order to take into account the uncertainties of the effect estimates, the HIA findings also give the lower and upper 95% confidence intervals.

What other points should be remembered when interpreting the findings?

When interpreting the findings on annual mortality, we should remember that the main effects are calculated for long-term exposure. Most of the acute effects on mortality are included in the long-term exposure and represent at least 15% of these chronic effects.

Finally, attributable cases are often interpreted as cases that would be removed if the exposure were removed. But caution must be used when interpreting the findings in this way. As discussed in the section on causality, for multicausal diseases the sum of percentages of attributable cases across several risk factors does not total 100%, but may be larger[96]. Impact measurements that take competing risks into account need to be developed[86,97]. Whereas for short-term effects attributable cases could be interpreted as "preventable", this interpretation is more questionable for long-term effects, where time to benefit may be very long.

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CONCLUSION

During its first and second years ending in April 2002, the Apheis programme assembled a network that brings together environmental and public-health professionals on the city, regional and national levels across Europe. This network performs epidemiological surveillance and HIA of air pollution in 26 European cities.

During the second year, we conducted individual HIAs in each of the cities participating in the project. The objective was to provide local decision makers with the most-complete information possible on air pollution and public health in their cities. Each local report, which includes the local HIA, provides a detailed description of the given city's characteristics, including climate, geography, sources of air pollution, information on health indicators and other key factors. However, most cities were unable to link PM_{10} measurements to PM_{10} sources in their reports. Identifying such links is important for decision-making purposes, and should be addressed in future Apheis work.

As the next step, we assembled the local characteristics and individual HIAs into a single study that provides a comparative view of demographic and air-pollution characteristics as well as HIA findings for 32 million citizens in Western and Eastern Europe for PM_{10} and 25 million citizens for black smoke. The objective was to provide European decision makers with a global view of the situation in Europe.

To ensure that findings were comparable across all 26 participating cities, our network used common methodology built on WHO and Apheis guidelines, and applied it consistently in all the cities.

Because we used a common methodology, our results for premature mortality are directly comparable across the participating cities. This is not the case, however, for hospital admissions, and our study stresses the need to promote the use of more-uniform hospital-admissions data in Europe.

By harmonising the information on exposure assessment, Apheis is contributing to more-uniform air-pollution measurements in Europe. Since black smoke has been measured for many years in most European cities, we would like to stress the importance of continuing to measure this air-pollution indicator, which represents small black particles (less than 4 µm), which have measurable health effects. We also encourage the implementation of PM_{10} measurements in every Apheis city, and equally encourage local air-pollution networks to start measuring $PM_{2.5}$ if they haven't already done so.

We chose different HIA scenarios in order to provide decision makers at the local, national and European levels with a range of possible benefits from reducing particulate air pollution for short- and long-term perspectives. These scenarios took into account Council Directive 1999/30/EC of 22 April 1999 relating to limit values for particulate matter and other pollutants that should not be exceeded in 2005 and 2010.

Since some countries already showed low levels of PM_{10} and BS, we also proposed smaller reductions such as 5 µg/m^3. We concluded that even very small and achievable reductions in air-pollution levels have an impact on public health, and that this impact justifies taking preventive measures even in cities with low levels of air pollution.

Three case studies in Dublin, Gothenburg and Stockholm, presented in Appendix 6, provide examples of achievable interventions that successfully reduced air-pollution levels.

The applicability of our findings to other European cities not involved in Apheis can be questioned. For this reason, we suggest that future Apheis HIAs include more European cities, including those that have already asked to participate, providing they meet our guidelines on organisation, data collection and analysis.

In conclusion, by translating epidemiological findings into a decision-making tool, the Apheis programme seeks to bridge the gap between data and action.

During our second year, the programme conducted an HIA that provides a conservative but accurate and detailed picture of the impact of air pollution on health in 26 European cities, and whose findings are consistent with those of other organisations that have conducted HIAs in the area of air pollution. Our findings thus add one more brick in the wall of evidence that air pollution continues to threaten public health in Europe.

MEETING INFORMATION NEEDS BETTER IN THE FUTURE

Apheis is a multiyear, multiphase proactive programme dedicated to answering key questions on air pollution and public health in Europe. Each phase of the programme builds on the learnings of the previous phase like a set of building blocks.

To keep the information we produce and disseminate as up-to-date and accurate as possible, during the third year of the Apheis programme, which started in April 2002, we will produce new exposure-response functions on the short-term effects of air pollution using our epidemiological surveillance system. And we will calculate years of life lost or reduction in life expectancy, in addition to the absolute number of attributable cases, in order to estimate the health impacts of long-term exposure to air pollution.

To fulfil our mission of ultimately making our learnings available to the broadest possible audiences for decision making on air-quality management, public policy, health care and personal behaviour, during the third year and for the first time we will also explore and understand how best to meet, in terms of content and form, the information needs of government decision and policy makers concerned with the impact of air pollution on public health.

In a future phase of the Apheis programme, as another new step we plan to collaborate with economists in order to calculate the costs to society of the health effects of air pollution in the cities participating in the programme.

We also hope to involve the Apheis programme more closely in local, regional, national and European programmes like NEHAPs (National Environmental Health Action Plans), the European network AIRNET the WHO programme on air pollution and healths, the CAFE (Clean Air for Europe) programme, and the EUROHEIS programme, and share with them our latest findings.

To be truly effective in meeting the information needs of the audiences it serves, the Apheis programme needs to function on a continuing, long-term basis. For this purpose, the programme requires the ongoing commitment and financial support of the European Commission and its member states.