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APHEIS

Air Pollution and Health : A European Information System

Health Impact Assessment of Air Pollution and Communication Strategy

Third-year Report

CSB Consorci Sanitari de Barcelona
Agència de Salut Pública

Institut de Veille Sanitaire

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Abbreviations

ACS study	American Cancer Society Study
AirQ	Air Quality Health Impact Assessment WHO software
APHEA	Air Pollution and Health: A European approach
APHEIS	Air Pollution and Health: A European Information System
BS	Black smoke particles
CI	Confidence intervals
E-R functions	Exposure-Response functions
HIA	Health Impact Assessment
ICD	International Classification of Diseases
InVS	National Institute for Public Health Surveillance
LCA	Lung cancer mortality
P5	5^{th} percentile of the distribution of the pollutant
P95	95^{th} percentile of the distribution of the pollutant
PM_{10}	particulate matter less than 10 micrometers of diameter
$PM_{2.5}$	particulate matter less than 2.5 micrometers of diameter
PSAS-9	French national programme on the surveillance of the effects of air pollution on health in nine French cities
RR	Relative risk
SD	Standard deviation
TEOM	Tapered oscillating microbalance method
TSP	Total suspended particulates
WHO-ECEH	World Health Organization European Centre for Environment and Health
YoLL	Years of life lost

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Apheis Web site

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How is Apheis organised

● Apheis Steering Commitee

■ Apheis cities and steering commitee

▲ Apheis cities

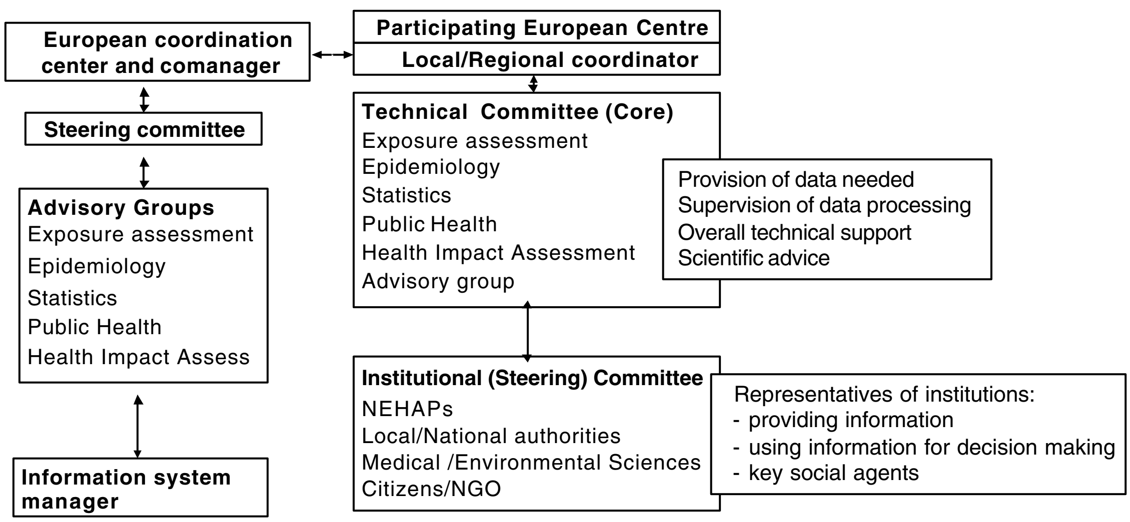
The Apheis programme comprises 16 centres totalling 26 participating cities in 12 European countries (Figure A).

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

Each Apheis centre is part of a local, regional or national institution active in the field of environmental health. The organisational models (Figure B) that support the development of Apheis are ample and diverse in terms of technical and scientific areas of expertise (for example the Advisory Groups and Technical committees) and are functioning well. On the other hand, it is desirable to involve decision makers more deeply in the organisational models needed to support Apheis activities through the Institutional (Steering Committees).

Figure B. Apheis general organisational model and functions



For more details on Apheis organisation:

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.net).

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Introduction

The Apheis programme seeks to meet the information needs of individuals and institutions in Europe concerned with air pollution, which continues to have a significant impact on public health. Communicating about the health effects of air pollution thus lies at the core of the Apheis programme, and constitutes a key objective that we are addressing for the first time in this, the programme's third year.

As a reminder, Apheis was created in 1999 to provide European policy and decision makers, environment and health professionals, the general public and the medias with an up-to-date, easy-to-use information resource on air pollution and public health to help them make better-informed decisions about the political, professional and personal issues they face in this area.

To develop this information resource, Apheis has created a public-health surveillance system that generates information for HIAs (health-impact assessments) of air pollution in Europe at the city, regional, national and European levels, on an ongoing basis.

Apheis-1 and Apheis-2

During the first phase known as Apheis-1, we achieved two key objectives:

- We defined the best indicators for epidemiological surveillance and HIAs of the effects of air pollution on public health in Europe. For this purpose, Apheis created five advisory groups in the fields of public health, health-impact assessment, epidemiology, exposure assessment and statistics. These groups drafted guidelines that define the best indicators for epidemiological surveillance of the effects of air pollution on public health in Europe, and provide a standardized protocol for data collection and analysis.
- We identified those entities best able to implement the surveillance system in the 26 cities in 12 European countries participating in the programme. We understood how the different entities could work together on the local, national and European levels. And we assessed each entity's ability to implement, during the programme's second phase, an HIA of particulate pollution using the guidelines drafted by the advisory groups (Medina *et al*, 2001).

During the second phase, Apheis-2, among other tasks Apheis used its epidemiological surveillance system to conduct an HIA of PM_{10} and black smoke (BS) applying the above guidelines to gather and analyse pertinent data. This first HIA found between 544 and 1 096 "premature" deaths that could be prevented annually if, all other things being equal, short-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3 in the Apheis cities. On the other hand, the expected benefits of reducing long-term mortality were still greater. The HIA estimated that, all other things being equal, between 3 368 and 7 744 "premature" deaths could be prevented annually if long-term exposure to outdoor concentrations of PM_{10} had been reduced by 5 µg/m^3 in each city. Apheis published the findings of this work in its second-year report, "Health Impact Assessment of Air Pollution in 26 European Cities" (Medina *et al*, 2002) and in the article "Apheis: Public Health Impact of PM_{10} in 19 European Cities" (Medina *et al*, 2004).

Apheis-3

In the third phase, Apheis-3 planned to develop a communications strategy and update the HIA using its epidemiological surveillance system.

In specific, Apheis-3 phase had the following objectives:

- **Communications strategy**: Develop a strategy to communicate the effects of air pollution on health to key audiences. As a first step, understand how best to meet the information needs of decision-makers and advisors together who constitute one of the many key European audiences concerned with the impact of air pollution on public health; and test the Apheis report's usefulness for meeting their needs.
- **Health impact assessment**: Through our epidemiological surveillance, update the estimates of the effects of air pollution on health and establish new all-ages respiratory exposure-response functions (E-R functions) suitable for HIA; introduce methodological innovations to improve the estimated impacts of short-term changes in exposure to air pollution and calculate reduction of life expectancy, beside the absolute number of cases, to estimate the health impacts of long-term exposure to air pollution.
- **Collaboration**: Investigate the possibility of making a geographical representation of the Apheis findings by collaborating with Euroheis (also funded by the programme Action on Pollution Related Diseases).

How this report is organised

In this report, the first section presents a summary report on the Apheis communications strategy. The second section describes how we conducted the HIAs and includes epidemiological findings. We then present and compare the characteristics and the HIAs of the participating cities. The following section describes how to interpret the findings, followed by the main conclusions.

The last section of this report comprises the appendices on the communications strategy, exposure assessment, epidemiological and statistical analysis, health-outcomes assessment, HIA tools, summary of Apheis-2 findings, the EC directives on PM_{10}, the EC Directives-WHO/EC assessment on $PM_{2.5}$, and the Euroheis collaboration.

We have produced 26 city-specific reports, which appear on the Apheis Web site.

Developing an Apheis Communications Strategy

Summary Report

Prepared by Michael Saklad, Saklad Consultants

April 22, 2004

Executive Summary

> *"The DETR (UK Department of the Environment, Transport and the Regions) has had little success ensuring that anyone takes any notice of the information provided." - Dr. Erik Millstone, Science and Technology Policy Unit, Sussex University*

The Apheis programme seeks to meet the information needs of a wide range of individuals and organizations concerned with the impact of air pollution on health in Europe; and most importantly the needs of those individuals who influence and set policy in this area on the European, national, regional and local levels.

Like other providers of scientific information, however, Apheis had reason to believe that its many audiences, and this one in particular, were making little use of the scientific reports it produces.

To ensure it meets the needs of policy advisors and makers, Apheis decided to develop a communications strategy based on learning this key audience's needs directly from its members.

For this purpose, Apheis interviewed 32 individuals who influence or set policy on air pollution and health in the UK and Spain and who are active in the fields of public health and the environment.

Through this research Apheis sought to describe this audience's information needs as accurately as possible; and then produce recommendations for developing communications tools that would help the audience's members best understand, absorb, process and act on the information Apheis provides.

Our research showed in particular that:

- Policy advisors and makers are generally unlikely to use the scientific reports we develop as is, contrary to scientists
- Each of our two audiences of scientific and policy users has different problems to solve, different ways of processing information, different levels of scientific knowledge and different cultures, meaning each audience has different information needs
- A long, complex chain comprising many players leads from the scientists to whom we distribute our reports directly, and who use them, to the policy makers who ultimately have the greatest effect on public health, but who only receive our reports indirectly and use them rarely, if at all.

Based on this evidence, we concluded that Apheis needs to act proactively to:

- Apply this knowledge to the way it shapes and delivers its information and messages
- Develop a range of communications tools that goes beyond our comprehensive scientific reports to include summary reports, brochures, presentations and Q&As whose focus, content and form are tailored to the separate information needs of scientific and policy users
- Ensure that the information needed by policy advisors and makers actually reaches them.

Taking these steps will greatly enhance the way Apheis communicates with the key audiences that set policy on air pollution in Europe, and will thus help Apheis contribute better to improving public health.

Summary Report

What is the mission of Apheis, and how has Apheis fulfilled it so far?

The Apheis programme was created in 1999 for the stated purpose of "providing European policy makers, environment and health professionals, the general public and the media with up-to-date, easy-to-use information on air pollution and public health to help them make better-informed decisions about the political, professional and personal issues they face in this area."

To fulfill this mission, during its first phases of work, Apheis has conducted health impact assessments on particulate pollution in 26 European cities using a standardized methodology. It then published its findings in the form of scientific reports.

Why develop a communications strategy?

As the next, key step in fulfilling its mission, during its third phase the Apheis programme wanted to go beyond just ensuring that its findings were scientifically valid and up-to-date.

Through this next step, Apheis also wanted to make sure its findings were relevant to the needs of its chosen groups of users, or audiences; that these audiences could easily use its findings; and that, to the extent possible, these audiences would actually use the work of the many individuals who give so much of their time and energy to the Apheis programme.

Indeed, it wasn't clear to us that the content and form of the information Apheis was producing were relevant to our users' needs and easy for them to use, or that our audiences were actually using our work when making decisions or acting on the information we provided.

At Apheis we had been producing reports from our own perspective with hypothetical audiences in mind. This approach caused us to fear our reports were sitting unread on potential users' shelves. And what scientists at other institutions told us about low usage of their reports only heightened our worries.

Given this situation, we resolved that Apheis would first study and seek to understand the seeming communications gap between our knowledge and our audiences' use of it, and then act on our understanding to bridge this gap. Through these two steps we hoped to close the apparent divide separating the world of our research and output from the ability of our users to understand, absorb, process and act on it.

We thus set about designing the Apheis Communications Strategy Project to close the gap between those who produce scientific information and those who use it.

What are the objectives of the communications-strategy project?

At the beginning of the project we first wanted to identify our users. By the broadest possible definition, we determined that those European audiences concerned with the impact of air pollution on public health -- and thus potential users of information produced by Apheis -- included such varied groups as:

- Government policy makers and influencers
- The media that inform and influence government policy makers and influencers, and other audiences
- Environment and health professionals who perform a similar role
- Industry and transport sectors, which include manufacturing industries and automotive manufacturers that pollute the atmosphere directly or indirectly
- Health-care providers who serve the needs of the public
- Vulnerable members of the population who seek to meet their special needs
- The general public.

We also determined how we hoped those audiences would use the information we produced. This included doings such things as:

- Improve the measurement of exposure to air pollution
- Incorporate our data and findings in scientific reports
- Pass our reports on to influencers and decision makers

- Influence and make policy decisions on air pollution and public health
- Disseminate information to the general public
- Inform and advise patients on preventive health measure
- Make industry decisions
- Make decisions about personal behavior.

Then, to ensure we achieved our goal of bridging the gap between Apheis and the audiences we had identified and what we hoped they would do with the information we produce, we set ourselves four key objectives:

- Identify the information needs of users of our work, our findings and our reports
- Understand how well we were meeting those needs with the reports we had produced
- Understand what we needed to do to meet users' needs better
- Develop a communications strategy that would identify and describe the communications tools, content and characteristics that would best meet the information needs of specific user groups effectively and efficiently.

What methodology did we use?

Target audiences and research sites

Given various budgetary and time constraints, to meet the project's stated objectives Apheis chose in a first phase to narrow the project's scope and investigate the information needs and behavior of a single, key target audience from among the large number of target audiences that require information on the impact of air pollution on public health.

From all the potential target audiences that deserved investigation, we chose government policy makers and influencers, since through their actions this group probably has the greatest impact of all our target audiences on improving public health.

To gain the best possible understanding of the chosen target audience, we decided to concentrate our investigations on members of this audience in a single country, and treat this research as a core case study.

By concentrating on one country, the UK, and specifically on one city within that country, London, that together have long experience both in the area of air pollution and public health and in its communications aspects, we hoped to form a rich, clear and concise picture of the thought and communications processes and information needs of our chosen target audience, and of the best practices for meeting those needs.

At the same time, we recognized the limitations of conducting research in a single country. Indeed, we felt that cultural, historical, regional, environmental or other reasons might prevent our findings concerning the audience in the UK from being directly applicable to the same or to other key target audiences in other Apheis countries.

To make the findings of our core case study more useful to the Apheis centers, we thus decided to enrich the findings of the core case study with the findings of a complementary case study conducted in two southern European cities, Barcelona and Madrid, where levels of air pollution were high and where people were just becoming aware of its damaging impact on public health. We also decided to model this complementary case study on the core case study, and use the second study to validate and broaden the findings of the first.

We also drew on information gathered from officials at the European Commission, and WHO and at an NGO, the International Society of Doctor for the Environment.

To further enrich the findings of these case studies and make them even more useful to all 26 Apheis centers, we asked those centers to provide minicase studies on their local communications needs and experiences; and to comment on the applicability of the two main case studies to developing local communications content and tools.

Subgroups we investigated within the target audience

While members of the chosen target audience can be grouped together under the single rubric of government policy makers and influencers, we determined that this audience in fact comprises many key subgroups that deserved investigating. Among others, these subgroups included combinations of the following:

- Individuals who make decisions directly regarding public policy
- Individuals who influence the making of such decisions
- Individuals active on the European, national, regional and local levels
- Individuals who recognize the benefits of reducing air pollution to improve public health and advocate such moves
- Individuals who reject, deny or question the benefits of reducing air pollution to improve public health, and who actively or passively oppose such moves
- Individuals who require technical information
- Individuals who require nontechnical information.

To obtain the best possible picture of our chosen target audience, we conducted 21 interviews for the core case study and 11 interviews for the complementary case study, all with individuals who combined the above characteristics in the following subgroups.

Direct advisors to government policy makers

While interviewing government policy makers, such as a European or country minister, a region's administrator or a city's mayor would have been highly informative, we couldn't reasonably expect to reach such busy people. Hence, we decided instead to gather information from the individuals who directly influence this topmost group of policy makers.

We thus chose to investigate individuals closest to government policy makers, in specific their direct advisors and members of their close political entourage. Members of this subgroup advise the policy maker directly, or the policy maker consults them directly for opinions and recommendations.

To get a representative view of this subgroup, we interviewed subjects in the UK and Spain who formed a cross section of individuals active on the European, national, regional and local levels.

Policy influencers

The policy influencers we investigated included representatives from the two key subgroups of individuals active in the field of public health and in the field of the environment.

Contrary to the previous subgroup, members of these subgroups are not direct political advisors to government policy makers or members of such individuals' close political entourage.

However, they are members of European, national, regional or municipal government bodies who consult with, advise or otherwise influence government policy makers or members of their political entourage.

To get a representative view of the subgroups of policy influencers from both the public-health and environment sectors, we again interviewed subjects in the UK and Spain who formed a cross section of individuals active on the European, national, regional and local levels. And we achieved a good balance of individuals from both sectors.

Topics we investigated

To gather information for our research, Apheis conducted one-on-one interviews, mostly in person, with key members of the above subgroups in the UK and in Spain.

The research focused on investigating the following main topics:

- What information do members of the target audience and those they influence require about the impact of air pollution on public health (this included areas of information wanted and level of scientific detail required)
- What is the decision-making process in which the target audience participates, and how does it work; who else participates in the process

- Who uses information on the impact of air pollution on public health (this includes both the target audience itself and pass-on users who can not be interviewed but with whom the target audience communicates, who require and request such information from the target audience as part of the decision-making process, and who are thus users of the information in their own right)
- For what purposes do these different individuals use that information, and how do they use it
- Which types of communications tools, content and form meet the information needs of these individuals, which don't, and why
- How well do the Apheis 2 draft report as a whole, and the compilation of findings and city reports individually, meet their information needs; is the content relevant, clear, understandable and usable; what's lacking in the content and in how that content is presented, what needs to be changed, and how.

What did we learn?

What attitudes did subjects hold about reducing air pollution?

On the whole, the 32 subjects interviewed showed a general willingness to advocate reducing air pollution. At the same time, they pointed out a need to compare air pollution with other public-health hazards, such as indoor sources.

Subjects in the UK indicated they expected the already marginal benefits of reductions in London air pollution to decrease even further while costs increased. Spanish subjects gave higher priority to reducing air pollution than did those in the UK. And there was a general call for Europe-wide policies, since some subjects felt local actions alone won't be effective, citing ozone reduction as an example.

What information can raise awareness of the impact of air pollution on health?

Subjects suggested different types of information they felt could help raise awareness among policy makers and influencers of the impact of air pollution on health.

These included providing peer-reviewed papers; cost-benefit analyses; information on health benefits and health-impact assessments; maps of air pollution and health-impact assessments that show inequalities in exposure and in health effects; and comparative risk assessments for air pollution and other environmental factors.

Other suggestions included emphasizing long-term effects and years of life lost; and providing the media with information on the health effects of air pollution.

Spanish subjects also recommended providing comparative figures across cities; comparisons with other health hazards; and use of strong graphical presentation of evidence.

How did subjects rate the Apheis 2 draft report?

All subjects interviewed received the first draft of the Apheis 2 report, which included a compilation of findings section and a sample city report. Subjects were then asked to rate the documents on scientific soundness, trustworthiness, relevance of content to their needs, and organization and presentation of information.

All subjects interviewed in Spain rated the Apheis documents favorably to very favorably overall, and rated them slightly better than did the subjects interviewed in London.

Subjects in London active in the environment sector found the Apheis 2 draft report to be more useful than did those active in the public-health sector, contrary to subjects in Spain, where subjects in the public-health sector rated the Apheis 2 draft report as more useful than did those in the environment sector.
Subjects generally praised the compilation of findings and the city reports for providing a detailed, comparative picture of air pollution and health in different European cities.

At the same time, a number of general and specific comments indicated there was room for improvement. One subject felt that, “The Apheis 2 reports fell between two stools,” reflecting a need to develop different communications tools for different Apheis audiences. Other subjects suggested including a glossary, and some called for more balanced writing when reporting deaths related to exposure to air pollution.

In addition, some Spanish subjects felt the reports should use simpler language, and more boxes, graphs, maps and colors.

What recommendations did subjects make for the compilation of findings?

Specific recommendations made by subjects concerning the compilation of findings section included the need to:

- Provide an executive summary of the findings
- Stress that Apheis uses a standardized methodology for quality control, data collection and analysis
- Indicate by how much deaths are brought forward (years of life lost or reduction in life expectancy)
- Explain uncertainties better (e.g., GAM modeling problems)
- Deal with the transferability of exposure-response functions (e.g., use of shrunken estimates).

What recommendations did subjects make for the city reports?

Specific recommendations made by subjects concerning the city reports included the need to:

- Provide an executive summary of local findings
- Indicate clearly if the report is for a nonscientific audience (in which case only provide the central estimate) or if it is for a scientific audience (provide more detailed methodological information and interpretation)
- Comment on implications for local transportation policy
- Provide comparative information with other cities
- Use clearer, simpler writing, and more bullet points.

Who are the audiences for our work?

The key objectives of the Apheis Communications Strategy Project call for ultimately providing the different users of our work with information chosen and presented in such a way that it is relevant to the needs of each group of users, or audience, and that each audience would find our information easy to use, thus ensuring it has an impact on policy making. Successfully achieving this objective thus meant understanding the information needs of each of our audiences.

As a reminder, in its first phase the project sought to meet the needs of both policy influencers and of direct advisors to government policy makers. Different individuals in these chosen groups, though, have different levels of knowledge about air pollution and its impact on health, and thus have different information needs; and they process information differently depending on their role in the decision-making process.

Given this diversity of needs and behavior, to meet its objectives effectively Apheis clearly needed to develop different communications tools (reports, brochures, slide presentations and so forth) and different types of content, and tailor each tool and its content to the needs of a specific group of individuals, all of whom share common information needs.

We called these groups “target communications audiences,” and as a first step in our analysis we sought to define the characteristics of these groups and their information needs.

To determine who the audiences of policy influencers and of direct advisors to government policy makers are for the information Apheis produces, we first sought to understand how policy on air pollution is made and by whom. For this purpose we drew on what we learned in the interviews conducted in London, Madrid and Barcelona, and on the analysis Saklad Consultants has conducted of complex decision-making processes in large organizations.

The diagram in Figure 1 below, which emerged from this work, portrays a chain of decision influencing and making -- and the information needed for this process -- that comprises multiple paths leading from Apheis as a source of information through scientists and scientific committees to policy advisors and, ultimately, to the policy makers themselves, seen at the bottom of the diagram.

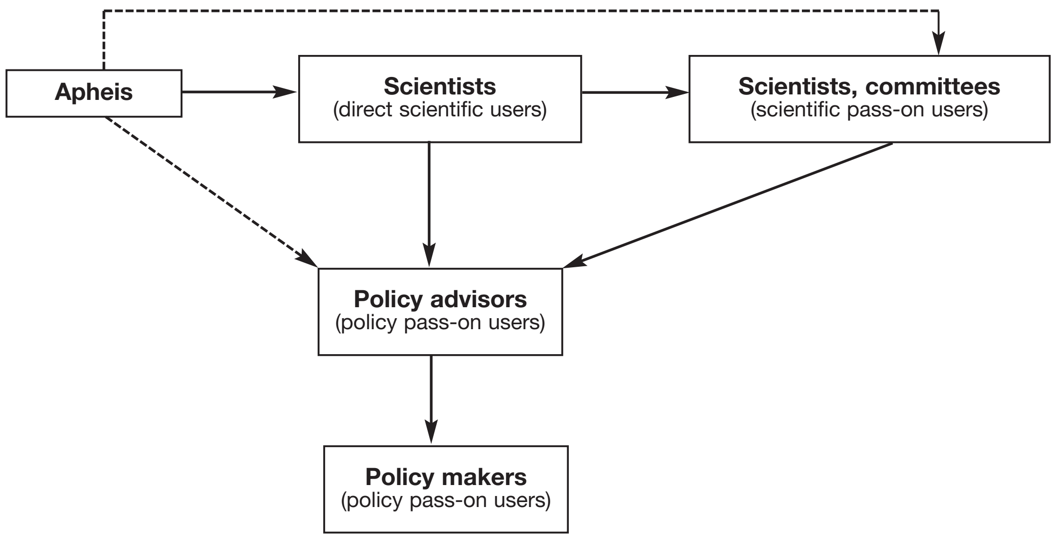
The diagram also shows the three main groups of people who receive and process the information Apheis produces. These are the direct scientific users, the scientific pass-on users and, below, the policy pass-on users.

The solid lines in the diagram indicate the main paths of information flow, while the dotted lines show the secondary paths of information flow.

It's worth noting that our research revealed that this general decision-making process, and the information flows that make it work, seem to apply across all local, regional, national and European levels of policy making.

As the diagram shows, the policy-making process includes what we call direct users of Apheis information, and indirect users, also known as pass-on users, as indicated in parentheses in the different boxes.

Figure 1. Who influences and sets policy and how information flows



Direct users of the information Apheis produces and disseminates include the scientists who appear just to the right of the Apheis box and who receive information directly from Apheis.

These scientists in turn pass that information on to other scientists and to committees, seen in the box further to the right, all of whom thus become pass-on users, because they receive the information Apheis produces indirectly from Apheis.

Then, the individual scientists and committees pass Apheis information on to the policy advisors below them, who form another group of pass-on users. And those policy advisors in turn pass the information on to policy makers, who review it and set policy.

To summarize, Apheis sends the information it produces to the people with whom it is in closest contact: primarily to scientists, as indicated by the solid line; and, to a lesser extent, to scientific committees and, infrequently, to policy makers, all as indicated by the dotted lines.

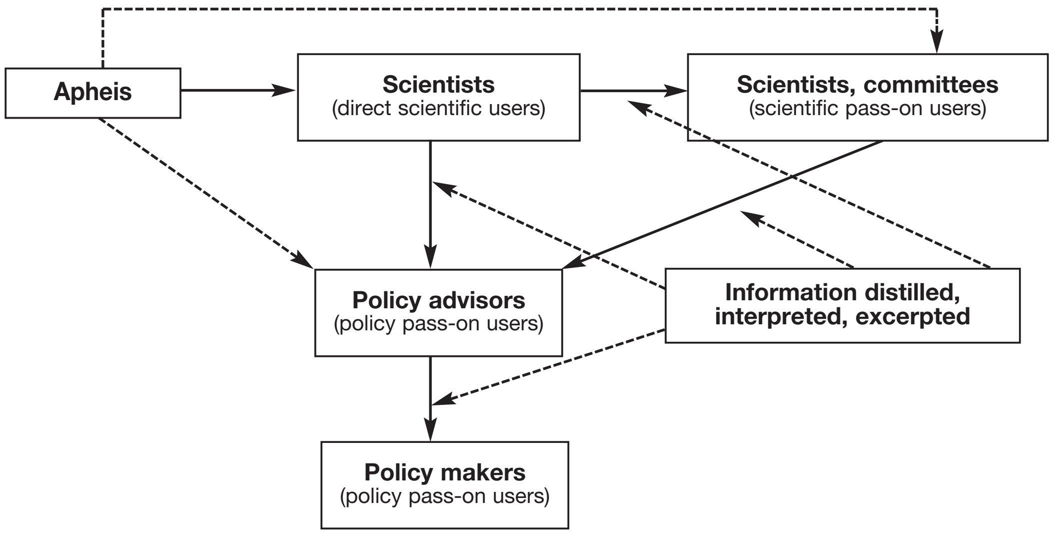
Note that, although this diagram provides a collapsed view of a complex process that comprises many different players and steps, it accurately reflects how policy on air pollution is set, who the different players are in that process, and how the information they need flows through the decision-making chain.

We have used this model to develop the Apheis communications strategy and to determine specifically with which audiences we need to communicate, what information each audience needs, and in what form they need it.

Figure 2 below adds a new and important layer of information to Figure 1, and shows that information is processed at virtually every step in the policy-making process.

By processed, we mean that individuals distill, interpret and extract the information they receive; frame it to meet various policy needs -- political, social and economic, among others; and usually incorporate the resulting information in other, often shorter documents for use by themselves and by others.

Figure 2. Information usually gets processed when passed on



The arrows that point from the box labeled "Information distilled, interpreted, excerpted" indicate where this processing occurs. So for instance, scientists and committees process information before handing it on to policy advisors, and policy advisors do the same before handing information on to policy makers.

And at the end of the chain, complex scientific information often gets boiled down to just a few pages and messages that reach the desks of the policy makers themselves.

What this means is that a series of people, with whom Apheis has little or no contact, extract what they want from the reports Apheis produces, and interpret it in ways over which Apheis has essentially no control.

Apheis thus needs to devise ways to control this process of distillation and interpretation better if it is to ensure that its work reaches the policy makers at the end of the chain both intact and in compelling form, rather than truncated inappropriately, distorted or weakened. Understanding this need to address each step in the policy-making process will inform the design and content of the communications tools Apheis develops.

Now let's examine more closely who the various players in this chain are, and what they do with the information they receive.

Who are the direct scientific users?

As we saw in the preceding diagrams, direct scientific users are the first link in the chain of scientists, committees and advisors that ultimately leads to government officials who set policy. Direct scientific users serve as the point of contact at which our information enters the decision-making chain, since they receive the information Apheis produces directly from us.

Our research told us that few of these direct scientific users advise policy makers directly; instead they advise policy advisors directly, and also indirectly through other scientists, committees, groups, agencies and departments, some of which are scientific and some political in nature.

As for what direct scientific users do with the information they receive from Apheis, some read our Apheis reports and make recommendations to others in the chain in writing, in meetings and in conferences. Some direct scientific users pass Apheis reports on to other scientists and to policy advisors as is, while some distill, interpret or excerpt it, and incorporate it in other documents. And some just read Apheis reports to keep informed.

Who are the scientific pass-on users?

Scientific pass-on users include fellow scientists who need information for the same purposes as direct scientific users. Scientific pass-on users also include scientific committees that gather information on a variety of subjects, review data and make recommendations, and pass reports on to policy advisors, again sometimes as is, and sometimes distilled, interpreted and excerpted or incorporated in other documents.

Who are the policy pass-on users?

Policy pass-on users include policy advisors, who prepare briefings for policy makers who in turn use them to make decisions on often complex public-health and environmental issues. Policy advisors exert greater influence on policy makers the closer they are to them.

Policy pass-on users also include policy makers themselves, who are generally not scientists. But policy pass-on users sometimes include scientists who advise and influence policy makers directly, or are policy makers themselves.

Policy pass-on users generally deal with political, economic and social issues. They tend to be less technically knowledgeable than scientists. And they prefer synthesized information presented and framed in terms of the issues they face.

For these reasons, policy pass-on users tend to read brochures, slide presentations and Q&As/FAQs (questions and answers/frequently asked questions), and told us that scientific reports are generally not relevant to their information or policy-making or -influencing needs.

What should our communications strategy be?

What do these findings mean for Apheis communications?

We have seen that a chain leads from the scientific data and analysis produced by Apheis to the setting of policy on air pollution. Individuals, committees and groups form successive links in that chain. And the closer individuals are to policy makers, the less technically knowledgeable they tend to be about air pollution and its impact on health.

We have also seen that many individuals in the policy-making chain distill, interpret and frame scientific content to make it understandable to the next user in the chain.

During our research, subjects told us that time is a critical factor when it comes to their absorbing written information (even two pages can be too many for some), and when they process and prepare information to pass on to others. They also said that having Apheis do the job of distilling, interpreting and framing information for them makes all the difference.

To understand how doing their job for them can benefit Apheis, let's take the example of a scientist or policy advisor involved in the policy-making chain. The next person in the chain after them closer to policy making has asked the scientist or policy advisor to boil down the Apheis report, frame the information it contains in terms he or she can understand, and shape it as a slide presentation or a briefing paper.

That scientist or policy advisor may very well not understand all the technicalities of the Apheis report, or the meaning or implications of the information it contains for the issues facing the next person in the chain. And chances are that scientist or policy advisor is also pressed for time in their job.

What this means is that, if Apheis has already developed such a document for that scientist or policy advisor to hand on to the next person in the chain, that scientist or policy advisor is more likely to pass it on as is and not modify, distort or misinterpret the information it contains when shaping it for the next user's needs.

From having interviewed many people in large organizations, this consultant knows that key individuals active in decision-making processes face this problem of preparing information for pass-on users almost on a daily basis; and that having the information provider prepare communications tools for the next person in line takes a heavy burden off their shoulders, makes them more likely to use the information provided -- and use it as is -- and gains their appreciation and goodwill.

Even more importantly, preparing tools for pass-on users means that the information Apheis produces will keep moving through the decision-making process rather that sitting unread and unused on someone's shelf, in a stack of folders on their desk or in their drawer.

What options does Apheis have for its communications?

Based on the above analysis, the Apheis programme has two choices concerning its communications, each with different consequences.

Apheis can continue to produce scientific reports alone, as it does today, and in their current form. Doing so will leave it up to each individual in the chain to distill, interpret, frame and communicate the information Apheis produces as they see fit and in the time available to them.

This means that Apheis will only reach the first, scientific link in the policy-making chain. Apheis will have no control over how its information is then processed or manipulated. People pressed for time or who don't understand the information Apheis produces will most likely neither process nor use it, or will misunderstand or distort it. And as a result, as we said Apheis reports will mostly likely sit on shelves unread and unused.

On the other hand, if the Apheis programme takes a proactive stance, the outcome will be radically different, and will lead to far greater use of the information Apheis produces.

In this scenario, Apheis would anticipate the needs of all individuals in the policy-making chain, from the initial scientists knowledgeable about the field of air pollution and health to policy advisors and makers who often have little familiarity with or understanding of our work, its concepts or its vocabulary. This means Apheis would prepare the information people need at each step in the chain in the form of communications tools tailored to their respective needs.

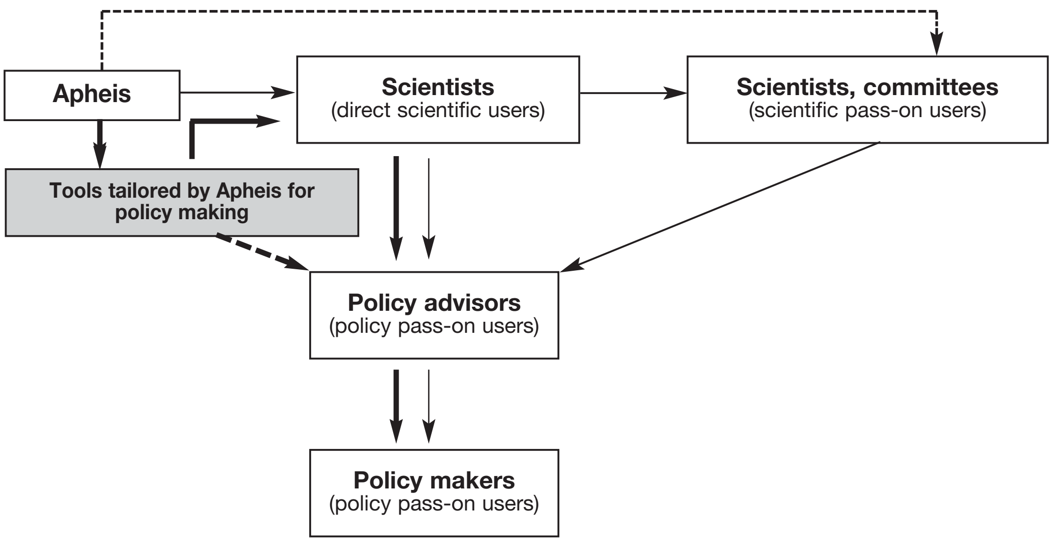
In other words, Apheis would speak to everyone in the chain at the same time but using different words and voices in different tools.

In addition, because Apheis lacks direct access to key policy advisors and makers, to ensure these target audiences receive the information it produces, Apheis needs to deliver the tools tailored to their needs to the individuals in the process who have access to these key but hidden pass-on users and who will pass our information on to these hard-to-reach policy advisors and makers.

If Apheis both prepares the right communications tools *and* gets them into the hands of those individuals who have access to key policy advisors and makers, the information Apheis produces will be far more likely to flow unimpeded through all the links in the policy-making chain and thus reach all the players with the greatest integrity, relevance and impact, thereby truly fulfilling Apheis' mission.

Figure 3 illustrates such a scenario, in which Apheis produces both scientific reports for scientists and communications tools tailored specifically to the needs of policy advisors and makers, and provides the latter to both scientists and policy advisors directly for their own use and for passing on to others.

Figure 3. Tools tailored by Apheis move through policy-making chain more effectively



Since it seems reasonable to assume that the Apheis programme prefers this type of proactive approach, we will now look at what that approach actually requires in order to produce communications tools and content tailored to the needs of everyone involved in influencing and making policy.

For this purpose, we'll first report what information content each group of users wants based on our research. Then we'll look at the communications tools they prefer that deliver that content, whether those tools are complete reports, peer-reviewed papers, brochures, slide presentations and so forth, and what they do with them when influencing and making policy decisions.

What information do direct and pass-on scientific users need?

Our research revealed that subjects active in the public-health sector in general asked for comparative figures across Europe for air pollution and health; exposure-response functions and HIA scenarios on mortality and morbidity; and health data for background prevalence or incidence rates.

In addition, subjects in Spain wanted to understand the public's perception of air pollution and its impact on health; and wanted to understand the threat of air pollution more in terms of public health than in terms of exposure-response functions.

Subjects active in the environment sector generally wanted Apheis to monitor trends in air pollution and health effects; they wanted meta-analytic findings and comparative figures; they wanted to know how the public perceives air pollution and its impact on health as determined by willingness-to-pay studies; and they wanted to understand policy options and their effectiveness.

Subjects in Spain also asked for information on industrial emissions, sources, technology used and related levels of air pollution; information on the seriousness of air pollution; and information on air-pollution legislation and on years of life lost.

What information do policy pass-on users need?

Policy pass-on users generally asked for information on air-pollution levels and sources; health effects; HIA scenarios; health costs related to air pollution and the costs of reducing air-pollution levels; and information on ad-hoc subjects.

What did we learn from the minicase studies?

In minicase studies, some of the Apheis centers reported on their local communications experiences following publication of the Apheis 2 report. In these studies they reported an increased awareness of air pollution and its impact on health in several cities like Bucharest, Budapest, Ljubljana and Stockholm, and in some cities in France and Spain.

They also observed some resistance to the dissemination of Apheis 2 findings coinciding with political elections.

Requests for information from local Apheis centers included a focus on susceptible populations (defined by their SES, age, history of disease and exposure to hotspots); the inclusion of more degrees of severity (other than mortality); a focus on areas “at risk”; the inclusion of specific HIAs of traffic-related air pollution; the development of HIA tools and different scenarios; and the inclusion of comparisons with other cities in the city report.

Which communications tools do Apheis audiences want?

When asked to rank the communications tools they deemed most useful for their needs, subjects interviewed in the UK expressed a nearly 50-percent preference for full scientific reports over PowerPoint-type slide presentations, summary reports and Q&As/FAQs in that order, and roughly equal preference for these other three types of tools.

Subjects interviewed in Spain expressed a similar, marked preference for full scientific reports, and again approximately equal preference for the remaining three tools, although the order of the latter three differed slightly from that seen among UK subjects.

In addition to these main communications tools, a few subjects mentioned peer-reviewed scientific papers as useful for conveying information on air pollution and health.

While just a handful of subjects greatly preferred a given communications tool over all the rest, most ranked at least one other tool as having the same or nearly equal usefulness to them. And many said they would use more than one type of tool, either for themselves alone or for both themselves and pass-on users.

This means it is important that the Apheis centers provide virtually every user with more than one communications tool.

Concerning specific tools, many subjects said they want a high level of scientific detail and have the time to read full scientific reports, reflecting the general preference for such reports.

A substantial number of others, however, said they or their pass-on users simply don't have the time or desire to read an entire scientific report and digest the complex information it contains. Such users include government officials and many scientists who are inundated with scientific information. Subjects said this type of user prefers receiving a brief summary report or brochure that provides key information and facts, and references the main report for further details.

When commenting on slide presentations, many subjects emphasized their usefulness for conveying information to other participants in the policy-making process in a simple manner enabling many people in a room to grasp key facts, points and messages quickly and easily.

Subjects who liked Q&As/FAQs called them good tools for providing information in simple form on narrower subjects.

Finally, users who requested communications tools with a policy focus said they are generally not experts in the area of air pollution and health, or lack a scientific background. As a result, they rely on others to digest and distill the scientific information they need, translate it into nontechnical language they understand, frame it for their policy-making needs, explain what the findings and information mean, and highlight the benefits of taking specific types of action.

Based on the research findings, we determined that the following types of communications tools can best meet the different needs of the main audiences who require the information Apheis produces and who would use it in their work as policy influencers and makers for themselves and for their pass-on users in the policy-making chain:

- Complete scientific reports
- Summary scientific reports
- Peer-reviewed scientific papers
- Brochures with a policy focus
- PowerPoint presentations with a scientific focus
- PowerPoint presentations with a policy focus
- Q&As/FAQs with a scientific focus
- Q&As/FAQs with a policy focus.

Because different audiences have different information needs, for each audience to get the information it wants in the form it wants it in, each Apheis center must first learn which of these tools best meet the needs of both direct and pass-on users in terms of content and form, and then use this knowledge to develop and provide tools tailored for each audience it wants to reach.

Following are what subjects told us are the main audiences for each of these communications tools, how these audiences use each tool, and what content and form they prefer for each. Knowledge of this information will help the Apheis centers better understand for whom they are developing each communications tool, and for what purpose members of each audience typically use the tools.

In terms of the information Apheis will provide, it should be noted that Apheis takes a multidisciplinary approach to the study of air pollution and its effects on health. And Apheis wishes to promote the exchange of know-how between public-health and environment professionals to achieve synergies and mutual enrichment of our respective work. Because of this integrated approach, our reports now provide information on both areas together, and will continue to do so.

Complete scientific report

Audiences for a complete scientific report include:

- Direct and pass-on scientific users, who use a complete scientific report as is, or may cut and paste sections of the report into other documents they create for their own use or that of others
- Policy pass-on users, who generally use a complete scientific report as a source to back up the information contained in shorter communications tools they pass on or who less frequently use the report as their primary source for decision making.

The main features subjects told us they want in a complete scientific report include:

- A high level of scientific detail and complexity
- A clear, concise executive summary that highlights the report's key points

- A detailed description of the methodology used
- A clear presentation of the findings and their interpretation
- A set of clear conclusions
- A recent bibliography
- The use of charts, graphs and boxes to help readers absorb complex information at a glance, and help them find, understand and remember the report's key points.

Summary scientific report

Audiences for a summary scientific report include:

- Direct and pass-on scientific users, both of whom use a summary scientific report to keep abreast of developments in various fields and of issues that are not necessarily central to their current work and with whose concepts they may not be familiar. Some use a summary scientific report as is. And some may cut and paste sections of it into other documents they create for their own use or that of others
- Policy pass-on users, who use the report as a source of summary information

The main features subjects told us they want in a summary scientific report include:

- A high level of scientific detail
- A clear, concise executive summary that highlights the report's key points
- A short description of the methodology used
- A set of clear conclusions
- A recent, short bibliography that enables users to obtain more complete data and analysis should they so desire
- The use of charts, graphs and boxes to help readers absorb complex information at a glance, and help them find, understand and remember the report's key points
- A total length of only a few pages.

Peer-reviewed scientific papers

Audiences for peer-reviewed scientific papers include:

- Direct and pass-on scientific users, who use peer-reviewed scientific papers as is, or may cut and paste sections of the papers into other documents they create for their own use or that of others
- Policy pass-on users who are not experts on air pollution and health and who will use the papers to back up the information contained in shorter communications tools they pass on or use as their primary sources for decision making.

The main features subjects told us they want in peer-reviewed scientific papers include:

- A clear, concise abstract that highlights key points
- A clear presentation of the objectives, methodology, findings, discussion and conclusions
- A recent bibliography
- The use of tables and graphs.

Brochures with a policy focus

Audiences for brochures with a policy focus include:

- Policy pass-on users who are not experts on air pollution and health and require information they can grasp quickly and easily. Some use brochures with a policy focus as is, while others may cut and paste sections of these brochures into other documents they create for their own use or that of others.

The main features subjects told us they want in a brochure with a policy focus include:

- A clear, concise executive summary that highlights key points
- Information presented in a simplified manner using easy-to-understand terms whose meanings are clearly defined

- A reduced level of scientific detail and complexity
- A few key messages presented simply and clearly with the help of bullet points, and of simple graphs, charts and/or tables
- Information framed and interpreted in terms relevant to policy-making needs
- A recent, short bibliography that enables users to obtain more complete data and analysis should they so desire
- A total length of only a few pages.

PowerPoint presentations with a scientific focus

Audiences for PowerPoint presentations with a scientific focus include:

- Direct and pass-on scientific users who need to send and receive scientific information in a form that is easy to understand and digest. Some use a PowerPoint presentation with a scientific focus as is, while others may cut and paste sections of the presentation into other documents they create for their own use or that of others. They all use presentations to convey information at meetings, conferences and other gatherings.

The main features subjects told us they want in a PowerPoint presentation with a scientific focus include:

- A summary of key findings
- A high level of scientific detail and complexity
- Content that is easy to understand and digest
- A recent bibliography.

PowerPoint presentations with a policy focus

Audiences for PowerPoint presentations with a policy focus include:

- Policy pass-on users who are not experts on air pollution and health and require information they can grasp quickly and easily. Some use a PowerPoint presentation with a policy focus as is, while others may cut and paste sections of the presentation into other documents they create for their own use or that of others. They all use presentations to convey information at meetings, conferences and other gatherings.

The main features subjects told us they want in a PowerPoint presentation with a policy focus include:

- A reduced level of scientific detail and complexity
- A few key messages presented simply and clearly in easy-to-understand terms using bullet points and supported, when appropriate, by simple graphs, charts and/or tables
- Information framed and interpreted in terms relevant to their policy-making needs
- A recent, short bibliography that enables users to obtain more complete data and analysis should they so desire.

Q&As/FAQs with a scientific focus

Audiences for Q&As/FAQs with a scientific focus include:

- Direct and pass-on scientific users, and policy pass-on users, all of whom use Q&As/FAQs as a source of information for their own use
- Policy pass-on users who are not experts on air pollution and health and who will use the Q&As/FAQs to back up the information contained in shorter communications tools they pass on or use as their primary sources for decision making.

The main features subjects told us they want in Q&As/FAQs with a scientific focus include:

- A high level of scientific detail and complexity
- A discussion of methodology issues
- A discussion of uncertainties
- A recent bibliography.

Q&As/FAQs with a policy focus

Audiences for Q&As/FAQs with a policy focus include:

- Policy pass-on users who are not experts on air pollution and health and require information they can grasp quickly and easily. Some use Q&As/FAQs with a policy focus as is, while others may cut and paste sections of Q&As/FAQs into other documents they create for their own use or that of others.

The main features subjects told us they want in Q&As/FAQs with a policy focus include:

- A clear, concise executive summary that highlights key points
- A reduced level of scientific detail and complexity
- Information framed and interpreted in terms relevant to their policy-making needs
- Simple, nonscientific discussions
- Uncertainties presented in a clear, simple manner
- A recent, short bibliography.

How can we now develop these communications tools?

In its current phase, the Apheis programme sought to identify the information needs of its target communications audiences.

In its next phase, the Apheis programme will draw on the learnings of the Apheis Communications Strategy Project to develop the communications tools described above in a generic form that the individual Apheis centers can then adapt to their local needs.

To develop the tools, Apheis plans to retain the services of a communications professional who will work closely with those individuals best able to provide the scientific content needed for each tool and its audience or audiences.

What will the Apheis centers do next?

The Apheis centers can use the generic communications tools we will develop as is, translate them into their local languages and disseminate them.

However, to reach each Apheis audience as effectively and efficiently as possible, the centers should adapt the tools to local needs and conditions.

For this purpose, each center should first ascertain that its target audiences share information needs similar to those we have identified in terms of content and form.

To do this, we recommend that each center conduct a smaller version of the research we have done when developing the Apheis communications strategy. In particular, each center should survey those individuals with whom it is in contact who influence policy making directly or indirectly to determine both their information needs in terms of content and form, and the corresponding needs of those pass-on users who play a critical role in policy making but to whom the Apheis centers have little or no direct access.

Based on this information and its analysis, each Apheis center should then take the generic communications tools Apheis will produce, and tailor them to local information needs; local awareness of air-pollution levels and of their impact on health; local environmental and public-health conditions; local health and policy issues; and local ways of communicating.

Once the centers have localized the communications tools Apheis will provide, each center will need to get the tools tailored to the needs of pass-on users into the hands of those people who have access to pass-on users.

For this purpose, the centers should again use the information they obtain from those individuals with whom they are in contact who influence policy directly or indirectly to determine what tools they should give them to pass on to others closer to policy advisors and makers.

By completing these two steps, the Apheis centers can best ensure that their work reaches the key people who influence and make policy on air pollution throughout Europe, so that our work makes the greatest possible contribution to reducing air pollution and to improving health.

Working group

Michael Saklad at Saklad Consultants, Paris, designed the Apheis Communications Strategy Project, supervised its execution, reanalyzed the findings (with the help of Sylvia Medina for scientific aspects), and wrote this Summary Report.

Rene van Bavel, at the London School of Economics, and Lucia Sell-Trujillo conducted the interviews, and analyzed and reported on the information gathered.

Sylvia Medina and Antoni Plasència, co-managers of the Apheis programme, supervised the project.

More detailed information on the design of this project can be found in the following two documents:

- "Developing an Apheis Communications Strategy," prepared by Michael Saklad, Saklad Consultants (Appendix 1)
- "Description of Tasks, Apheis Communications Strategy Project," prepared by Michael Saklad, Saklad Consultants (Appendix 2).

To obtain information on the project's fieldwork, please write to Dr. Sylvia Medina, National Institute for Public Health Surveillance (InVS), 12 rue du Val d'Osne, 94415 Saint-Maurice Cedex, France.

We would again like to thank the many people who took time from their work to be interviewed for this project. The complete list of names appears on page 2 of this report.

Health Impact Assessment

Key HIA findings

This report sought to analyse the impact of air pollution on public health in 26 cities in 12 European countries as part of the ongoing work of the Apheis programme.

This Apheis-3 phase added further evidence to the finding in Apheis-2 that air pollution continues to pose a significant threat to public health in urban environments in Europe.

In particular, concerning the ability of Apheis cities across Europe to meet future standards designed to reduce the impact of air pollution on health, Apheis-3 determined that, while most of the 26 cities studied met the annual mean cut-off of 40 $\mu g/m^3$ set as the limit value for PM_{10} to be reached by all member states of the European Union by 2005, 21 cities still exceeded the 2010 limit value of 20 $\mu g/m^3$. Nonetheless, nine cities nearly met the latter value.

Concerning the impact of exposure to PM_{10} in the very short, short and long terms, in the 23 Apheis cities that measured PM_{10}, totalling almost 36 million inhabitants, if all other things were equal and exposure to outdoor concentrations of raw PM_{10}[1] were reduced to 20 $\mu g/m^3$ in each city, 2 580 premature deaths, including 1 741 cardiovascular and 429 respiratory deaths, could be prevented annually if the impact is only estimated over a very short term of 2 days. The short-term impact, cumulated over 40 days, would be more than twice as great, totalling 5 240 premature deaths prevented annually, including 3 458 cardiovascular and 1 348 respiratory deaths. And the long-term impact[2] over several years would be even higher, totalling 21 828 premature deaths prevented annually.

Apheis-3 also contributed the following significant findings:

For both total and cause-specific mortality, the benefit of reducing converted $PM_{2.5}$[3] levels to 15 $\mu g/m^3$ is more than 30% greater than for a reduction to 20 $\mu g/m^3$. Moreover, even at 15 $\mu g/m^3$ a significant health impact can be expected.

In specific, the Apheis-3 HIA estimated that 11 375 "premature" deaths, including 8 053 cardiopulmonary deaths and 1 296 lung-cancer deaths, could be prevented annually if long-term exposure to the annual mean of converted $PM_{2.5}$ levels were reduced to 20 $\mu g/m^3$ in each city; and that 16 926 premature deaths, including 11 612 cardiopulmonary deaths and 1 901 lung-cancer deaths, could be prevented annually if long-term exposure to converted $PM_{2.5}$ were reduced to 15 $\mu g/m^3$.

In terms of life expectancy, if all other things were equal and the annual mean of $PM_{2.5}$ converted from PM_{10}[3] did not exceed 15 $\mu g/m^3$ the potential gain in life expectancy of a 30-year-old person would average between 2 and 13 months, due to the reduction in total mortality.

Black smoke is often considered a good proxy for traffic-related air pollution. In the 16 cities that measured BS, which total over 24 million inhabitants, if all other things were equal and BS levels were reduced to a 24-hour value of 20 $\mu g/m^3$, 1 296 total "premature" deaths including 405 cardiovascular deaths and 109 respiratory deaths, could be prevented annually.

In the Apheis cities, particulate pollution contributed in a non-negligible manner to the total burden of mortality as follows:

- All other things being equal, when only considering very short-term exposure, the proportion of all-causes mortality attributable to a reduction to 20 $\mu g/m^3$ in raw PM_{10} levels would be 0.9% of the total burden of mortality in the cities measuring PM_{10}. This proportion would be greater, 1.8%, for a cumulative short-term exposure up to 40 days. Effects of long-term reduction in corrected PM_{10} levels would account for 7.2% of the burden of mortality.

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[1] For HIAs of short-term exposure, we used raw PM_{10} and BS levels measured directly at monitoring stations.

[2] For HIAs of long-term exposure, we had to correct the automatic PM_{10} measurements used by most of the cities by a specific correction factor (local or, by default, the European factor of 1.3) in order to compensate for losses of volatile particulate matter.

[3] For most of the cities, $PM_{2.5}$ measurements were not available, and $PM_{2.5}$ levels had to be calculated from PM_{10} measurements. For this purpose a conversion factor (local or, by default, the European factor of 0.7) was used.

- For black smoke, only very short-term exposure (raw levels) was considered. All other things being equal, the proportion of all-causes mortality attributable to a reduction to 20 µg/m^3 in BS levels would be 0.7% of the total burden of mortality.
- For long-term exposure to $PM_{2.5}$ converted from corrected PM_{10}, all other things being equal the proportion of all-causes mortality attributable to a reduction to 20 µg/m^3 in converted $PM_{2.5}$ levels would be 4% of the total burden of mortality.

In order to provide a conservative overall picture of the impact of urban air pollution on public health in Europe, like its predecessor Apheis-2 the Apheis-3 phase used a limited number of air pollutants and health outcomes for its HIAs. Apheis-3 also established a good basis for comparing methods and findings between cities, and explored important HIA methodological issues.

Our findings add further support to WHO's view that "it is reasonable to assume that a reduction of air pollution will lead to considerable health benefits." And, at least for particulate pollution, our findings support WHO's already strong recommendation for "further policy action to reduce levels of air pollutants including PM, NO_2 and ozone"(WHO 2004).

Introduction

The information Apheis provides is based on HIA. 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.

Apheis HIAs aim to provide the number of health events that could be prevented (or the gain in life expectancy) from air pollution in the target population. This enables evaluating different policy scenarios for reducing air-pollution levels and helps to assess new air-quality directives. For the time being, Apheis does not calculate the external monetary costs of air pollution or the benefits of preventive actions.

Apheis-3 updated the HIAs and provided new indicators of particles, new health outcomes and, in addition to the absolute number of cases, life-expectancy findings to estimate the health impacts of long-term exposure to particulate pollution.

Methods

HIA methodology

Apheis-3 followed the recommendations of the WHO Guidelines on the Assessment and Use of Epidemiological Evidence for Environmental Health Risk Assessment (WHO 2000, 2001):

- "Specify exposure. If exposure represents a mixture, the selection of the most reasonable indicator(s) of the mixture has to be discussed. Attention should be paid to the time dimension of exposure (averaging times and duration). The distribution of exposure in the target population and in the epidemiological studies used to derive the exposure-response functions should be coherent. The magnitude of the impact depends on the level and range of exposure for which HIA is required to estimate the number of cases. The choice of a reference level may consider epidemiological and other data with regard to issues such as the existence of thresholds and natural background levels. If exposures in the target population exceed or are below those studied, it will be necessary to determine whether exposure-response functions should be extrapolated or not."
- "Define the appropriate health outcomes. The purpose of the HIA, the definition of exposure and the availability of the necessary data will guide the selection of outcomes. In some cases, the HIA should be assessed separately for each health outcome for which there is evidence of an effect. In other cases, in particular when estimating the monetary costs, we should avoid overlapping of various health outcomes."
- "Specify the exposure-response relationship. The exposure-response function is the key contribution of epidemiology to HIA. The function may be reported as a slope of a regression line or as a relative risk for a given change in exposure. Exposure-response functions may be derived from pooled analysis or published meta-analyses."
- "Derive population baseline frequency measures for the health outcomes under consideration. This is to quantify the prevalence or incidence of the selected outcomes. This information should preferably be obtained from the target population for which HIA is being made."
- "Calculate the number of cases, under the assumption that exposure causes the health outcome, based on the distribution of the exposure in the target population, the estimates of the epidemiology exposure-response function and the observed baseline frequency of the health outcome in the population."

Data collection and exposure-response functions

For the present HIA, Apheis has analysed the acute effects of PM_{10} and BS on premature mortality and hospital admissions. We also estimated the impacts on premature mortality of long-term exposure to PM_{10} and $PM_{2.5}$.

Air pollution indicators: particulate matter

Air pollution is a complex mixture of various substances. However, most epidemiological studies find a range of health outcomes to be consistently related to particulate matter. A recent WHO review (WHO 2003) concludes that ambient PM per se is considered responsible for the health effects seen in large epidemiological studies relating ambient PM to mortality and morbidity. This conclusion is also supported by toxicological evidence. These epidemiological studies provide exposure-response functions necessary for HIA. In its first HIA, Apheis chose PM_{10} and BS as particulate-matter indicators. In the HIA presented below, $PM_{2.5}$ was also included based on recent evidence (WHO, 2003, 2004) and on the status of $PM_{2.5}$ within the EC legislation process (Appendix 11).

Exposure measurements

In order to harmonise and compare the information relevant to exposure assessment provided by the 26 Apheis cities, the Apheis Exposure Assessment Advisory Group prepared a questionnaire to assess the cities' fulfilment of the Apheis guidelines on exposure assessment. A full description of the exposure assessment in each city appears in Appendix 3. The description includes: the total number and type of monitoring stations and the number used for HIA purposes; the measurement methods and the use of a correction and/or conversion factors; the quality assurance and control and data quality.

Considerations regarding PM measurements

PM_{10} correction factor

For the purpose of long-term HIA only, not for short-term, because the exposure-response functions used are taken from publications that used gravimetric methods (Künzli *et al.*. 2000, and Pope *et al.* 2002), to be consistent we decided to correct the automatic PM_{10} measurements (ß-attenuation and TEOM) used by most of the cities by a specific correction factor in order to compensate losses of volatile particulate matter. A local correction factor chosen with the advice of the local air-pollution network was used when available; otherwise, the cities used the 1.3 European default correction factor recommended by the EC Working Group on Particulate Matter (**http://europa.eu.int/comm/environment/air/pdf/finalwgreporten.pdf**) (see Table 1 and Appendix 3 for more details).

$PM_{2.5}$ conversion factor

For most of the cities, $PM_{2.5}$ measurements were not available and the cities had to estimate $PM_{2.5}$ data from PM_{10} measurements. For this purpose they used a conversion factor, also for long-term HIA only. If available, a local conversion factor (ranging between 0.5 and 0.8), selected with the advise of the local air-monitoring network was applied. If no local factor was available, 0.7 was used as default conversion factor. The default factor of 0.7 was recommended by the Apheis Exposure Assessment Working Group as a mean value based on two different, recent publications. First, within the process of the revision and update of the so-called 1st European Daughter Directive, the 2nd Position Paper on Particulate Matter (draft of 20 August 2003, available for the PM Meeting in Stockholm) presents the results from 72 European locations reported by several Member states from 2001. It gives $PM_{2.5}/PM_{10} = 0.65$ (range 0.42-0.82, se = 0.09). Second, Van Dingeren *et al.* 2004 recently published a European research activity, with a smaller number of stations (11 stations), giving the ratio = 0.73, se = 0.15 (range 0.57-0.85) (see Table 1 and Appendix 3 for more details).

Total suspended particulates (TSP) conversion factor

Only two cities, Bucharest and Budapest, evaluated 12 TSP monitoring stations (7%) as appropriate for HIA. They converted TSP to PM_{10}, using respectively 0.6 and 0.58 as local conversion factors.

Table 1. Measurement methods, correction and conversion factors used in Apheis-3

City	Measurement method				PM_{10} correction factor	Conversion factor from PM_{10} to $PM_{2.5}$
	PM_{10}	$PM_{2.5}$	Black smoke	TSP[1]		
Athens	ß-attenuation		reflectometry		1.3*	0.3-0.63***[2]
Barcelona			normalised smoke		not applicable	not applicable
Bilbao	ß-radiation absorption		reflectometry		1.2[#]	0.7**
Bordeaux	TEOM (50°C)	TEOM (50°C)	reflectometry		1[s]; 1.3[w]	0.67***
Bucharest				gravimetric	[x]	0.7**
Budapest				ß-ray-operation	[xx]	0.7**
Celje	TEOM (50°C)		reflectometry		1.3*	0.7**
Cracow	ß-gauge-monitor		reflectometry		1.25[#]	0.8***
Dublin			reflectometry		not applicable	not applicable
Gothenburg	TEOM (50°C)	TEOM (50°C)			1.3*	0.66***
Le Havre	TEOM (50°C)	TEOM (50°C)	reflectometry		1[s]; 1.253[w]	0.7**
Lille	TEOM (50°C)	TEOM (50°C)	reflectometry		1.18[s]; 1.27[w]	0.66***
Ljubljana	TEOM (50°C)		reflectometry		1.3*	0.7
London	TEOM	TEOM	reflectometry		1.3	0.7
Lyon	TEOM		reflectometry		1.221[w]	0.7**
Madrid	ß-attenuation				1[#]	0.51***
Marseille	TEOM (50°C)	TEOM (50°C)	reflectometry		1[s]; 1.13[w]	0.65***
Paris	TEOM	TEOM	reflectometry		1[s]; 1.37[w]	0.7**
Rome	ß-gauge monitor				1.3*	0.7**
Rouen	TEOM (50°C)	TEOM (50°C)	reflectometry		1[s] ; 1.22[w]	0.7**
Seville	ß-radiation-attenuation				1.13[#]	0.7**
Stockholm	TEOM (50°C)	TEOM (50°C)			1.2[#]	0.65***
Strasbourg	TEOM (50°C)	TEOM (50°C)			1[s]; 1.21[w]	0.7**
Tel Aviv	TEOM				1.3*	0.5***
Toulouse	TEOM (50°C)	TEOM (50°C)			1[s]; 1.2[w]	0.65***
Valencia			reflectometry		not applicable	not applicable

* For HIA purpose PM_{10} TEOM has been corrected by a European default factor of 1.3 from the EC working group on Particulate Matter
** To convert PM_{10} to $PM_{2.5}$ the European default conversion factor 0.7 was used
*** To convert PM10 to $PM_{2.5}$ a local conversion factor was used
[#]: derived from parallel PM_{10} measurements within the city
[1]. TSP: total suspended particulates
[2]. Range of $PM_{2.5}$ converstion factor, because month-specific factors were used
[s]: summer
[w]: winter
[x] PM_{10}=TSP*0.6
[xx] PM_{10}=TSP*0.58

Health outcomes and E-R functions

HIAs for short-term exposure

For comparison purposes, and to provide a better understanding of the effects of particulate pollution on health over time, HIAs on the effects of short-term exposure used two types of exposure-response functions: for a very short exposure (usually 1 or 2 days) and for a cumulative exposure (up to 40 days):

- For the very short exposure, we used a new exposure-response function developed by Apheis-3 for all-ages respiratory admissions (Appendix 4). We also used exposure-response functions newly developed by WHO as a result of a meta-analysis of time series and panel studies of particulate matter (PM). The calculations were done by a group of experts at St. George's Hospital in London, UK, guided by a WHO task group. The WHO report is available at the following address: **http://www.euro.who.int/document/E82792.pdf.**
- For a cumulative short-term exposure, Zanobetti *et al.* examined up to 40 days of follow-up for all causes (Zanobetti *et al*, 2002) and cardiovascular and respiratory deaths (Zanobetti *et al*, 2003) in the APHEA-2 study. Zanobetti's report showed the cumulative effect was more than twice that found using only 2 days of follow-up. Then, for Apheis-3, we also used Zanobetti's estimates using distributed-lag models.

The following health outcomes were selected, based on the availability of the E-R functions:

- Total premature mortality, excluding accidents and violent deaths.
- Cardiovascular mortality.
- Respiratory mortality.
- Cardiac hospital admissions.
- Respiratory hospital admissions.

Most HIAs, including Apheis HIAs, use overall estimates from multi-centre studies. However some people who conduct an HIA in a particular city where an epidemiological study has been conducted providing local E-R functions prefer to use city-specific estimates. Apheis has discussed the issue of using city-specific estimates, and the Statistical Advisory Group conducted a sensitivity analysis using different effect estimates (Appendix 5). Consequently, additional HIAs comparing the use of these estimates were conducted for some cities that are also part of the APHEA-2 project.

HIAs for long-term exposure

Apheis-3 conducted HIAs on the effects of long-term exposure in terms of number of cases for PM_{10} and $PM_{2.5}$ and in terms of reduction in life expectancy for $PM_{2.5}$.

Based on the availability of the exposure-response functions:

- For long-term exposure to PM_{10}, we estimated the impact on premature mortality using the E-R function already applied in Apheis-2. This E-R function is based on the first ACS study and on the Six Cities Study and was used in the HIA conducted in Austria, France and Switzerland (Kunzli *et al.*, 2000).
- For long-term exposure to $PM_{2.5}$, we used average estimates of the more recent ACS study based on the average $PM_{2.5}$ (Pope, 2002), and the health outcomes were studied for all-causes mortality, cardiopulmonary mortality and lung-cancer mortality.

Appendix 6 gives a full description of the health indicators used for this new phase of Apheis, including the types 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.

HIA tools: PSAS-9 Excel spreadsheet and AirQ

Number of short and long-term cases

Calculations of the number of short and long-term cases were made using an Excel spreadsheet (Appendix 7) developed by the French surveillance system on air pollution and health, called the

PSAS-9 programme coordinated by InVS, the National Institute for Public Health Surveillance (**http://www.invs.sante.fr/psas9**).

An estimate of the impact can be based on the calculation of the attributable proportion (AP), indicating the fraction of the health outcome that can be attributed to the exposure in a given population (provided there is a causal association between the exposure and the health outcome). With the population distribution of exposure determined in the exposure assessment stage, and the identified E-R function, the attributable proportion can be calculated using the formula:

$$AP = \sum \{ [RR(c) - 1] \times p(c)\} / \sum [RR(c) \times p(c)] \quad [1]$$

where: RR(c) is the relative risk for the health outcome in category c of exposure ;

p(c) is the proportion of the target population in category c of exposure.

Knowing (or, often, assuming) a certain underlying frequency of the outcome in the population, I, the rate (or number of cases per unit population) attributed to the exposure in the population can be calculated as:

$$IE = I \times AP$$

Consequently, the frequency of the outcome in the population free from the exposure can be estimated as:

$$INE = I - IE = I \times (1 - AP) \quad [2]$$

For a population of a given size N, this can be converted to the estimated number of cases attributed to the exposure, NE = IE X N.

Knowing the (estimated) incidence among the non-exposed population and the relative risk at a certain pollution level, it is also possible to estimate an excess incidence (I+(c)) and excess number of cases (N+(c)), at a certain category of exposure:

$$I+(c) = (RR(c) - 1) \times p(c) \times INE \quad [3]$$

$$N+(c) = I+(c) \times N \quad [4]$$

Gain in life expectancy and years of life lost

We calculated gain in life expectancy and years of life lost using the WHO-ECEH Air Quality Health Impact Assessment software (AirQ) (Appendix 8)
(**http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20040428_2**).

The "life tables" module of AirQ calculates the health effects attributable to changes in long-term exposure to air pollution. The assessment uses evidence generated by epidemiological cohort studies showing an increase in the mortality risk in populations living in areas with a higher than average long-term air-pollution level. The underlying assumption of the procedure is the applicability of relative risk estimates and of the exposure-response function estimated in epidemiological studies (evidentiary population) in the target population.

The observed age structure of the population and age-specific mortality data are used to calculate the number of survivals and number of "premature" deaths in each age category in future years. The difference between the survival functions of the population at risk due to increased pollution and without risk enables calculating several parameters of impact. The program displays selected parameters (reduction of life expectancy at certain age, loss of expected years of life due to "premature" deaths in 1 year, years of life lost in 1 year or in the entire period of follow-up due to the risk factor).

The program can calculate changes in survival related to the impact of the pollution on all causes of death or on one (or two) of the selected specific causes of death (cardiovascular disease and lung cancers).

Calculations can be based on the risk coefficients provided by the user or on the WHO default values. The present version uses the risk coefficients for $PM_{2.5}$ from the American Cancer Society cohort study (Pope CA, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston G. Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution. JAMA 2002; 287(9):1132-1141).

Life expectancy

Life-expectancy calculations are based on the following considerations: the survival curve for a birth cohort predicts the temporal pattern of deaths in the cohort. Expected life from birth can be calculated by summing the life years over all period and dividing by the size of the starting population. Conditional expectation of life, given achieving a certain age, can also be calculated by summing the years of life at that age and later, and dividing by the number achieving that age (Miller BG in WHO, 2001).

Life expectancy with zero mortality for one cause can be used to indicate the relative importance of an illness. A life table is calculated assuming the complete elimination of a particular cause, and the resulting hypothetical life expectancy is compared with the actual life expectancy (Romeder and McWhinnie, 1977). The greater is the difference, the greater is the relative importance of the cause. In air pollution health impact assessment, a similar approach can be used, and actual life expectancy can be compared with the hypothetical life expectancy obtained for the baseline scenario. For that purpose, hazard rates must be predicted in the baseline scenario. Apheis it has been assumed the same proportional hazard reduction for every age group (age > 30), and we calculated hazard rates of the baseline scenario by dividing the actual hazard rates by the corresponding relative risk (RR).

Years of life lost

With the AirQ software version 2.2, long-term effects of air pollution can be assessed by calculating years of life loss (YoLL) in a population exposed to a certain level of air pollution for a specified time period. YoLL can thus be attributable to this specific population exposure, all other factors being stable over the specified time period. "Years of life lost for starting year of simulation" compares the absolute numbers of YoLL based on the initial distribution (Appendix 8).

In Apheis-3, YoLL findings are displayed in each city report. In this, the main report we chose to present the gain in life expectancy.

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Compilation of findings

Descriptive findings

A summary of Apheis-2 findings appears in Appendix 9. In this new phase, air pollution data (Table 2) was available for 2000 and beyond in all the cities, except Tel Aviv. Demographic and health data were also available for 2000 and beyond in most of the cities, except French cities, Seville and Tel Aviv.

Table 2. Years for air pollution and health data in Apheis-3

City	Air pollution data			Health Data	
	BS	PM_{10}	$PM_{2.5}$	Mortality	Hospital admissions
Athens	2001	2001	$PM_{2.5}$ converted from PM_{10}	2001	
Barcelona	2000			2000	2000
Bilbao	2002	2002	$PM_{2.5}$ converted from PM_{10}	2001	2001
Bordeaux	2002	2000	2002	1999	2000
Bucharest	2000	PM_{10} converted from TSP	$PM_{2.5}$ converted from PM_{10}	2000	
Budapest	2000	PM_{10} converted from TSP	$PM_{2.5}$ converted from PM_{10}	2000	2000
Celje	2000	2000	$PM_{2.5}$ converted from PM_{10}	2000	2000
Cracow	2000	2000	$PM_{2.5}$ converted from PM_{10}	2000	
Dublin	2000			2000	
Gothenburg		2000	2000	2000	2000
Le Havre	2000	2000	2002	1999	2000
Lille	2001	2001	2001	1999	2001
Ljubljana	2000	2000	$PM_{2.5}$ converted from PM_{10}	2000	2000
London	2001	2001	2001	2001	2001
Lyon	2001	2000	$PM_{2.5}$ converted from PM_{10}	1999	2000
Madrid		2000	$PM_{2.5}$ converted from PM_{10}	2000	2001
Marseille	2000	2000	2002	1999	2001
Paris	2000	2000	2000	1999	2001
Rome		2001	$PM_{2.5}$ converted from PM_{10}	2001	2001
Rouen	2001	2001	2002	1999	2000
Seville		2000	$PM_{2.5}$ converted from PM_{10}	2000	1999
Stockholm		2000	2000	2000	2000
Strasbourg		2002	2002	1999	2000
Tel Aviv		1998	$PM_{2.5}$ converted from PM_{10}	1998	1998
Toulouse		2000	2000	1999	2000
Valencia	2000			2000	2000

Demographic characteristics

The total population of almost 39 million inhabitants covered by Apheis-3 is comparable to the previous one covered by the Apheis-2 phase. The proportion of people over 60 years of age has increased 1% over Apheis-2 findings, ranging from 12.8% in Dublin and Lille to 21.9% in Barcelona (Table 3).

Table 3. Demographic characteristics

City	Year	Population (number)	Population over 65 years (percent)
Athens	2001	3 188 305	15.9
Barcelona	2000	1 512 971	21.9
Bilbao	2001	708 395	19.3
Bordeaux	1999	584 164	15.8
Bucharest	2000	2 009 200	13.0
Budapest	2000	1 797 088	18.7
Celje	2000	48 943	14.9
Cracow	2000	737 927	13.6
Dublin	2002	495 781	12.8
Gothenburg	2000	462 470	16.4
Le Havre	1999	254 585	15.1
Lille	1999	1 091 156	12.8
Ljubljana	2000	263 290	20.9
London	2001	6 796 900	13.8
Lyon	1999	782 828	15.7
Madrid	2000	2 938 723	21.4
Marseille	1999	856 165	18.7
Paris	1999	6 164 418	13.2
Rome	2000	2 643 581	18.0
Rouen	1999	434 924	15.2
Seville	2000	700 715	13.9
Stockholm	2000	1 173 000	15.6
Strasbourg	1999	451 133	13.3
Tel Aviv	1998	1 139 360	15.0
Toulouse	1999	690 162	13.5
Valencia	2000	742 813	19.0

Air pollution levels

In our surveillance system, black smoke measurements were provided by 16 cities (including one more city than in Apheis-2: Lyon): Athens, Barcelona, Bilbao, Bordeaux, Celje, Cracow, Dublin, Le Havre, Lille, Ljubljana, Lyon, London, Marseille, Paris, Rouen and Valencia.

PM_{10} measurements were provided by 21 cities (including four more cities than in Apheis-2: Athens, Bilbao, Le Havre and Rouen): Athens, Bilbao, Bordeaux, Celje, Cracow, Gothenburg, Le Havre, Lille, Ljubljana, London, Lyon, Madrid, Marseille, Paris, Rome, Rouen, Seville, Stockholm, Strasbourg, Tel Aviv and Toulouse. Bucharest and Budapest converted TSP into PM_{10}.

For the first time in Apheis, $PM_{2.5}$ measurements were provided by 11 cities: Bordeaux, Gothenburg, Le Havre, Lille, London, Marseille, Paris, Rouen, Stockholm, Strasbourg and Toulouse. The other cities converted $PM_{2.5}$ from PM_{10}.

Some cities provided black smoke and/or PM_{10} and/or $PM_{2.5}$ measurements.

According to the European Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and all nitrogen oxides, particulate matter and lead in ambient air (Official Journal L 163, 29/06/1999 P. 0041 – 0060), 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 (Appendix 10).

Table 4 and Figures 1, 2 and 3 give a broad picture of current observed levels of particulate pollution in the 26 cities (mean levels, standard deviation [SD], 5th and 95th percentiles of the distribution of the pollutant in each city). These levels are still not adjusted for HIA estimations. Table 7 provides the adjusted exposure levels for HIA on long-term exposure.

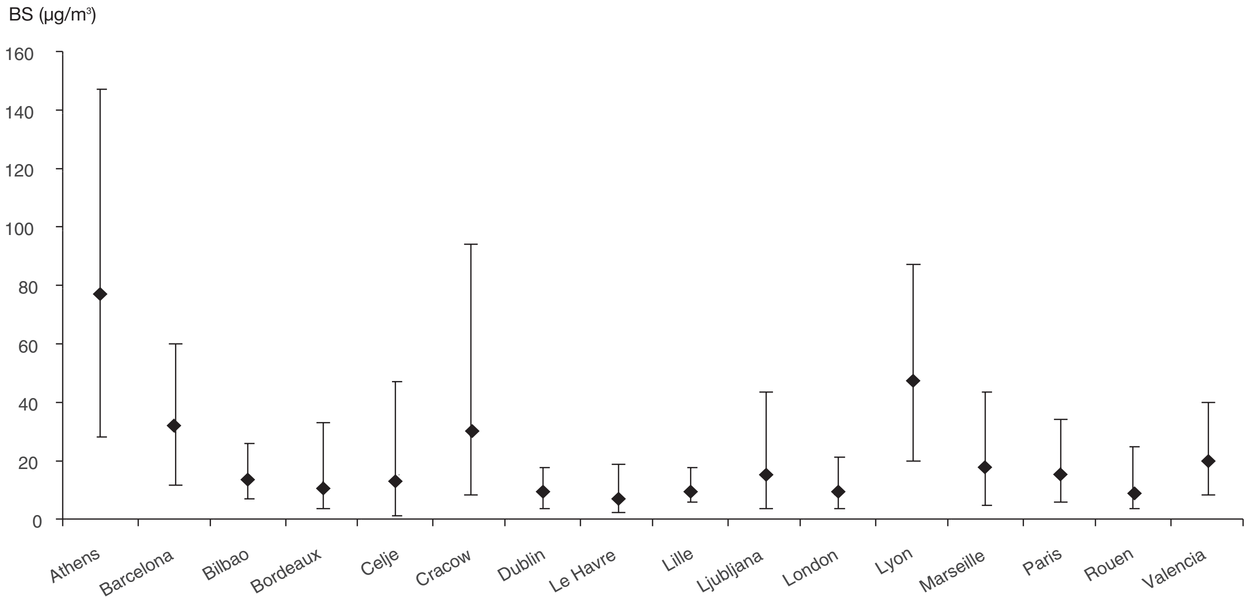
When reading these tables and figures, keep in mind the possible different sources of variability in the exposure measurements (see section "How to Interpret the Findings" and Appendix 3).

Table 4. Measured PM_{10}, $PM_{2.5}$ and BS levels (µg/m^3) in 26 Apheis cities

City	Year	PM_{10}				$PM_{2.5}$				BS			
		Mean	SD[1]	P5[2]	P95[3]	Mean	SD	P5	P95	Mean	SD	P5	P95
Athens	2001	52	19	25	87					77	37	28	147
Barcelona	2000									32	13	11	59
Bilbao	2002	36	17	16	69					13	6	9	25
Bordeaux	2000/2002[4]	20	10	9	43	13	6	6	25	11	11	3	33
Bucharest[5]	2000	61	20	40	88								
Budapest[5]	2000	29	12	13	50								
Celje	2000	36	20	11	70					14	16	1	47
Cracow	2000	32	18	12	70					31	28	8	94
Dublin	2000									9	5	3	18
Gothenburg	2000	18	10	6	36	9	5	3	18				
Le Havre	2000/2002[4]	21	8	11	39	13	8	6	29	7	7	2	19
Lille	2001	26	15	12	48	16	11	7	31	10	4	6	18
Ljubljana	2000	32	24	4	72					15	17	3	44
London	2001	22	8	13	38	13	6	7	24	9	6	3	21
Lyon	2000/2001[4]	23	12	10	45					48	21	20	87
Madrid	2000	37	17	15	69								
Marseille	2000/2002[4]	27	10	13	42	18	8	8	33	18	13	5	43
Paris	2000	22	9	12	37	14	7	7	26	16	11	6	34
Rome	2001	47	17	25	77								
Rouen	2001/2002[4]	21	9	12	38	15	8	7	29	8	7	3	24
Seville	2000	44	12	27	65								
Stockholm	2000	17	9	7	34	9	4	5	18				
Strasbourg	2002	23	12	9	46	16	10	6	34				
Tel Aviv	1998	66	119	29	105								
Toulouse	2000	24	10	11	44	16	7	7	30				
Valencia	2000									20	11	8	40

1. SD: Standard deviation
2. P5: 5th percentile of the distribution of the pollutant
3. P95 : 95th percentile of the distribution of the pollutant
4. For Bordeaux, year 2000 for PM_{10} and year 2002 for $PM_{2.5}$ and BS; for Le Havre and Marseille, year 2000 for PM_{10} ans BS and year 2002 for $PM_{2.5}$; for Lyon, year 2000 for PM_{10} and year 2001 for BS; for Rouen, year 2001 for BS and PM_{10} and year 2002 for 2002 for $PM_{2.5}$
5. PM_{10} converted from TSP

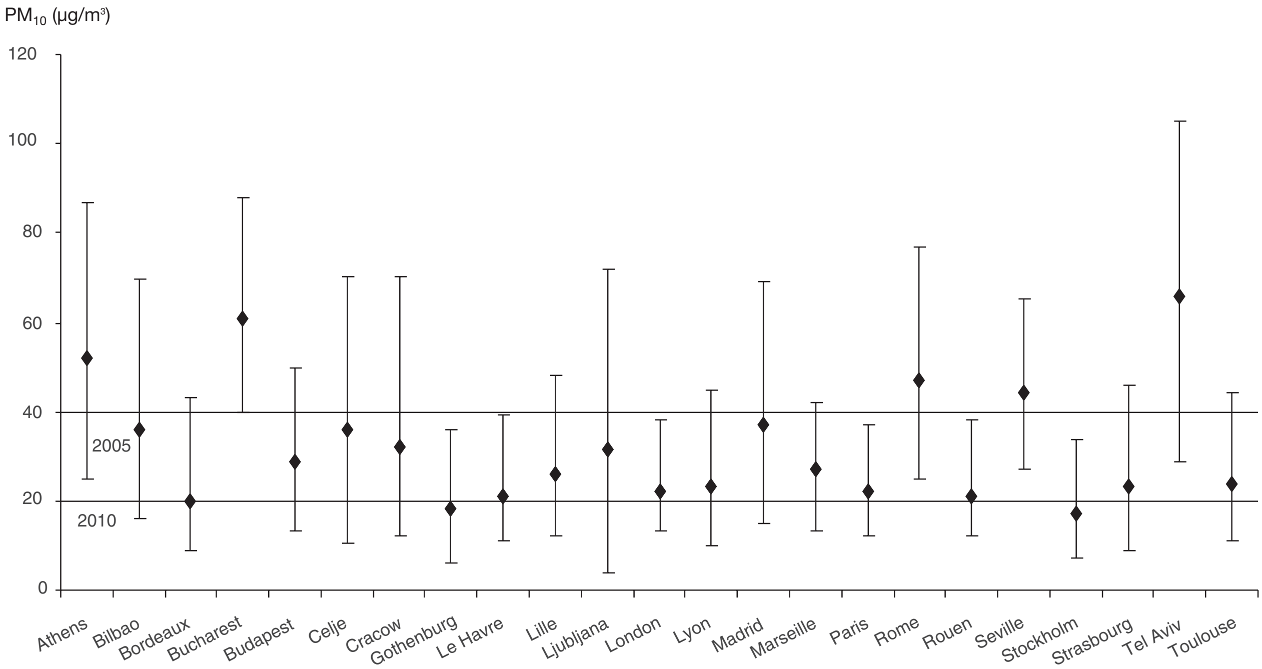
Figure 1. Annual mean levels and 5th and 95th percentiles of the distribution of black smoke (BS)



Compared to Apheis-2, Athens continues to show by far the highest mean levels of BS (77 µg/m³). One of the reasons for these high levels may still be that the two selected stations measuring BS are in the centre of Athens and are characterized as traffic stations. Note that, all other things being equal, BS levels in this city increased by 17% (11 µg/m³) between 1996 and 2001.

Lyon, Barcelona and Cracow follow with levels higher than 30 µg/m³. Most of the cities showed a reduction in their BS levels. The lowest BS levels (below 10 µg/m³) are seen in Dublin, Le Havre, London and Rouen.

Figure 2. Annual mean levels and 5th and 95th percentiles of the distribution of PM_{10}



Horizontal lines indicate the European Commission (EC) PM_{10} annual mean cut-offs of 40 µg/m^3 and 20 µg/m^3 to be reached respectively in 2005 and 2010.

Tel Aviv shows the highest mean values of PM_{10} levels (65 µg/m^3), partly influenced by wind-blown sand from the desert. All other things being equal, PM_{10} levels in this city increased by 15% (8.6 µg/m^3) between 1996 and 1998.

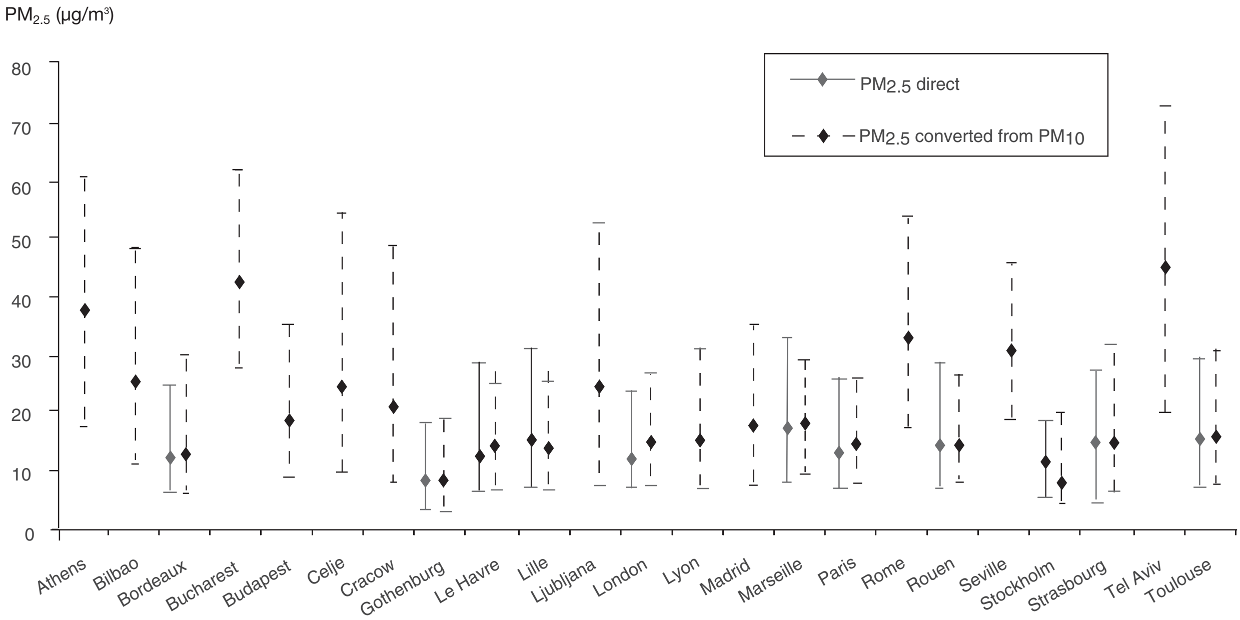
Bucharest continues to show high PM_{10} levels (61 µg/m^3) but lower than in Apheis-2 (73 µg/m^3). In this city measurements continue to be available for 4 weekdays (Monday to Thursday); this may explain the high levels observed.

Athens, which measures PM_{10} for the first time in Apheis, also shows quite high levels (52 µg/m^3) in particular because four of the six stations that measure PM_{10} have been characterised as traffic stations.

Rome and Seville show PM_{10} levels higher than the PM_{10} annual limit value (40 µg/m^3) not to be exceeded by 1 January 2005. Compared to Apheis-2, all other things being equal, Cracow is now below this limit, with most of the cities in the range between 40 and 20 µg/m^3. Gothenburg and Stockholm continue to show levels below 20 µg/m^3.

Again, it should be remembered that annual means of different years may have potential sources of variability in the measurements in the different cities (see section "How to Interpret the Findings" and Appendix 3).

Figure 3. Annual mean levels and 5th and 95th percentiles of the distribution of $PM_{2.5}$ direct and $PM_{2.5}$ converted from PM_{10} using the European conversion factor



$PM_{2.5}$ direct measurements ranged between 9 µg/m^3 in Gothenburg and Stockholm and 18 µg/m^3 in Marseille.

In order to assess the local validity of the 0.7 European conversion factor from PM_{10} used in cities where a local conversion factor was not available, we asked those cities with both PM_{10} and $PM_{2.5}$ direct measurements to provide both direct $PM_{2.5}$ measurements and converted $PM_{2.5}$ using the European conversion factor.

Figure 3 shows that the converted $PM_{2.5}$ levels using the European conversion factor from PM_{10} are quite similar to the direct levels, although sometimes slightly higher than them. Levels of $PM_{2.5}$ converted from PM_{10} follow PM_{10} patterns.

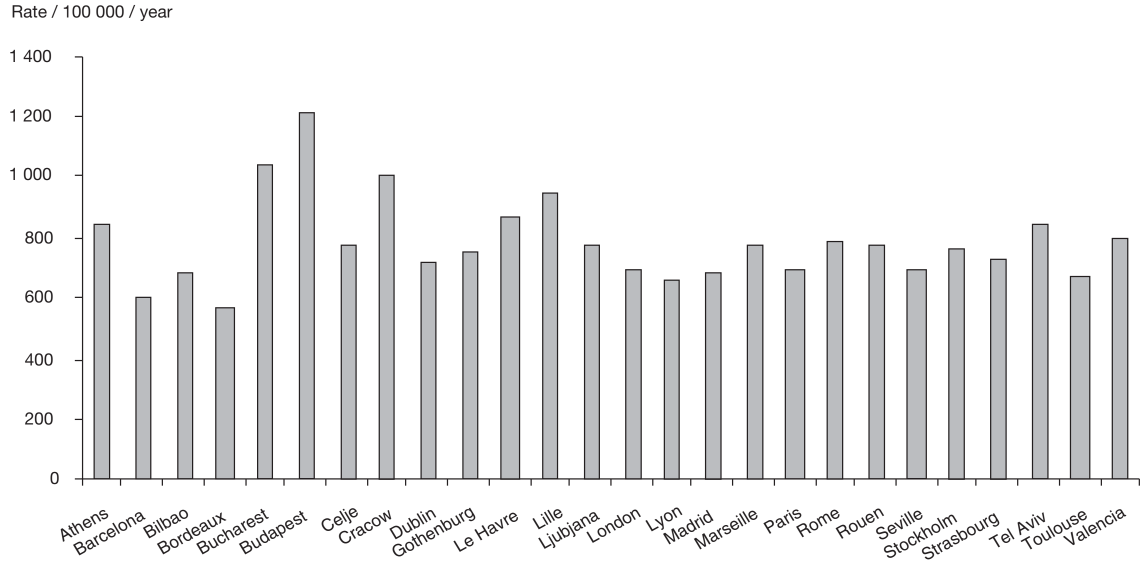
Please note that the bars are slightly shifted to the right.

Health indicators

Mortality

Figure 4 shows the standardised mortality rates for all causes of death, including violent causes, in the 26 cities. The highest rates are for Budapest, Bucharest and Cracow (over 1 000 per 100 000).

Figure 4. Age-standardised mortality rates for all causes of death in the 26 cities



Age-standardised mortality rate per 100 000 including violent deaths using the European population for 2000 year (United Nations, 2001)[4]

Hospital admissions

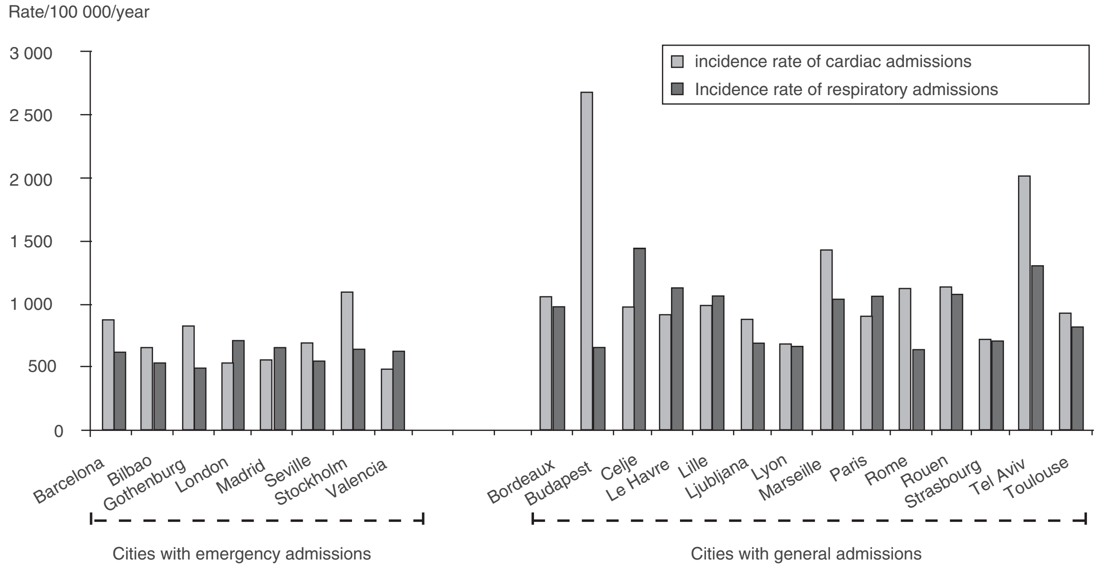
Twenty-two cities provided data on hospital admissions in Apheis-3. All the registries run a quality-control programme, and completeness in the diagnosis for the cause of admission is quite high, with a percentage of missing data of 1% or lower in 19 of the 22 registries. We didn't know this percentage in two cities (London and Tel Aviv).

The main problem for comparability remains the differences in the availability of information in the registries. The information sources used in Barcelona, Bilbao, Budapest, Gothenburg, London, Madrid, Seville, Stockholm and Valencia allowed selecting emergency admissions. Yet, for Bordeaux, Celje, Le Havre, Lille, Ljubljana, Lyon, Marseille, Paris, Rome, Rouen, Strasbourg, Tel Aviv and Toulouse, it was not possible to distinguish between emergency and total admissions.

Athens, Bucharest, Cracow and Dublin have not estimated the impact on hospital admissions.

[4] United Nations. Population Division Department of Economic and Social Affairs. World Population Prospects: The 2000 Revision.

Figure 5. Incidence rates for hospital admissions in 22 cities (9 with emergency admissions, 13 with general admissions)



In the nine cities where emergency-admissions data was available, the incidence rate for cardiac admissions for all ages was the highest in Budapest (2 686 per 100 000) followed by Stockholm (1 093 per 100 000), and the lowest was for Valencia (485 per 100 000). The incidence rate for respiratory admissions was slightly higher for London (719 per 100 000).

The high rate for cardiac emergency hospital admissions in Budapest was checked and compared to the previous 3 years. It may be explained by the high rate of mortality and also by people's habit of calling for an ambulance instead of going to general practitioners in Budapest

In the 13 cities where the distinction between emergency and non-emergency admissions could not be made, the incidence rate for cardiac admissions for all ages was the highest for Tel Aviv (2 018 per 100 000); five cities showed rates above 1 000 per 100 000: Bordeaux, Lille, Marseille, Rome, and Rouen. Incidence rates for respiratory admissions were higher for Celje, Le Havre, Marseille, Paris, Rouen and Tel Aviv (above 1 000 per 100 000).

Note that in both groups, all other things being equal, the incidence rates for respiratory admissions all ages are 3 to 6 times lower than in Apheis-2, where only respiratory admissions over 65 years of age were included. Incidence rates for cardiac admissions are more variable and remain quite similar to Apheis-2.

The Apheis-3 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 in the "Interpretation of findings" section, we only show the HIA on hospital admissions city by city.

Benefits of reducing PM_{10}, black smoke and $PM_{2.5}$ levels for different scenarios

The following two tables summarise the HIAs conducted in Apheis-3 specifying: the air pollution indicators, the health outcomes and their ICD codes, the HIA tool used, the relative risks (or E-R functions) selected, the scenarios and the references.

Table 5a. Summary of data components used for health impact assessment of short-term exposure in Apheis-3

Summary SHORT-TERM HIA							
	Health indicator	ICD		Tool	RR (95% IC) For 10 µg/m^3 increase	Scenarios	References
Attributable cases		ICD9	ICD10			Daily mean	
ST HIA for all Apheis cities							
Black smoke	All ages, all causes mortality (excluding external causes)	< 800	A00-R99		1.006 (1.004 - 1.009)		WHO, 2004
	All ages, cardiovascular mortality	390-459	I00-I99		1.004 (1.002 - 1.007)		WHO, 2004
	All ages, respiratory mortality	460-519	J00-J99	PSAS-9	1.006 (0.998 - 1.015)	Reduction to 50 µg/m^3	WHO, 2004
	All ages, cardiac hospital admissions	390-429	I00-I52	Excel	1.011 (1.004 - 1.019)	Reduction to 20 µg/m^3	APHEIS 3, 2004
	All ages, respiratory hospital admissions	460-519	J00-J99	spreadsheet	1.0030 (0.9985 -1.0075)	Reduction by 5 µg/m^3	APHEIS 3, 2004
PM_{10} very short-term	All ages, all causes mortality (excluding external causes)	< 800	A00-R99		1.006 (1.004 - 1.008)		WHO, 2004
	All ages, cardiovascular mortality	390-459	I00-I99		1.009 (1.005 - 1.013)		WHO, 2004
	All ages, respiratory mortality	460-519	J00-J99	PSAS-9	1.013 (1.005 - 1.021)	Reduction to 50 µg/m^3	WHO, 2004
	All ages, cardiac hospital admissions	390-429	I00-I52	Excel	1.006 (1.003 - 1.009)	Reduction to 20 µg/m^3	APHEIS 3, 2004
	All ages, respiratory hospital admissions	460-519	J00-J99	spreadsheet	1.0114 (1.0062 - 1.0167)	Reduction by 5 µg/m^3	APHEIS 3, 2004
PM_{10} cumulative short-term (40 days)	All ages, all causes mortality (excluding external causes)	< 800	A00-R99	PSAS-9	1.01227 (1.0081 - 1.0164)	Reduction to 50 µg/m^3	A. Zanobetti *et al*, 2002
	All ages, cardiovascular mortality	390-459	I00-I99	Excel	1.01969 (1.0139 - 1.0255)	Reduction to 20 µg/m^3	A. Zanobetti *et al*, 2003
	All ages, respiratory mortality	460-519	J00-J99	spreadsheet	1.04206 (1.0109 - 1.0742)	Reduction by 5 µg/m^3	A. Zanobetti *et al*, 2003
Complementary ST HIA for some Apheis cities							
PM_{10} with shrunken estimates	All ages, all causes mortality (excluding external causes)	< 800	A00-R99	PSAS-9 Excel spreadsheet	RRs calculated from betas & se of Apheis shrunken estimates for each city	Reduction to 50 µg/m^3 Reduction to 20 µg/m^3 Reduction by 5 µg/m^3	Apheis 3, 2004

Table 5b. Summary of data components used for health impact assessment of long-term exposure in Apheis-3

Summary LONG-TERM HIA							
	Health indicator	**ICD 9**	**ICD10**	**Tool**	**RR (95% IC) For 10 µg/m³ increase**	**Scenarios**	**References**
LT HIA for all-cities report							
Attributable cases						**Annual mean**	
PM_{10}	All causes mortality (excluding external causes)	< 800	A00-R99	PSAS-9 Excel spreadsheet	Trilateral & Apheis 2 1.043 (1.026 -1.061)	Reduction to 40 µg/m³ Reduction to 20 µg/m³ Reduction by 5 µg/m³	Kunzli *et al.* 2000
$PM_{2.5}$					Average Pope, 2002		
	All causes mortality	0-999	A00-Y98	PSAS-9	1.06 (1.02 - 1.11)	Reduction to 20 µg/m³	C.A. III Pope, 2002
	Cardiopulmonary mortality	401-440 and 460-519	I10-I70 and J00-J99	Excel	1.09 (1.03 - 1.16)	Reduction to 15 µg/m³	C.A. III Pope, 2002
	Lung cancer	162	C33-C34	spreadsheet	1.14 (1.04 - 1.23)	Reduction by 3.5 µg/m³	C.A. III Pope, 2002
Gain in life expectancy						**Annual mean**	
$PM_{2.5}$	Age > 30 only				Average Pope, 2002		
	All causes mortality	0-999	A00-Y98		1.06 (1.02 - 1.11)	Reduction to 20 µg/m³	C.A. III Pope, 2002
	Cardiopulmonary mortality	401-440 and 460-519	I10-I70 and J00-J99		1.09 (1.03 - 1.16)	Reduction to 15 µg/m³	C.A. III Pope, 2002
	Lung cancer	162	C33-C34	AirQ	1.14 (1.04 - 1.23)	Reduction by 3.5 µg/m³	C.A. III Pope, 2002

Exposure and outcome data for HIAs of short-term exposure

For HIAs of short-term exposure, we used PM_{10} and BS levels measured directly at monitoring stations (see Table 4).

We also used daily mortality means and rates shown in Table 6 and the following map.

Table 6. Daily mean, standard deviation, daily death rate per 100 000 for each health indicator in the 26 cities for short-term health impact assessment calculations in Apheis-3

City	Year	All causes mortality			Cardiovascular mortality			Respiratory mortality		
		Daily mean	Standard deviation	Daily rate per 100 000	Daily mean	Standard deviation	Daily rate per 100 000	Daily mean	Standard deviation	Daily rate per 100 000
Athens	2001	76.0	11.0	2.4	38.3	7.6	1.2	6.0	2.8	0.2
Barcelona	2000	38.5	8.3	2.5	13.0	6.7	0.9	5.0	2.3	0.3
Bilbao	2001	17.0	4.5	2.4	5.6	2.4	0.8	1.6	1.2	0.2
Bordeaux	1999	12.5	3.7	2.1	4.1	2.1	0.7	1.0	1.0	0.2
Bucharest	2000	57.0	n.a.	2.8	33.4	n.a.	1.7	3.0	n.a.	0.1
Budapest	2000	63.9	10.1	3.7	33.8	8.2	1.9	1.8	1.6	0.1
Celje	2000	1.5	1.2	3.1	0.7	0.8	1.4	0.2	0.4	0.4
Cracow	2000	17.0	4.9	2.3	8.7	3.2	1.2	0.7	0.9	0.1
Dublin	2000	12.3	4.1	2.5	5.1	2.4	1.0	1.8	1.7	0.4
Gothenburg	2000	12.0	3.7	2.6	5.9	2.5	1.3	0.9	1.0	0.2
Le Havre	1999	5.7	2.5	2.3	1.7	1.3	0.7	0.5	0.7	0.2
Lille	1999	23.0	5.4	2.1	7.0	2.9	0.4	2.0	1.7	0.2
Ljubljana	2000	6.9	2.8	2.6	3.0	1.9	1.1	0.5	0.7	0.2
London	2001	144.1	18.4	2.1	57.9	9.6	0.8	22.1	6.4	0.3
Lyon	1999	15.4	4.6	2.0	5.2	2.4	0.7	1.2	1.2	0.2
Madrid	2000	68.7	11.3	2.3	22.3	5.3	0.8	8.8	4.1	0.3
Marseille	1999	21.6	6.0	2.5	7.2	3.0	0.8	2.0	1.6	0.2
Paris	1999	114.0	16.7	1.9	32.9	6.9	0.5	9.0	4.1	0.2
Rome	2001	56.5	9.5	2.1	23.2	5.7	0.9	3.1	1.9	0.1
Rouen	1999	9.1	3.2	2.1	2.9	1.9	0.7	0.7	0.9	0.2
Seville	2000	15.4	4.6	2.2	6.7	2.8	1.0	1.5	1.5	0.2
Stockholm	2000	28.3	6.4	2.4	13.5	4.1	1.2	2.3	1.7	0.2
Strasbourg	1999	8.6	3.0	2.0	3.0	1.6	0.7	0.8	0.8	0.2
Tel Aviv	1998	24.4	n.a.	2.2	9.9	n.a.	0.9	1.8	n.a.	0.2
Toulouse	1999	11.7	3.9	1.7	3.8	2.0	0.6	0.9	1.0	0.1
Valencia	2000	15.8	4.7	2.1	5.7	2.5	0.8	1.8	1.6	0.2

n.a. : not available

Map of daily death rates per 100 000 for each health indicator in the 26 cities for short-term health impact assessment calculations in Apheis-3

Exposure and outcome data for HIAs of long-term exposure

As described in the "Methods" section above, for long-term HIAs, because the exposure-response functions used are taken from publications that used gravimetric methods (Künzli *et al.* 2000 and Pope *et al.* 2002), for consistency we corrected the automatic PM_{10} measurements used by most of the cities by a specific correction factor in order to compensate for losses of volatile particulate matter. A local correction factor chosen with the advice of the local air-pollution network was used when available; otherwise cities used the 1.3 European default correction factor recommended by the EC working group on particulate matter.

It should be remembered that, for most of the cities, $PM_{2.5}$ measurements were not available and that the cities had to calculate $PM_{2.5}$ data from PM_{10} measurements. For this purpose a conversion factor was used: a local conversion factor (ranging between 0.5 and 0.8) with the advice of the local air- monitoring network or 0.7 as the default European conversion factor, because no local factor was available. The default factor of 0.7 was recommended by the Apheis Exposure Assessment Working Group (see "Methods" section and Appendix 3).

The following table 7 provides the corrected/converted PM levels used for long-term HIAs.

Table 7. Corrected PM_{10} and converted $PM_{2.5}$ levels (µg/m³) in 26 cities for long-term health impact assessment calculations in Apheis-3

City	Year	Corrected PM_{10}*				Converted $PM_{2.5}$**			
		Mean	SD[1]	P5[2]	P95[3]	Mean	SD	P5	P95
Athens	2001	68	25	32	113	31	14	14	56
Bilbao	2002	43	20	19	83	30	14	13	58
Bordeaux	2000/2002[4]	24	14	10	56	16	9	7	37
Bucharest[5]	2000					43	14	28	62
Budapest[5]	2000	38	16	17	65	27	11	12	45
Celje	2000	47	26	14	91	33	18	10	64
Cracow	2000	40	22	15	87	32	18	12	70
Gothenburg	2000	18	10	6	36	12	6	4	23
Le Havre	2000	23	10	12	42	16	7	8	29
Lille	2001	26	15	12	48	17	10	8	32
Ljubljana	2000	41	31	5	94	29	22	4	65
London	2001	29	11	16	50	20	8	11	35
Lyon	2000	25	14	11	49	17	10	7	34
Madrid	2000	37	17	15	69	19	9	8	35
Marseille	2000/2002[4]	28	10	14	46	18	7	9	30
Paris	2000	26	13	13	47	18	9	9	33
Rome	2001	61	22	32	100	43	15	23	70
Rouen	2002	24	11	12	45	17	8	9	32
Seville	2000	50	13	31	73	35	9	22	51
Stockholm	2000	17	9	7	34	11	6	5	22
Strasbourg	2002	25	14	11	50	18	10	8	35
Tel Aviv	1998	85	155	38	136	42	78	19	68
Toulouse	2000	26	12	12	49	17	8	8	32

*PM_{10} measurements corrected by European or local correction factor

** $PM_{2.5}$ measurements converted from PM_{10} by European or local conversion factor

1. SD: Standard deviation
2. P5: 5th percentile of the distribution of the pollutant
3. P95 : 95th percentile of the distribution of the pollutant
4. For Bordeaux, year 2000 for PM_{10} and year 2002 for $PM_{2.5}$; for Marseille, 2000 for PM_{10} and 2002 for $PM_{2.5}$
5. PM_{10} converted from TSP

For HIAs of lon-terme exposure, we used the annual deaths and rates shown in Table 8 and the correponding map.

Table 8. Annual deaths and death rates per 100 000 for each health indicator in the 26 cities for long-term health impact assessment calculations in Apheis-3

City	Year	Total mortality		Cardiopulmonary mortality		Lung cancer mortality	
		Annual deaths	Annual rate per 100 000	Annual deaths	Annual rate per 100 000	Annual deaths	Annual rate per 100 000
Athens	2001	29 072	912	15 931	500	1 583	50
Bilbao	2001	6 440	909	2 505	354	369	52
Bordeaux	1999	4 928	844	1 716	294	256	44
Bucharest	2000	21 831	1 086	12 216	608	1 005	50
Budapest	2000	24 951	1 434	13 049	750	1 584	91
Celje	2000	617	1 261	310	633	32	65
Cracow	2000	6 572	891	3 354	455	392	53
Gothenburg	2000	4 550	974	2 378	509	157	34
Le Havre	1999	2 258	889	762	300	112	44
Lille	1999	8 977	822	3 182	292	500	46
Ljubljana	2000	2 692	1 022	1 203	457	143	54
London	2001	53 947	794	27 233	401	3 137	46
Lyon	1999	6 055	774	2 199	281	337	43
Madrid	2000	26 061	887	10 787	367	1 426	49
Marseille	1999	8 486	991	3 109	363	441	52
Paris	1999	44 257	718	14 273	232	2 379	39
Rome	2001	21 737	822	9 230	349	1 708	65
Rouen	1999	3 621	833	1 235	284	206	47
Seville	2000	5 646	806	2 898	414	308	44
Stockholm	2000	11 307	964	5 763	491	402	34
Strasbourg	1999	3 319	736	1 254	278	198	44
Tel Aviv	1998	10 032	912	4 125	375	308	28
Toulouse	1999	4 552	657	1 574	226	232	33

Map of annual death rates per 100 000 for each health indicator in the 26 cities for long-term health impact assessment calculations in Apheis-3

Summary findings of Apheis-3 HIAs in terms of potential reductions in the number of "premature" deaths

The following table summarises the HIA findings in terms of number of "premature" deaths and rates per 100 000 that, all other things being equal, could be potentially reduced for different scenarios of particulate pollution reductions. All these findings are detailed in the following pages.

Table 9. Summary findings of Apheis-3 HIAs in terms of potential reductions in the number of "premature" deaths and rates per 100 000

Summary findings in terms of attributable cases								
Air pollution indicator	Health indicator	HIA scenario	Potential reduction in the number of deaths					
			Very short-term		Cumulative short-term		Long-term	
			Number of deaths	Number of deaths/ 100 000/ year	Number of deaths	Number of deaths/ 100 000/ year	Number of deaths	Number of deaths/ 100 000/ year
BS	All causes mortality*	Reduction to 50 µg/m^3	572	2				
		Reduction to 20 µg/m^3	1 296	5				
		Reduction by 5 µg/m^3	557	2				
	Cardiovascular mortality	Reduction to 50 µg/m^3	188	1				
		Reduction to 20 µg/m^3	405	2				
		Reduction by 5 µg/m^3	142	1				
	Respiratory mortality	Reduction to 50 µg/m^3	47	0.2				
		Reduction to 20 µg/m^3	109	0.4				
		Reduction by 5 µg/m^3	61	0.2				
PM_{10}	All causes mortality*	Reduction to 50 ** µg/m^3 /40** µg/m^3	559	2	1 150	3	8 550	24
		Reduction to 20 µg/m^3	2 580	7	5 240	15	21 385	60
		Reduction by 5 µg/m^3	868	2	1 739	5	6 143	17
	Cardiovascular mortality	Reduction to 50 µg/m^3	412	1	877	2		
		Reduction to 20 µg/m^3	1 741	5	3 458	10		
		Reduction by 5 µg/m^3	527	1	897	2		
	Respiratory mortality	Reduction to 50 µg/m^3	87	0.2	288	1		
		Reduction to 20 µg/m^3	429	1	1 348	4		
		Reduction by 5 µg/m^3	162	0.5	489	1		
$PM_{2.5}$	All causes mortality	Reduction to 20 µg/m^3					11 375	32
		Reduction to 15 µg/m^3					16 926	47
		Reduction by 3.5 µg/m^3					6 355	18
	Cardiopulmonary mortality	Reduction to 20 µg/m^3					8 053	22
		Reduction to 15 µg/m^3					11 612	32
		Reduction by 3.5 µg/m^3					4 199	12
	Lung cancer mortality	Reduction to 20 µg/m^3					1 296	4
		Reduction to 15 µg/m^3					1 901	5
		Reduction by 3.5 µg/m^3					743	2

* Excluding external causes

** Reduction to 50 µg/m^3 for very short-term and cumulative short-term. Reduction to 40 µg/m^3 for long-term

NOTE:
IT IS OF CRUCIAL IMPORTANCE TO NOTE THAT the HIA findings shown in the table above are for different scenarios and for different particulate indicators. THEY MUST NOT BE ADDED TOGETHER because the pollutants are highly correlated and some of the impacts provided by one air-pollution indicator are already included in another indicator and some of the impacts provided in one scenario are already included in another scenario.

Black smoke findings

We considered only the short-term exposure or acute-effects scenarios, since no reliable exposure-response functions were available for the long-term effects of black smoke at the time we did the analysis.

As we did for Apheis-2, we considered the application of PM_{10} scenarios to BS beneficial, even if the objective is not to compare PM_{10} and BS findings.

In Apheis-3, in addition to total mortality excluding external causes, we also conducted HIAs for cardiovascular and respiratory mortality.

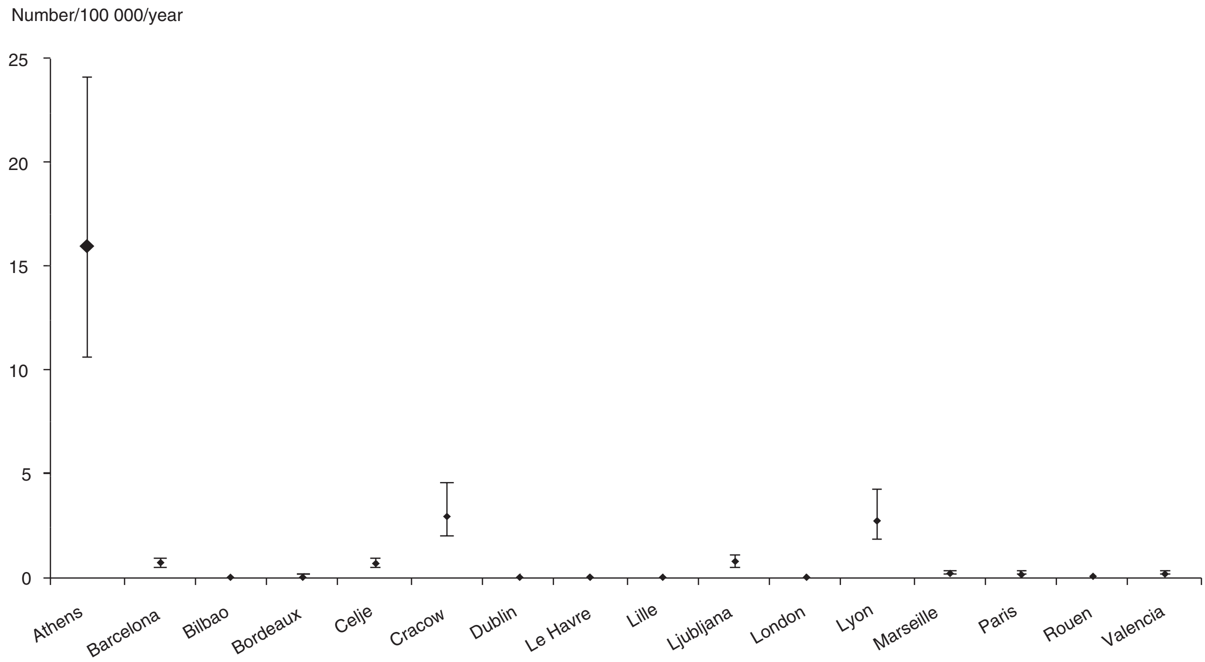
Acute effects scenarios

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: Short-term impact on total mortality (ICD9 < 800)

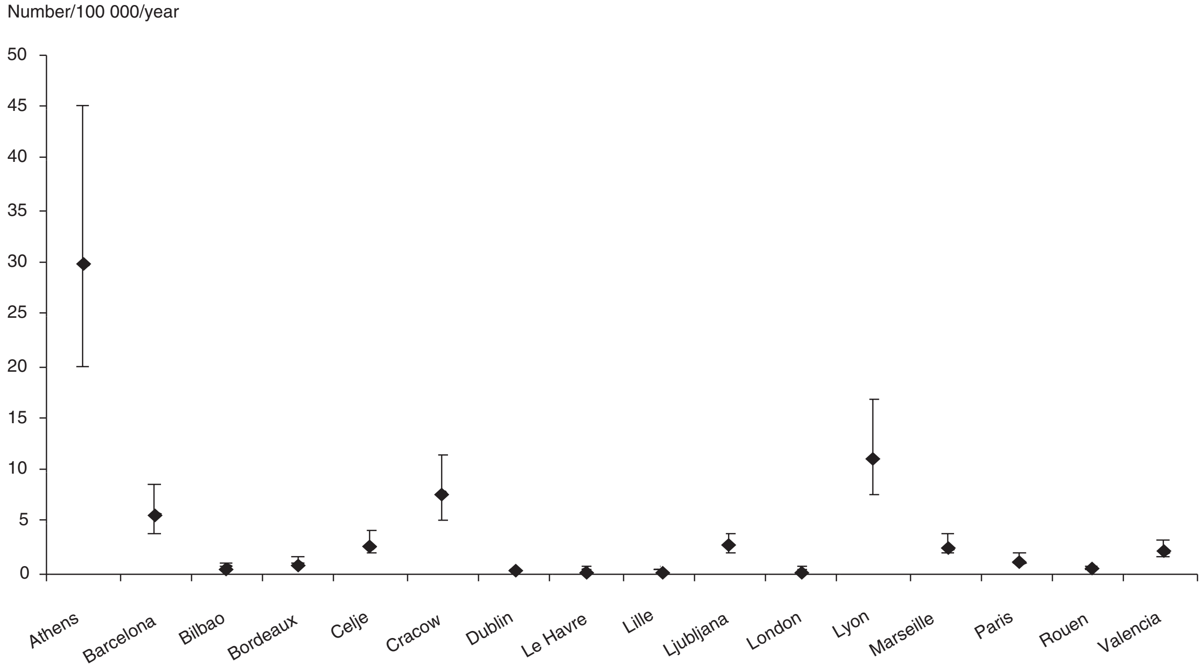
Figure 6. Black smoke: Short-term (ST) impact on all-causes mortality (ICD 9 < 800). Reductions to 50 µg/m^3. Number of "premature" deaths per 100 000 inhabitants



Among the 16 cities that measured black smoke, all other things being equal, Athens would show by far the highest decrease in the number of "premature" deaths per 100 000 inhabitants (16 deaths) if BS levels for all days exceeding a 24-hour value of 50 µg/m^3 were reduced to 50 µg/m^3. Remember that Athens shows the highest BS levels, probably because of the direct influence of traffic. Cracow and Lyon follow with almost three "premature" deaths per 100 000. The health benefits of this scenario for the other cities are extremely low. The 16 cities measuring BS would average two "premature" deaths per 100 000 inhabitants.

In these 16 cities totalling 24 663 565 inhabitants, our HIA found that, all other things being equal, 572 "premature" deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced to 50 µg/m^3.

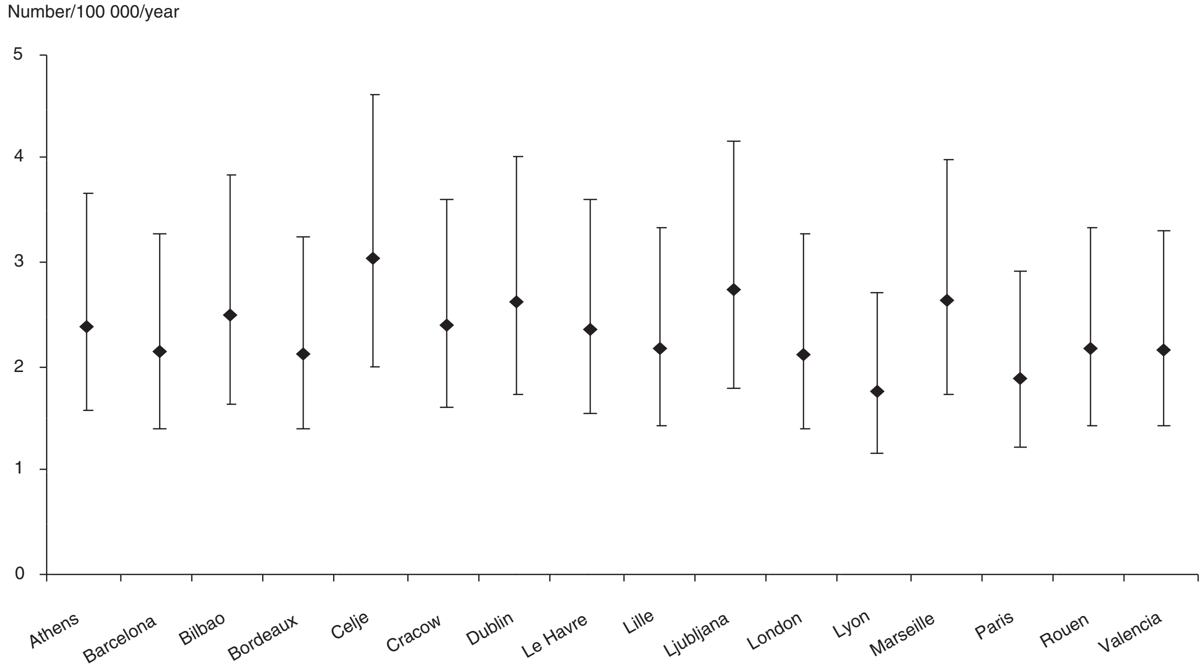
Figure 7. Black smoke: Short-term (ST) impact on all-causes mortality (ICD9 < 800).
Reductions to 20 µg/m³. Number of «premature» deaths per 100 000 inhabitants



If BS levels for all days when they exceeded a 24-hour value of 20 µg/m³ were reduced to 20 µg/m³ in the 16 cities measuring BS, all other things being equal, Athens would continue to show the highest decrease in the number of «premature» deaths per 100 000 inhabitants (30 "premature" deaths). Lyon would follow with 11 deaths, Cracow with 7 and Barcelona with 5 deaths per 100 000. Together, the 16 cities measuring BS would average five «premature» deaths per 100 000 inhabitants.

In these 16 cities, our HIA found that, all other things being equal, 1 296 "premature" deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced to 20 µg/m³.

Figure 8. Black smoke: Short-term (ST) impact on all-causes mortality (ICD9 < 800). Reductions by 5 µg/m³. Number of «premature» deaths per 100 000 inhabitants



If daily BS levels were reduced by 5 µg/m³, all other things being equal, the consequent reduction in the number of "premature" deaths per 100 000 inhabitants would range between two and three "premature" deaths per 100 000 inhabitants in the 16 cities measuring BS.

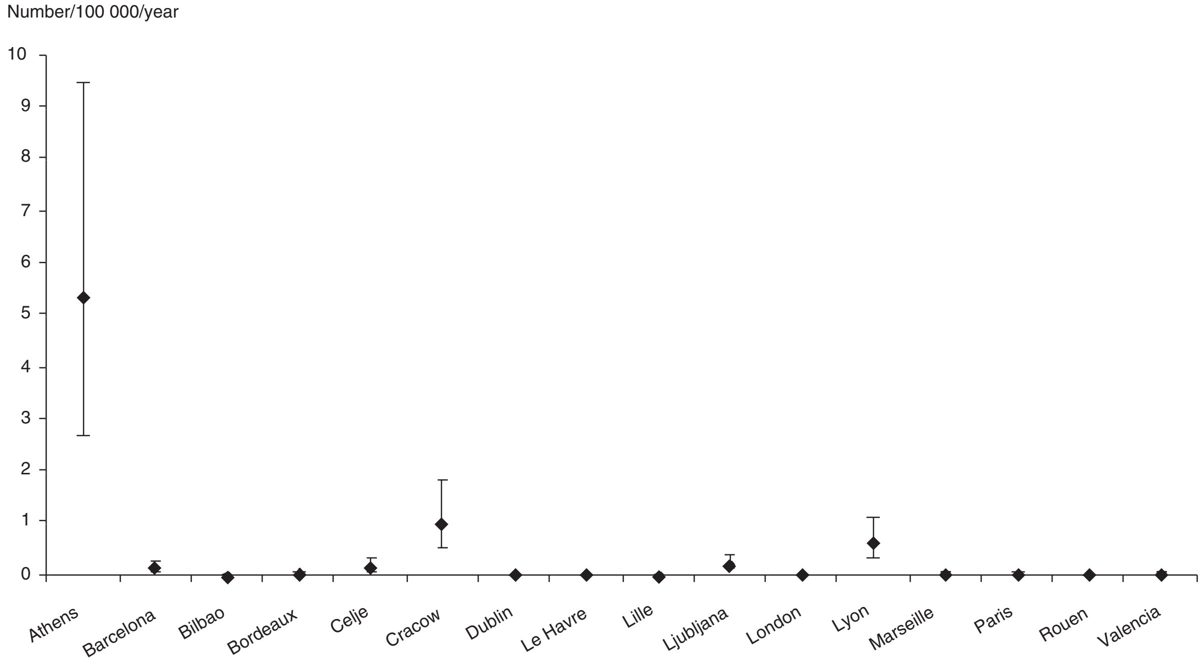
In these 16 cities, our HIA found that, all other things being equal, 557 "premature" deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced by 5 µg/m³.

All other things being equal, BS findings are quite similar to those obtained in Apheis-2.

Black smoke: Short-term impact on cardiovascular mortality (ICD9 390-459)

In Apheis-3, we were able to perform an HIA on BS and cause-specific mortality using newly developed E-R functions.

Figure 9. Black smoke: Short-term (ST) impact on cardiovascular mortality (ICD9 390-459). Reductions to 50 µg/m^3. Number of «premature» deaths per 100 000 inhabitants



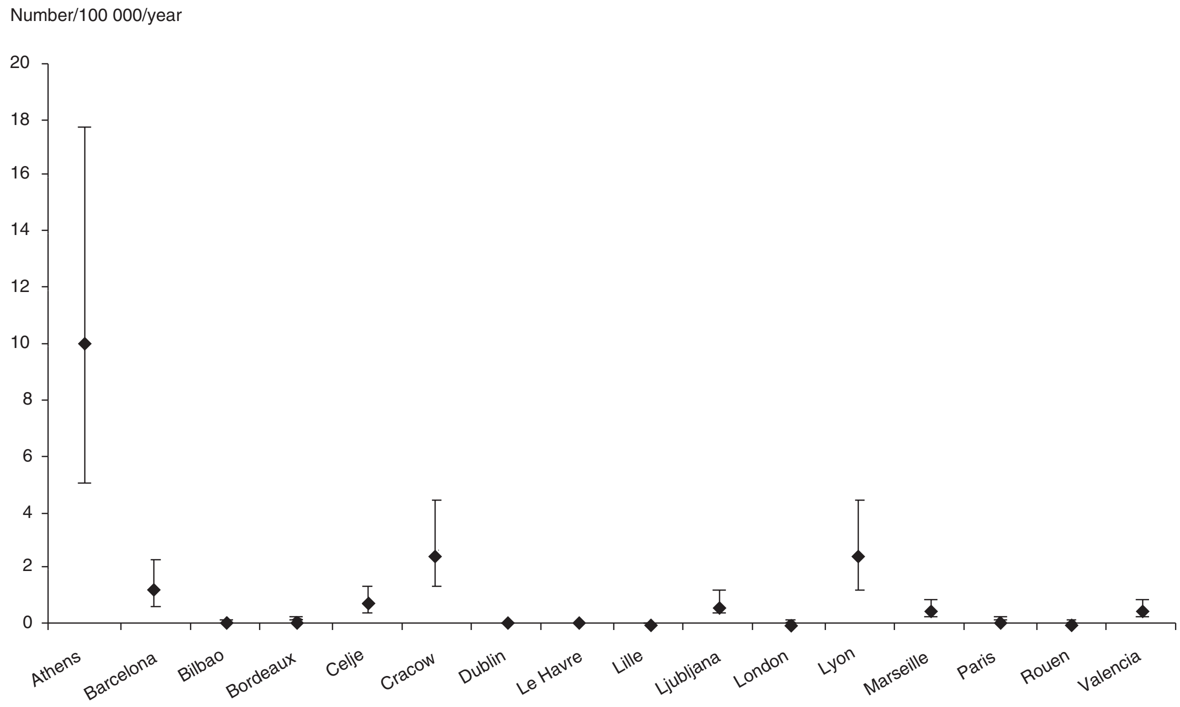
Athens continues to show the highest decrease in the number of “premature” cardiovascular deaths per 100 000 inhabitants (5 deaths) if BS levels for all days exceeding a 24-hour value of 50 µg/m^3 were reduced to 50 µg/m^3.

Cracow and Lyon follow respectively with 1 and 0.6 “premature” cardiovascular deaths per 100 000.

The health benefits of this scenario in the other cities are extremely low.

In the 16 cities that measured BS, our HIA found that, all other things being equal, 188 “premature” cardiovascular deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced to 50 µg/m^3.

Figure 10. Black smoke: Short-term (ST) health impact on cardiovascular mortality (ICD9 390-459). Reductions to 20 µg/m^3. Number of «premature» deaths per 100 000 inhabitants



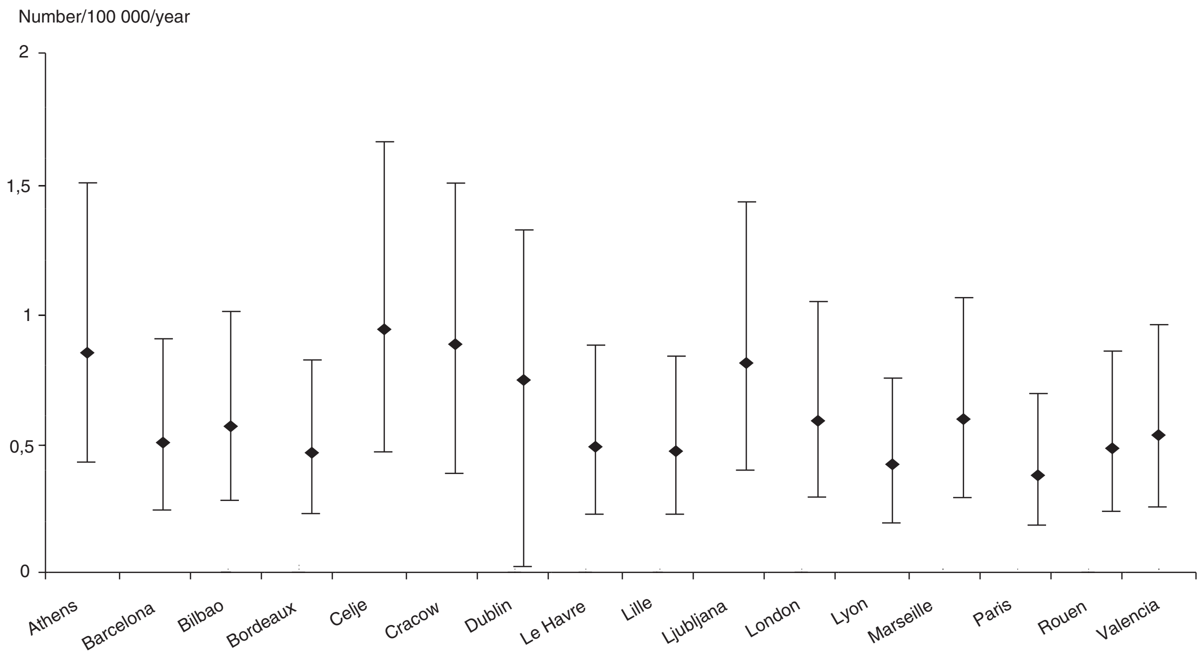
If BS levels for all days when they exceeded a 24-hour value of 20 µg/m^3 were reduced to 20 µg/m^3 in the 16 cities that measured BS, all other things being equal, Athens would show a decrease of 10 cardiovascular deaths per 100 000 inhabitants.

Lyon and Cracow would follow with 2.5 "premature" cardiovascular deaths per 100 000.

The health benefits of this scenario in the other cities are extremely low.

In the 16 cities, our HIA found that, all other things being equal, 405 "premature" cardiovascular deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced to 20 µg/m^3.

Figure 11. Black smoke: Short-term (ST) health impact on cardiovascular mortality (ICD9 390-459). Reductions by 5 µg/m³. Number of «premature» deaths per 100 000 inhabitants

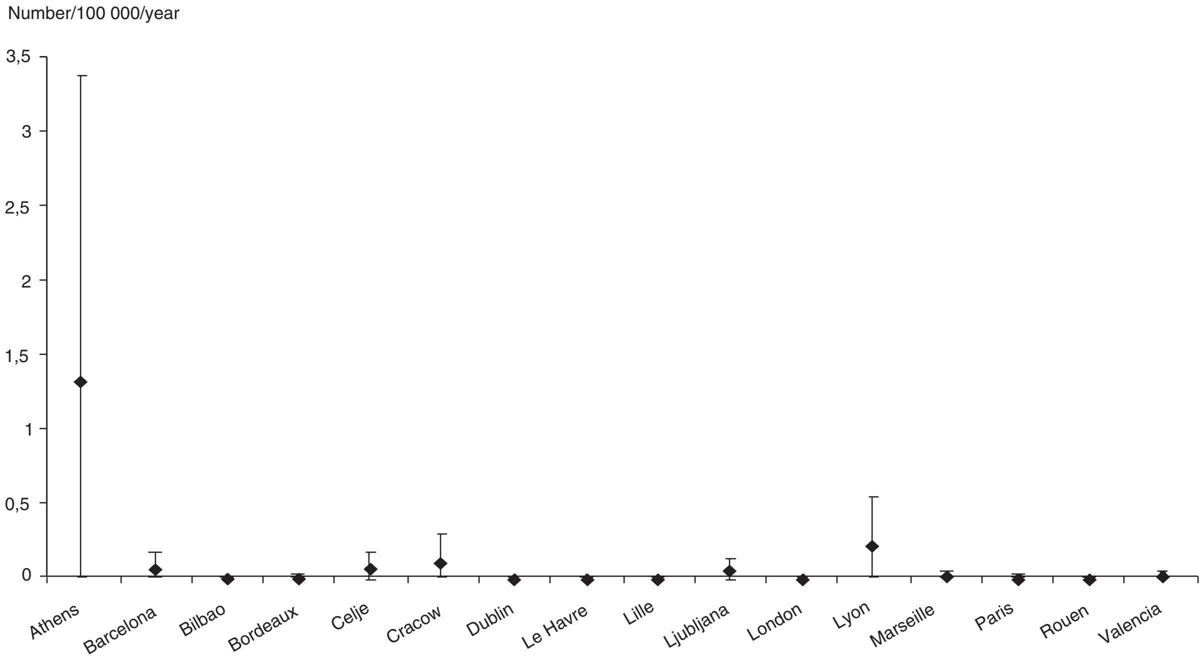


If daily BS levels were reduced by 5 µg/m³ in the 16 cities that measured BS, all other things being equal, the consequent reduction in the number of "premature" cardiovascular deaths per 100 000 inhabitants would range between 0.9 in Celje and Cracow and 0.4 in Lyon and Paris.

In the 16 cities, our HIA found that, all other things being equal, 142 "premature" cardiovascular deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced by 5 µg/m³.

Black smoke: Short-term impact on respiratory mortality (ICD9 460-519)

Figure 12. Black smoke: Short-term (ST) health impact on respiratory mortality (ICD9 460-519). Reductions to 50 µg/m³. Number of «premature» deaths per 100 000 inhabitants

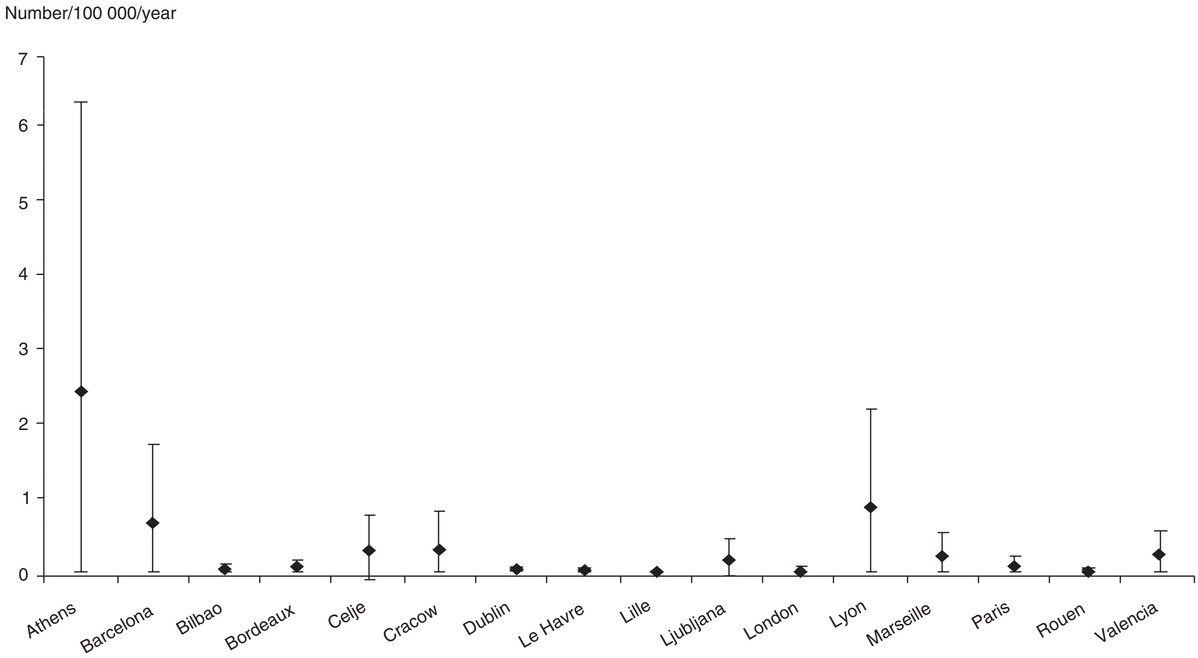


All other things being equal, Athens would show more than one "premature" respiratory deaths per 100 000 inhabitants if BS levels for all days exceeding a 24-hour value of 50 µg/m³ were reduced to 50 µg/m³.

The health benefits of this scenario for the other cities are extremely low.

In the 16 cities that measured BS our HIA found that, all other things being equal, 47 "premature" respiratory deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced to 50 µg/m³.

Figure 13. Black smoke: Short-term (ST) health impact on respiratory mortality (ICD9 460-519). Reductions to 20 µg/m³. Number of «premature» deaths per 100 000 inhabitants

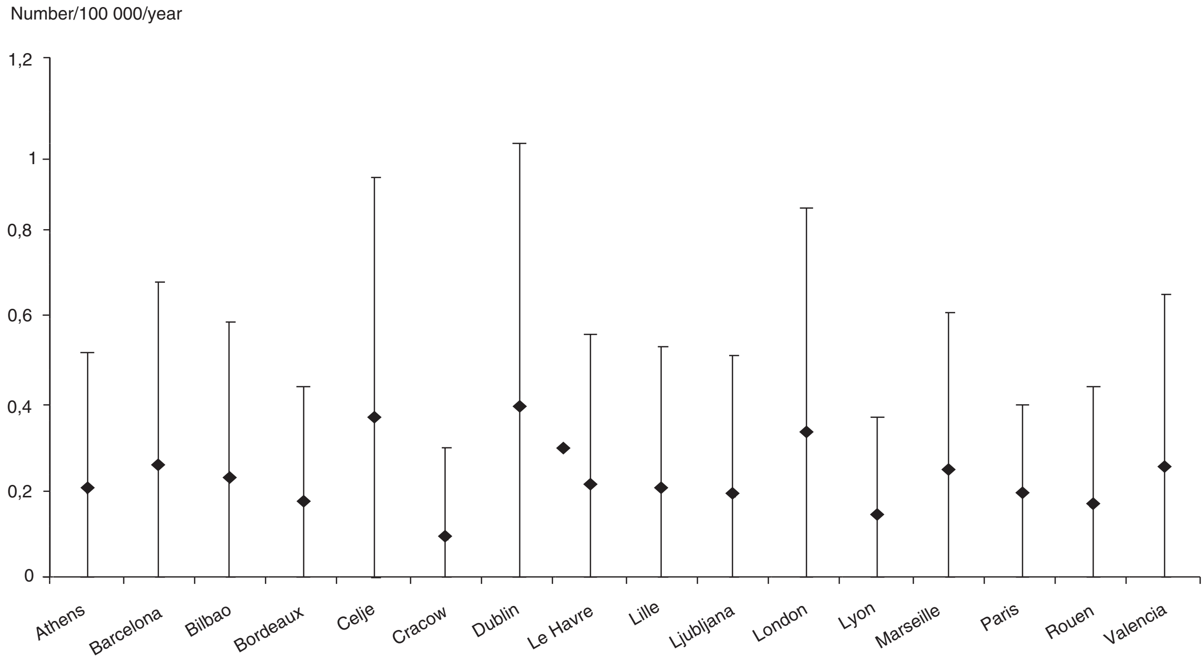


If BS levels for all days when they exceeded a 24-hour value of 20 µg/m³ were reduced to 20 µg/m³, all other things being equal, Athens would show a decrease of more than two respiratory deaths per 100 000 inhabitants.

The rest of the cities would show decreases below one respiratory death.

In the 16 cities measuring BS, our HIA found that, all other things being equal, 109 "premature" respiratory deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced to 20 µg/m³.

Figure 14. Black smoke: Short-term (ST) health impact on respiratory mortality (ICD9 460-519). Reductions by 5 µg/m³. Number of «premature» deaths per 100 000 inhabitants



If daily BS levels were reduced by 5 µg/m³ in the 16 cities measuring BS, all other things being equal, the consequent reduction in the number of «premature» respiratory deaths per 100 000 inhabitants would all be below one respiratory death.

Our HIA found that, all other things being equal, 61 "premature" respiratory deaths could be prevented if short-term exposure to outdoor concentrations of BS were reduced by 5 µg/m³.

For each city measuring BS, the following map shows the short-term health impact for up to 2 days on total, cardiovascular and respiratory mortality for a reduction to 20 µg/m³ in black smoke levels expressed in number of deaths per 100 000 inhabitants.

Map of short-term impact (up to-2 days) on total, cardiovascular and respiratory mortality for a reduction to 20 µg/m^3 in black smoke levels. Number of «premature» deaths per 100 000 inhabitants

PM_{10} findings

In accordance with Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and all nitrogen oxides, particulate matter and lead in ambient air (Official Journal L 163, 29/06/1999 P. 0041 – 0060) (Appendix 10), and to take account of the fact that some countries already present low levels of PM_{10}, we conducted our HIA for almost the same scenarios to reduce PM_{10} levels as used in Apheis-2.

Acute effects scenarios

We used three scenarios to estimate the acute effects of short-term exposure to raw PM_{10} values on total mortality (excluding external causes), and on cardiovascular and respiratory 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 three scenarios to estimate the chronic effects of long-term exposure to corrected PM_{10} 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 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 (the measurements were available only four weekdays from Monday to Thursday).

PM_{10}: Short-term, cumulative short-term and long-term impact on total mortality (ICD9 < 800)

Because the PM_{10} 24-hour value to be reached in 2005 and 2010 is 50 µg/m^3 and the annual mean to be reached in 2005 is 40 µg/m^3, we have used two figures to present the short-term and long-term impacts respectively.

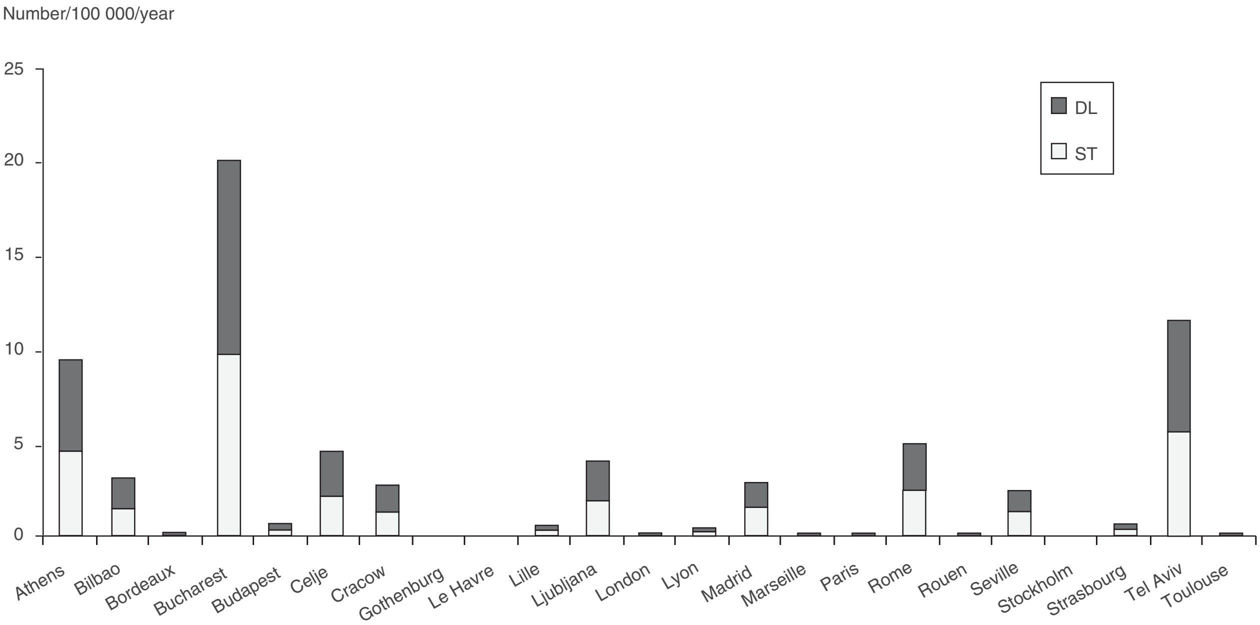
Note that in the following figures, when presenting short-term (ST) and cumulative short-term (DL) impacts in a bar, the dark part of the bar is DL-ST. Also when presenting short-term (ST), cumulative short-term (DL) and long-term impacts (LT) in a bar, one on top of the other, DL includes ST, and LT includes ST and DL.

Figure 15a shows the potential benefits, for the short-term and cumulative short-term exposures, of reducing raw PM_{10} levels to a 24-hour value of 50 µg/m^3 (2005 and 2010 limit values) on all days exceeding this value. Figure 15b shows the potential benefit of reducing long-term exposure to corrected PM_{10} levels to an annual mean value of 40 µg/m^3 (2005 limit values for PM_{10}).

The potential health benefits are expressed as mortality rates per 100 000 inhabitants.

Please note that the bars are slightly shifted to the right. The cities of Gothenburg, Le Havre and Stockholm have no bars because they already show 24-hour values of PM_{10} below 50 µg/m^3, and do not show any health benefit in this scenario.

Figure 15a. PM_{10}: Short-term (ST) and cumulative short-term (DL) health impact on all causes mortality (ICD 9 < 800). Reductions to 50 µg/m^3 (ST-DL). Number of «premature» deaths per 100 000 inhabitants

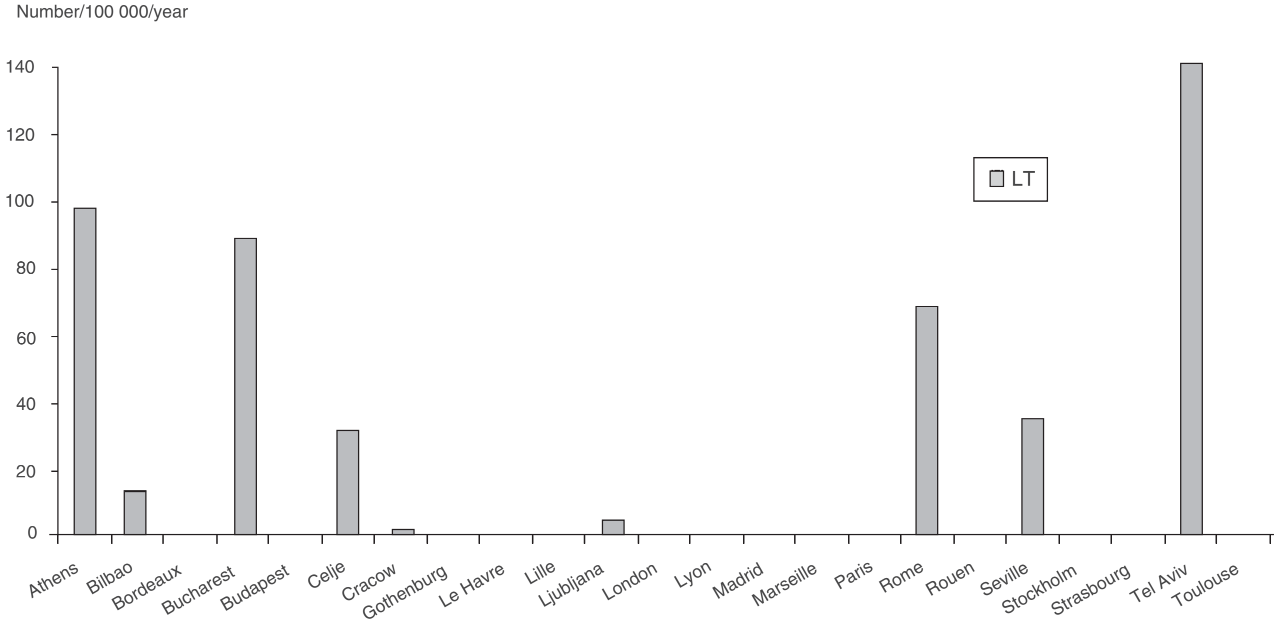


All other things being equal, if raw PM_{10} levels for all days when they exceeded this value were reduced to 50 µg/m^3, the greatest benefits would be for Athens, Bucharest and Tel Aviv.

Cumulative short-term impacts would be reduced respectively by 9 «premature» deaths per 100 000 inhabitants in Athens, 20 Bucharest, and 11.5 in Tel Aviv.

For total non-violent mortality, findings of our HIA were similar to those of Apheis-2. For all the 23 cities that measured PM_{10}, the HIA estimated that, all other things being equal, 559 and 1 150 "premature" deaths related respectively to short and cumulative short-term exposure would be prevented by reducing daily raw PM_{10} to below 50 µg/m^3.

Figure 15b. PM_{10}: Long-term (LT) health impact on all causes mortality (ICD 9 < 800). Reductions to 40 µg/m^3 (LT). Number of «premature» deaths per 100 000 inhabitants

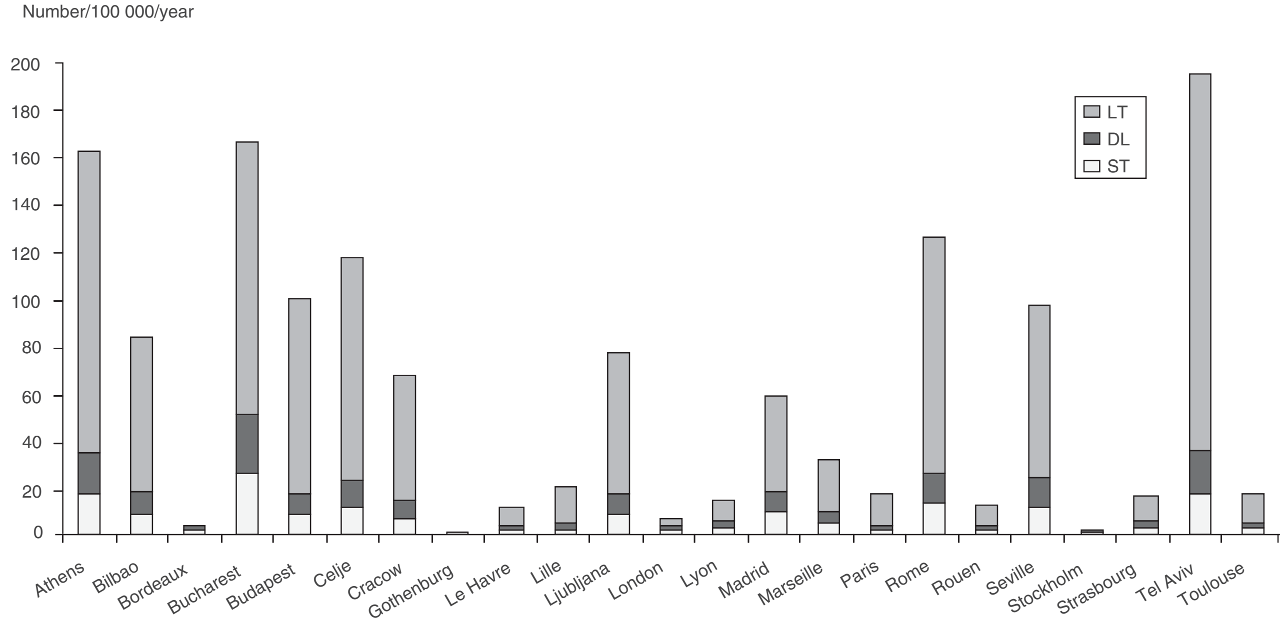


In the long term (Figure 15b), corrected annual mean levels of PM_{10} were above 40 µg/m^3 in nine cities: Athens, Bilbao, Bucharest, Celje, Cracow, Ljubljana, Rome, Seville and Tel Aviv. All other things being equal, the reduction of the annual mean value to 40 µg/m^3 would reduce the number of "premature" deaths per 100 000 inhabitants by 96 in Athens, 88 in Bucharest, 30 in Celje, 0.5 in Cracow, 3.7 in Ljubljana, 67 in Rome, 33.7 in Seville and 139.6 in Tel Aviv. The 23 cities that measured PM_{10} would average 24 "premature" deaths per 100 000 inhabitants.

In all these 23 cities, the HIA estimated that, all other things being equal, 8 550 "premature" deaths could be prevented annually if long-term exposure to outdoor concentrations of PM_{10} were reduced to 40 µg/m^3 in each city.

Findings of our HIA of long-term exposure to PM_{10} are not comparable to Apheis-2, because in Apheis-2 we used raw data while in Apheis-3 we used corrected data.

Figure 16. PM_{10}: Short-term (ST), cumulative short-term (DL), long term (LT) health impact on all causes mortality (ICD 9 < 800). Reductions to 20 µg/m³. Number of «premature» deaths per 100 000 inhabitants



If we now consider the second scenario, a reduction to 20 µg/m³ in the long term[5] (2010 limit value not to be exceeded for PM_{10}), most of the cities would benefit from this reduction in corrected PM_{10} levels. All other things being equal, the corresponding reductions in the number of "premature" deaths per 100 000 inhabitants would be: 161 in Athens, 165 in Bucharest (including 25 and 51 related to short and cumulative short-term exposure[6]), 117 in Celje, 125 in Rome and 194 in Tel Aviv. The 23 cities that measured PM_{10} would average 60 "premature" deaths per 100 000 inhabitants. In all these cities, all other things being equal, the HIA estimated that 21 828 "premature" deaths could be prevented annually if long-term exposure to outdoor concentrations of corrected PM_{10} were reduced to 20 µg/m³ in each city.

On the other hand, all other things being equal, a reduction to 20 µg/m³ in short-term and cumulative short-term exposure to raw PM_{10} values would lead respectively to the following reductions in the number of "premature" deaths per 100 000 inhabitants: Athens 17 and 34, Bucharest 25 and 51, Celje 11 and 23, Rome 13 and 26, Tel Aviv 17 and 35.

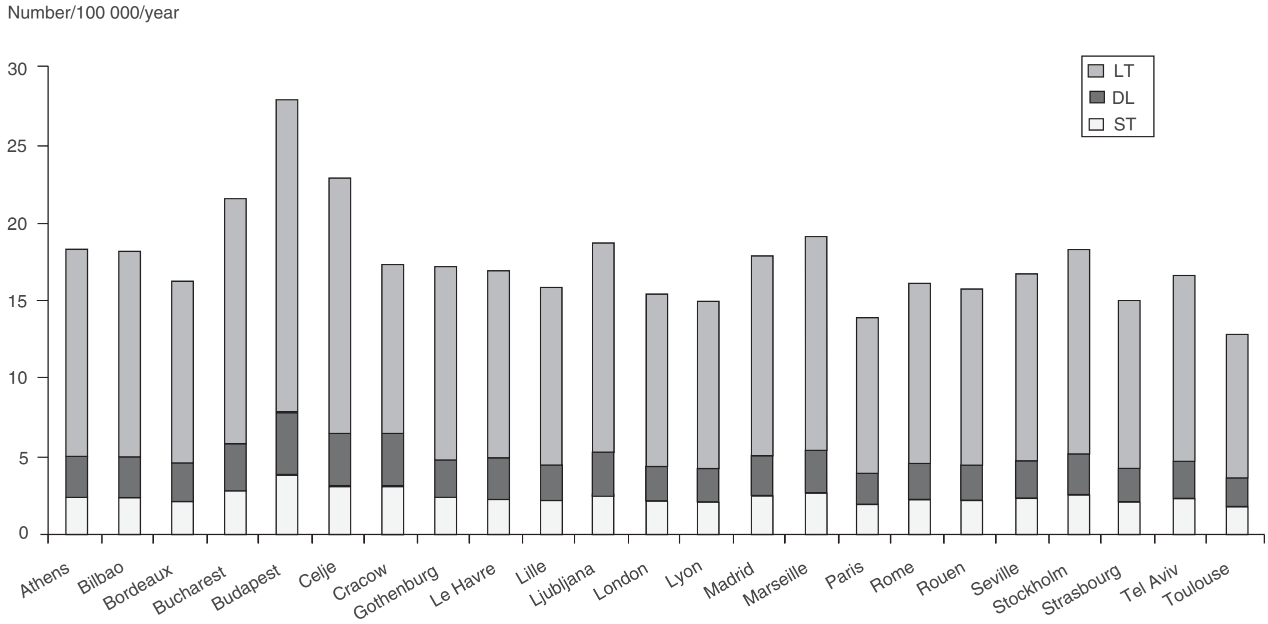
In all the 23 cities, all other things being equal, the HIA estimated that 2 580 and 5 240 "premature" deaths could be prevented annually if short and cumulative short-term exposure to outdoor concentrations of raw PM_{10} were reduced to 20 µg/m³ in each city.

Swedish cities (Gothenburg and Stockholm) already comply with this scenario.

[5] For HIAs of long-term exposure, we had to correct the automatic PM_{10} measurements used by most of the cities by a specific correction factor (local or, by default, the European factor of 1.3) in order to compensate for losses of volatile particulate matter.

[6] For HIAs of short-term exposure, we used raw PM_{10} and BS levels measured directly at monitoring stations

Figure 17. PM_{10}: Short-term (ST), cumulative short-term (DL), long term (LT) health impact on all-causes mortality (ICD 9 <800). Reductions by 5 µg/m^3. Number of «premature» deaths per 100 000 inhabitants



If the annual mean of corrected PM_{10} values were reduced by 5 µg/m^3 in all the 23 cities, the consequent reduction in the number of "premature" deaths per 100 000 inhabitants would range between 28 in Budapest and 13 in Toulouse. These cities would average 17 "premature" deaths per 100 000 inhabitants in the 23 cities measuring PM_{10}.

In all the 23 cities, all other things being equal, the HIA estimated that 6 143 "premature" deaths could be prevented annually if long-term exposure to outdoor concentrations of corrected PM_{10} levels were reduced by 5 µg/m^3 in each city.

If daily mean raw values of PM_{10} were reduced by 5 µg/m^3 in all the cities, for short-term and cumulative short-term exposure scenarios, the consequent reduction in the number of "premature" deaths per 100 000 inhabitants would range respectively between 4 and 8 in Budapest and 2 and 4 in Toulouse.

For all the cities, all other things being equal, the HIA estimated respectively that 868 and 1 739 "premature" deaths related to short-term and cumulative short-term exposure could be prevented annually if raw outdoor concentrations of PM_{10} were reduced by 5 µg/m^3 in each city.

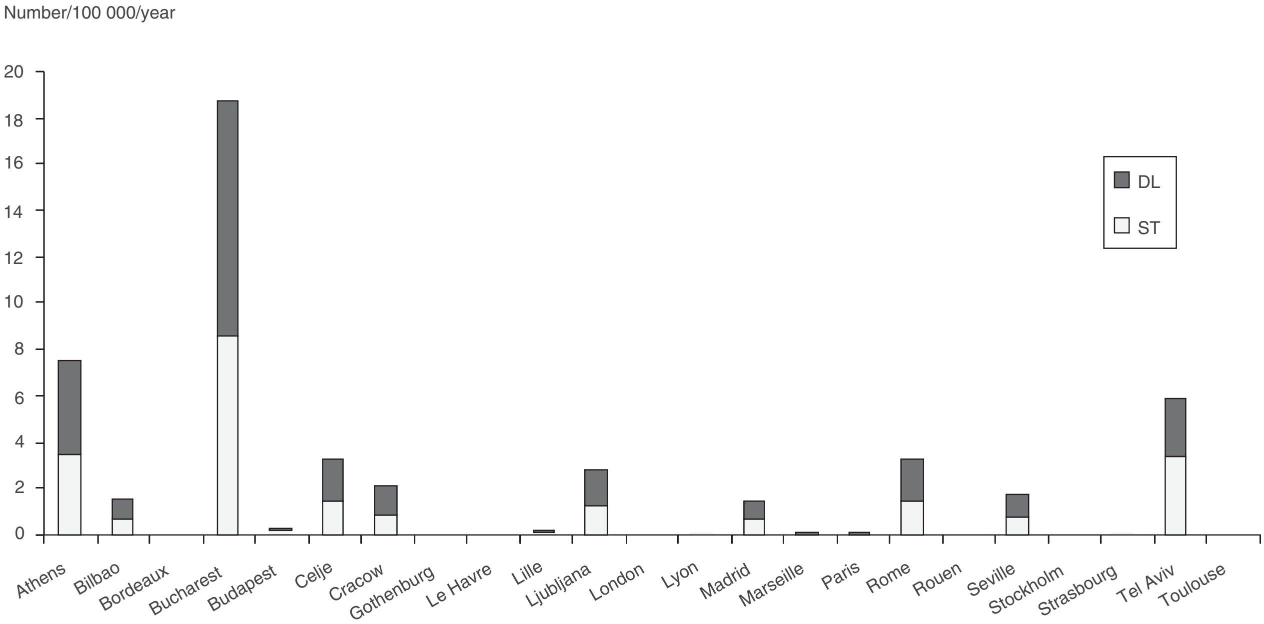
Note that most, but not all, the potential benefits of reducing short-term and cumulative short-term exposure to PM_{10} are included in the benefits of reducing long-term exposure.

PM_{10}: *Short and cumulative short-term impacts on cardiovascular mortality (ICD9 390-459)*

In Apheis-3, the HIA assessed not only total mortality but also cause-specific mortality.

Figure 18 shows the potential benefits, in the short-term and cumulative short-term exposure, of reducing raw PM_{10} levels to a 24-hour value of 50 µg/m^3 (2005 and 2010 limit values) on all days exceeding this value. No exposure-response functions were available for HIAs of long-term exposure to PM_{10} on cardiovascular mortality.

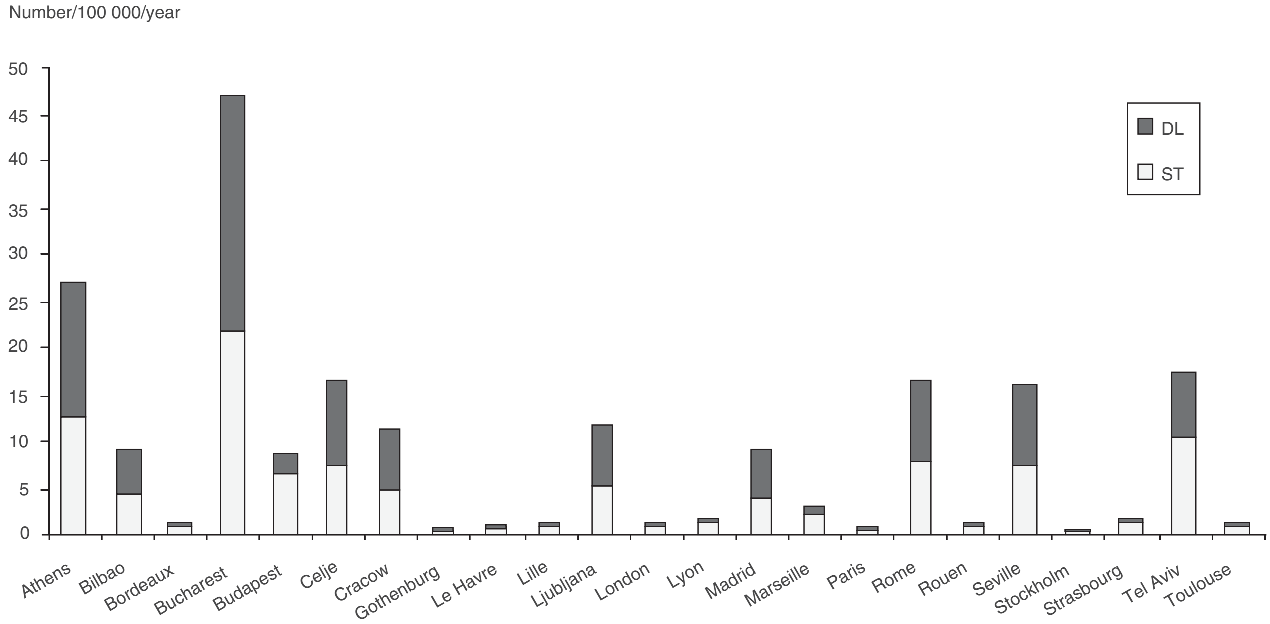
Figure 18. Short-term (ST) and cumulative short-term (DL) health impact on cardiovascular mortality (ICD9 390-459). Reductions to 50 µg/m^3. Number of «premature» deaths per 100 000 inhabitants



If PM_{10} levels for all days when they exceeded this value were reduced to 50 µg/m^3 in the 23 cities that measured PM_{10}, all other things being equal, cumulative short-term impact would be reduced respectively by almost 8 "premature" cardiovascular deaths per 100 000 inhabitants in Athens (including 3 related to a very short-term exposure), 19 in Bucharest (including 8 related to a very short-term exposure), and 6 in Tel Aviv (including 3 related to a very short-term exposure). Celje, Ljubljana and Rome would benefit from a reduction of around 3 "premature" cardiovascular deaths per 100 000 inhabitants. Bilbao, Cracow, Madrid and Seville would benefit from a reduction of around 2 "premature" cardiovascular deaths per 100 000 inhabitants. The 23 cities would average 2 "premature" cardiovascular deaths per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 877 "premature" cardiovascular deaths (including 412 related to very short-term exposure) could be prevented annually if cumulative short-term and short-term exposure to outdoor concentrations of PM_{10} were reduced to 50 µg/m^3 in each city.

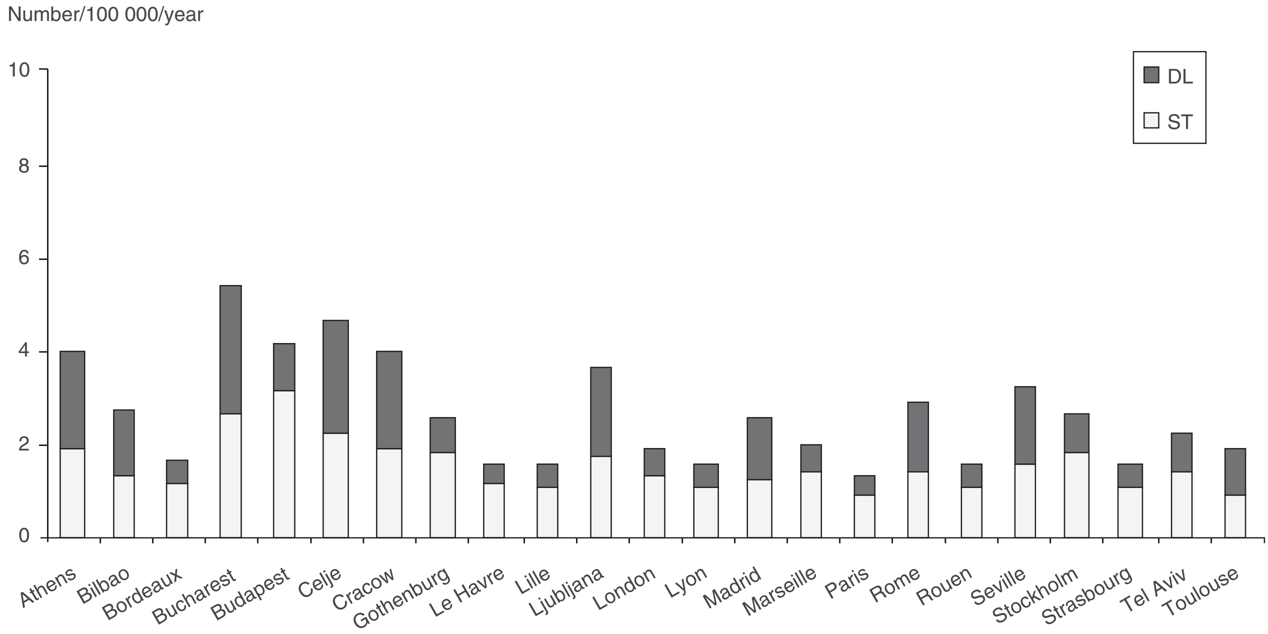
Figure 19. PM_{10}: Short-term (ST) and cumulative short-term (DL) health impact on cardiovascular mortality (ICD9 390-459). Reductions to 20 µg/m³. Number of «premature» deaths per 100 000 inhabitants



If we now consider a reduction in daily mean values of PM_{10} to 20 µg/m³ (2010 limit values for PM_{10}) in the 23 cities that measured PM_{10}, all other things being equal, the corresponding reductions in the number of "premature" cardiovascular deaths per 100 000 inhabitants would be: 27 in Athens (including 13 related to very short-term exposure to PM_{10}), 47 in Bucharest (including 22 related to a very short-term exposure), 17 in Celje (including 8 related to short-term exposure), 17 in Rome (including 8 related to a very short-term exposure), 16 in Seville (including 8 related to a very short-term exposure) and 18 in Tel Aviv (including 11 related to a very short-term exposure to PM_{10}). The 23 cities would average 10 "premature" deaths per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 3 458 "premature" cardiovascular deaths (including 1 741 related to very short-term exposure) could be prevented annually if cumulative short-term and short-term exposure to outdoor concentrations of PM_{10} were reduced to 20 µg/m³ in each city.

Figure 20. PM_{10}: Short-term (ST) and cumulative short-term (DL) health impact on cardiovascular mortality (ICD9 390-459). Reductions by 5 µg/m³. Number of «premature» deaths per 100 000 inhabitants

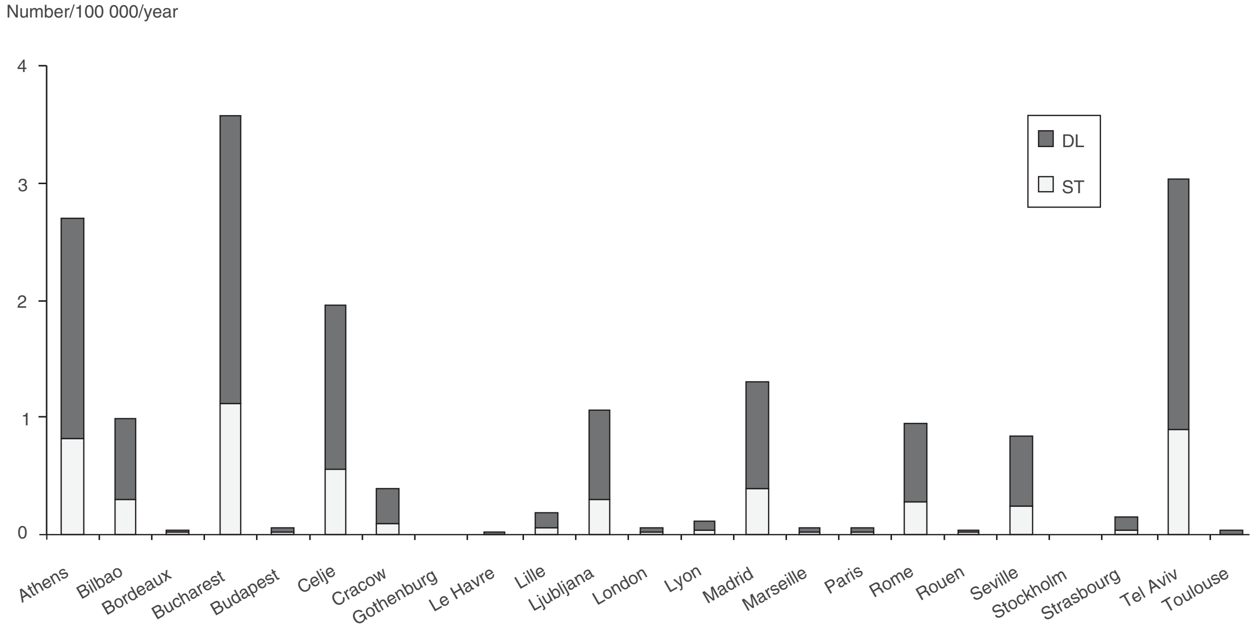


If daily mean values of PM_{10} were reduced by 5 µg/m³ in all the 23 cities that measured PM_{10}, all other things being equal, the consequent reduction in the number of "premature" cardiovascular deaths per 100 000 inhabitants would range between 1.3 in Paris (including 1 death related to very short-term exposure to PM_{10}) and 5 in Bucharest (including almost 3 related to short -term exposure). The 23 cities would average 2 «premature» deaths per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 897 "premature" cardiovascular deaths (including 527 related to very short-term exposure), could be prevented annually if cumulative short-term and short-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m³ in each city.

PM_{10}: Short and cumulative short-term impacts on respiratory mortality (ICD9 460-519)

Figure 21. PM_{10}: Short -erm (ST) and cumulative short-term (DL) health impact on respiratory mortality (ICD9 460-519). Reductions to 50 µg/m^3. Number of «premature» deaths per 100 000 inhabitants

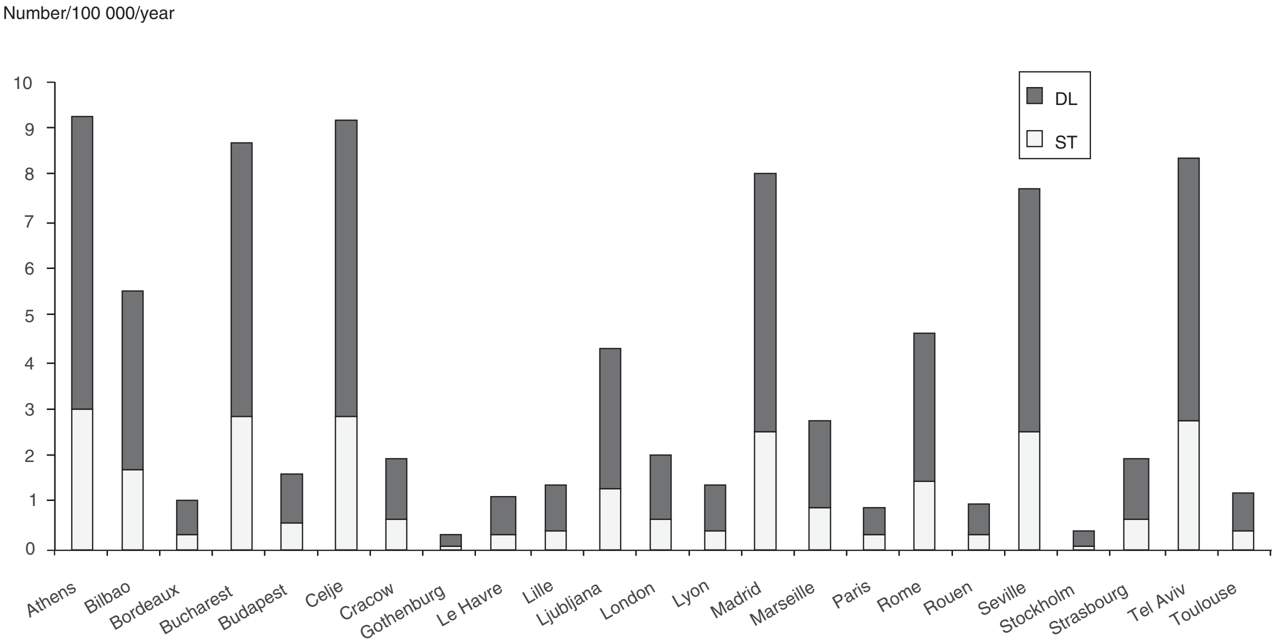


If PM_{10} levels for all days when they exceeded this value were reduced to 50 µg/m^3 in the 23 cities that measured PM_{10}, all other things being equal, the cumulative short-term impact would be reduced respectively by almost 3 "premature" respiratory deaths per 100 000 inhabitants in Athens (including almost 1 related to a very short-term exposure), almost 4 in Bucharest (including 1 related to a very short-term exposure), almost 2 in Celje (including 0.5 related to a very short-term exposure) and 3 in Tel Aviv (including 1 related to a very short-term exposure).

The 23 cities would average 1 "premature" respiratory death per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 288 "premature" respiratory deaths (including 87 related to very short-term exposure) could be prevented annually if cumulative short-term exposure and short-term exposure to outdoor concentrations of PM_{10} were reduced to 50 µg/m^3 in each city.

Figure 22. PM_{10}: Short-term (ST) and cumulative short-term (DL) health impact on respiratory mortality (ICD9 460-519). Reductions to 20 µg/m³. Number of «premature» deaths per 100 000 inhabitants

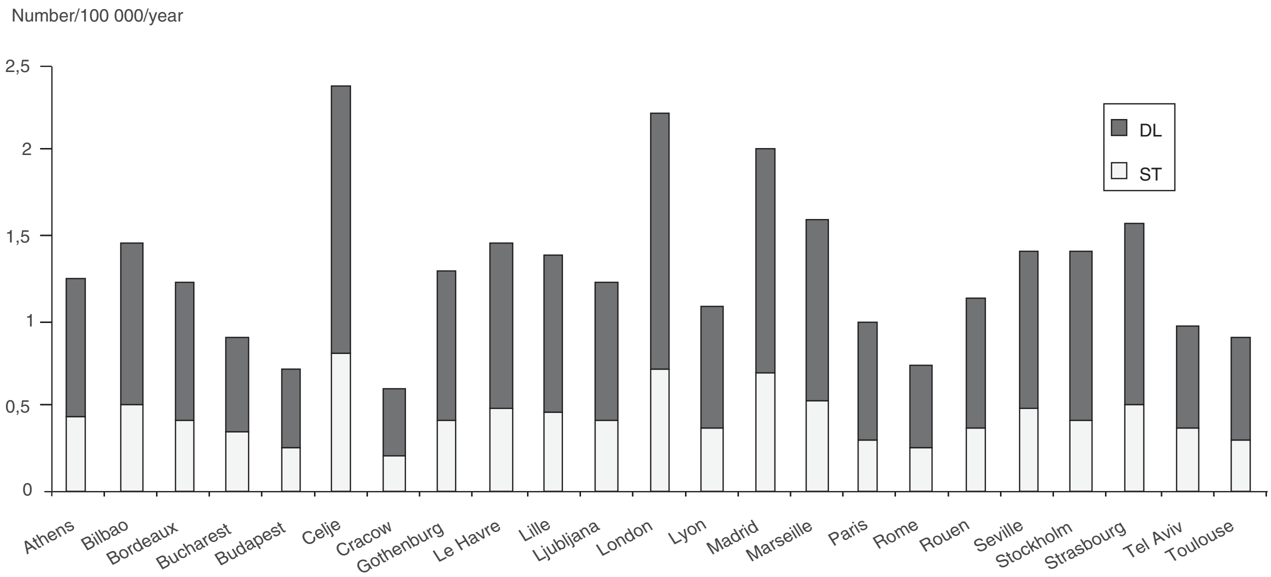


If we now consider a reduction in daily mean values of PM_{10} to 20 µg/m³ (2010 limit values for PM_{10}) in the 23 cities that measured PM_{10}, all other things being equal, the corresponding reductions in the number of "premature" respiratory deaths per 100 000 inhabitants would be: 9 in Athens and Celje (including almost 3 related to very short-term exposure to PM_{10}), 8.7 in Bucharest (including 2.8 related to a very short-term exposure), 4 in Ljubljana (including 1.3 related to a very short-term exposure), 4.6 in Rome (including 1.5 related to a very short-term exposure), 7.7 in Seville (including 2.5 related to a very short-term exposure and 8.4 in Tel Aviv (including 2.7 related to a very short-term exposure to PM_{10}).

The 23 cities would average four "premature" respiratory deaths per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 1 348 "premature" respiratory deaths (including 429 related to very short-term exposure) could be prevented annually if cumulative short-term and short-term exposure to outdoor concentrations of PM_{10} were reduced to 20 µg/m³ in each city.

Figure 23. PM_{10}: Short-term (ST) and cumulative short-term (DL) health impact on respiratory mortality (ICD9 460-519). Reductions by 5 µg/m^3. Number of «premature» deaths per 100 000 inhabitants



If daily mean values of PM_{10} were reduced by 5 µg/m^3 in all the 23 cities that measured PM_{10}, all other things being equal, the consequent reduction in the number of "premature" respiratory deaths per 100 000 inhabitants would be the highest, between 2 and 2.5 in Celje, London and Madrid (including almost 1 death related to a very short-term exposure to PM_{10}).

The 23 cities would average 1 "premature" respiratory death per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 489 "premature" respiratory deaths (including 162 related to very short-term exposure) could be prevented annually if cumulative short-term and short-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3 in each city.

For each city, the following map shows the cumulative short-term health impact for up to 40 days on total, cardiovascular and respiratory mortality for a reduction in PM_{10} levels to 20 µg/m^3 expressed in number of deaths per 100 000 inhabitants

Map of cumulative short-term impact (up to 40 days) on total, cardiovascular and respiratory mortality for a reduction to 20 µg/m³ in PM_{10} levels. Number of deaths per 100 000 inhabitants

PM_{10}: Meta-analytic vs shrunken estimated number of cases

The value of different estimates to assess the relationship between particulate pollution and acute mortality and its consequences for HIA was investigated by the Apheis Statistical Advisory Group (Appendix 5).

Applying the so-called shrunken estimate in Athens or in Cracow would lead to almost 100% more “premature” deaths or 40% less deaths respectively than those calculated with the overall meta-analytic estimate in the scenario reducing PM_{10} by 5 µg/m^3. This shrunken estimate has the property to derive the overall estimate at the local level by combining information from the city-specific estimate with the overall one and can be considered as a weighted mean between these two estimates.

The impact is quite different when one looks at reducing PM_{10} levels to a certain point, for instance to 20 or 50 µg/m^3. Not every city can contribute to these scenarios, i.e. cities with levels of particulate pollution already below these levels will not contribute at all. The overall mean is then driven by cities with the highest particulate pollution levels. In this small sample, reducing PM_{10} levels to 50 µg/m^3, using shrunken estimates would lead to 58% more “premature” deaths on average than using the overall estimate, and 42% for a reduction to 20 µg/m^3.

Figure 24. PM_{10}: Meta-analytic vs shrunken estimated health impact on all-causes mortality (ICD9 < 800; ICD10 A00-Q99). Reductions to 50 µg/m^3. Number of deaths per 100 000 inhabitants

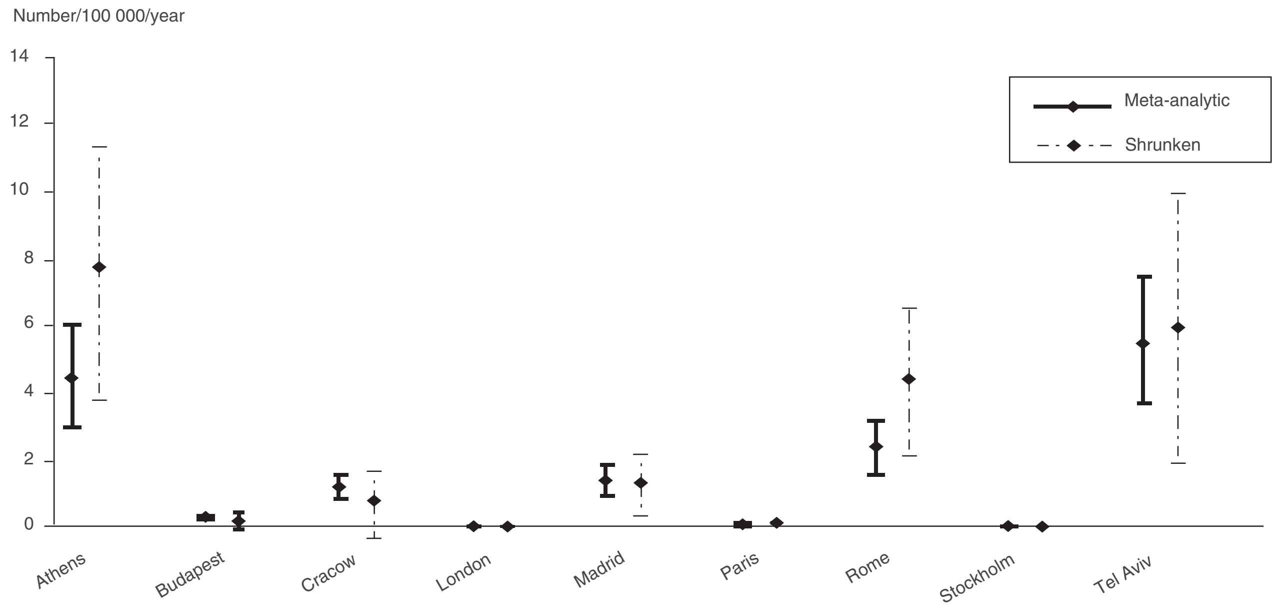


Figure 25. PM_{10}: Meta-analytic vs shrunken estimated health impact on all-causes mortality (ICD9 < 800; ICD10 A00-Q99). Reductions to 20 µg/m^3. Number of deaths per 100 000 inhabitants

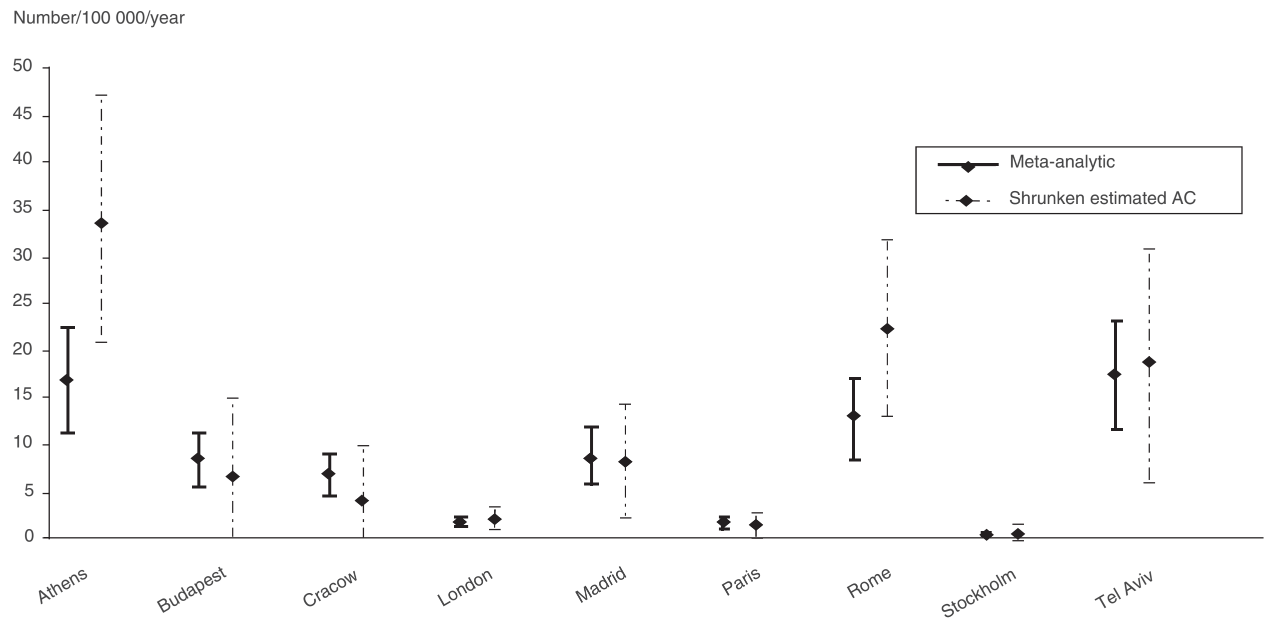
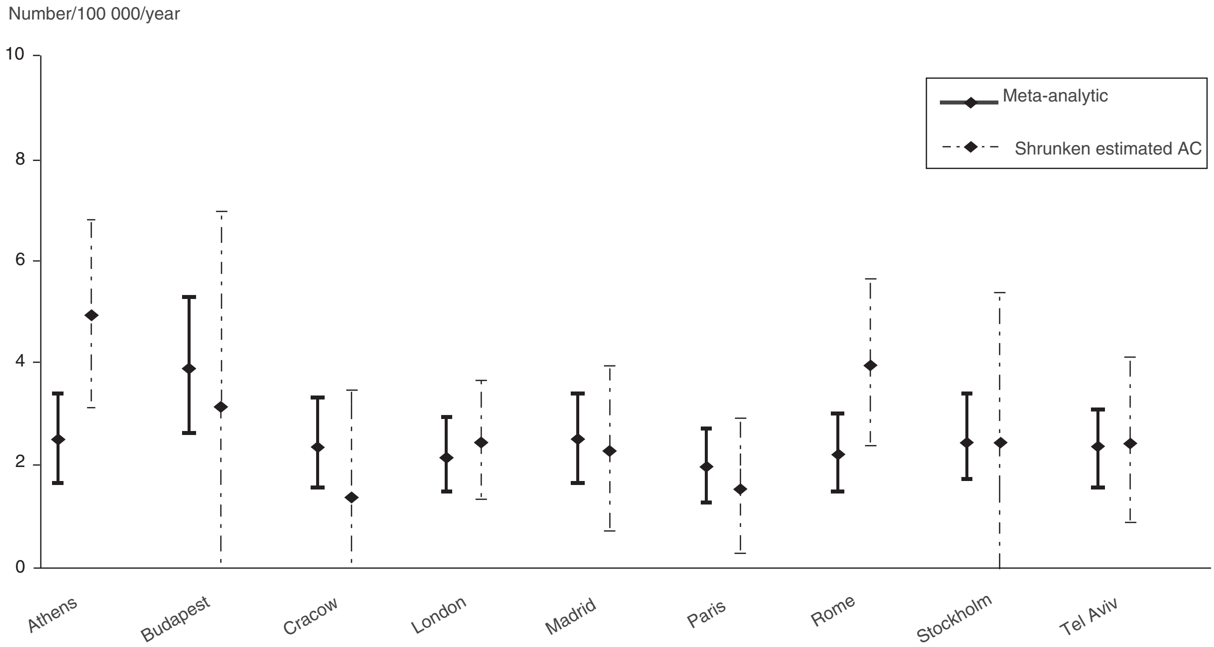


Figure 26. PM_{10}: Meta-analytic vs shrunken estimated health impact on all causes mortality (ICD9 < 800; ICD10 A00-Q99). Reductions by 5 µg/m³. Number of deaths per 100 000 inhabitants



A discussion of the use of different estimates and its consequences for HIAs appears in the "Interpretation of findings" section.

$PM_{2.5}$ findings

For the first time in Apheis, we conducted HIAs of long-term exposure to $PM_{2.5}$. To contribute to the current discussions within the EC legislation process on the limit values[7] to be attributed to $PM_{2.5}$, we conducted our HIA for the following chronic-effect scenarios.

For long-term exposure to $PM_{2.5}$, we used average estimates of the more recent ACS study (Pope, 2002) that provided E-R functions for the following health outcomes: all-causes mortality, cardiopulmonary mortality and lung-cancer mortality.

HIAs of long-term exposure to $PM_{2.5}$ were conducted converting corrected PM_{10} values by a local or European default value (see “Methods” section).

Chronic effects scenarios

We used three scenarios to estimate the chronic effects of long-term exposure to $PM_{2.5}$ on total and cause-specific mortality over a 1-year period:

- reduction of the annual mean value of $PM_{2.5}$ to a level of 20 µg/m^3;
- reduction of the annual mean value of $PM_{2.5}$ to a level of 15 µg/m^3;
- reduction by 3.5 µg/m^3 of the annual mean value of $PM_{2.5}$ (equivalent to 5 µg/m^3 in PM_{10} using the European conversion factor 0.7).

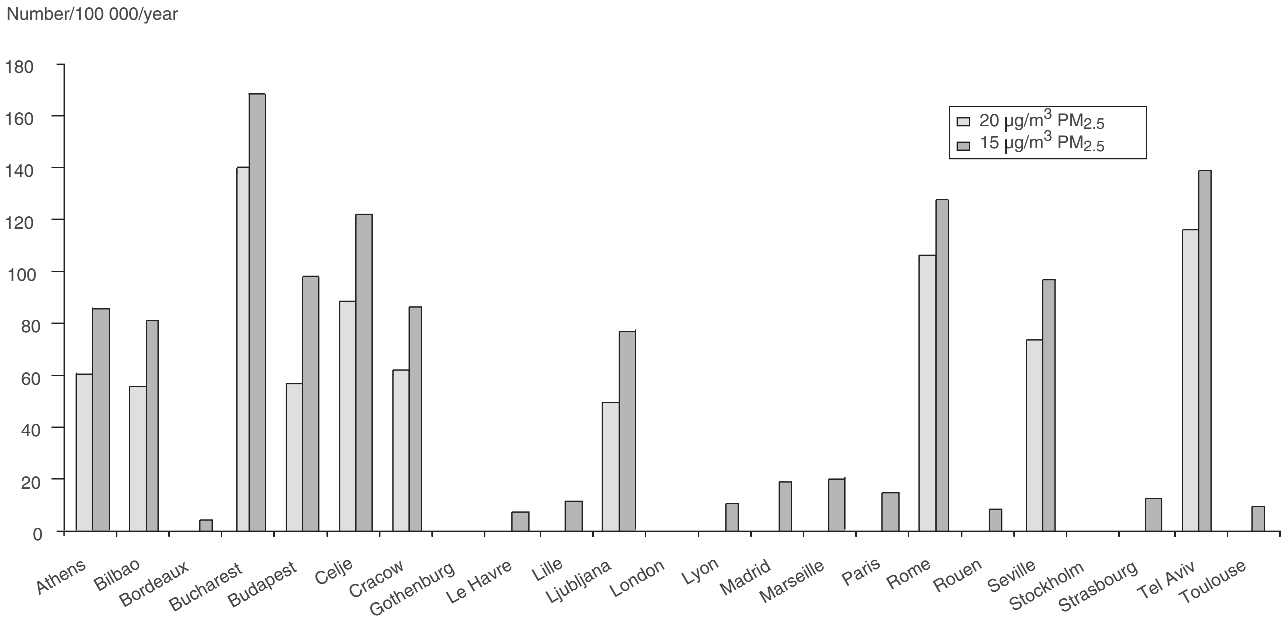
$PM_{2.5}$: Long-term impact on total mortality

The following figures show the impact of long-term exposure to converted $PM_{2.5}$ levels for different scenarios of $PM_{2.5}$ reductions in terms of number of “premature” deaths for all causes mortality, cardiopulmonary and lung-cancer mortality.

Please note that in figures 27, 29 and 31 the bars are slightly shifted to the right and that some cities have only one or no bars because they already show values of $PM_{2.5}$ below 20 or 15 µg/m^3, and do not show any health benefit in these scenarios.

[7] http://europa.eu.int/comm/environment/air/café/index.htm)

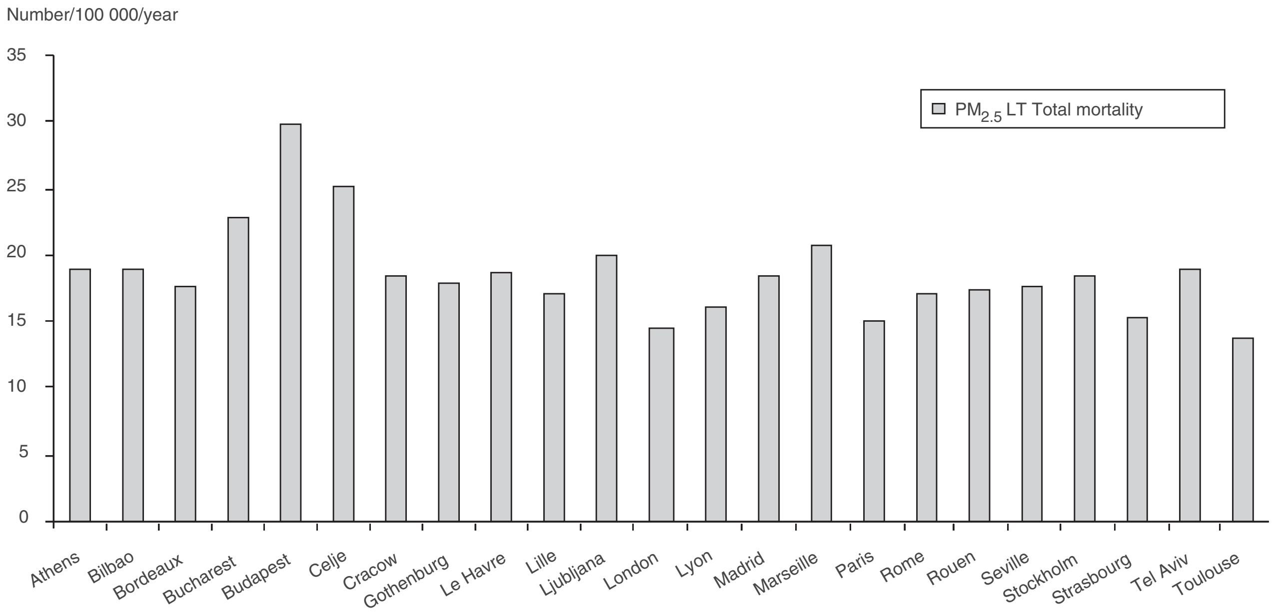
Figure 27. $PM_{2.5}$: Long term (LT) health impact on all-causes mortality (ICD 9 0-999). Reductions to 20 and 15 µg/m^3. Number of deaths per 100 000 inhabitants



If the annual mean of converted $PM_{2.5}$ values were reduced to 20 or 15 µg/m^3 in the 23 cities that measured PM_{10}, all other things being equal, the consequent reduction in the number of “premature” deaths per 100 000 inhabitants would be respectively: 140/168 in Bucharest, 115/139 in Tel Aviv, 106/127 in Rome, 88/122 in Celje, 73/96 in Seville, 62/86 in Cracow, 60/85 in Athens, 57/98 in Budapest, 55/80 in Bilbao and 49/76 in Ljublana. All other cities would only benefit for a reduction to 15 µg/m^3, excepting the Swedish cities (Gothenburg, Stockholm), which are already below these levels of $PM_{2.5}$. The 23 cities would average 32 “premature” deaths per 100 000 inhabitants for a reduction to 20 µg/m^3 in converted $PM_{2.5}$ values. This average would be 47 “premature” deaths per 100 000 inhabitants if the reduction were to 15 µg/m^3.

For all the 23 cities, all other things being equal, the HIA estimated that 11 375 “premature” deaths could potentially be prevented annually if long-term exposure to converted $PM_{2.5}$ levels were reduced to 20 µg/m^3 in each city. There would be 16 926 “premature” deaths if long-term exposure to converted $PM_{2.5}$ levels were reduced to 15 µg/m^3.

Figure 28. $PM_{2.5}$: Long-term (LT) health impact on all-causes mortality (ICD-9 0-999). Reductions by 3.5 µg/m^3. Number of deaths per 100 000 inhabitants



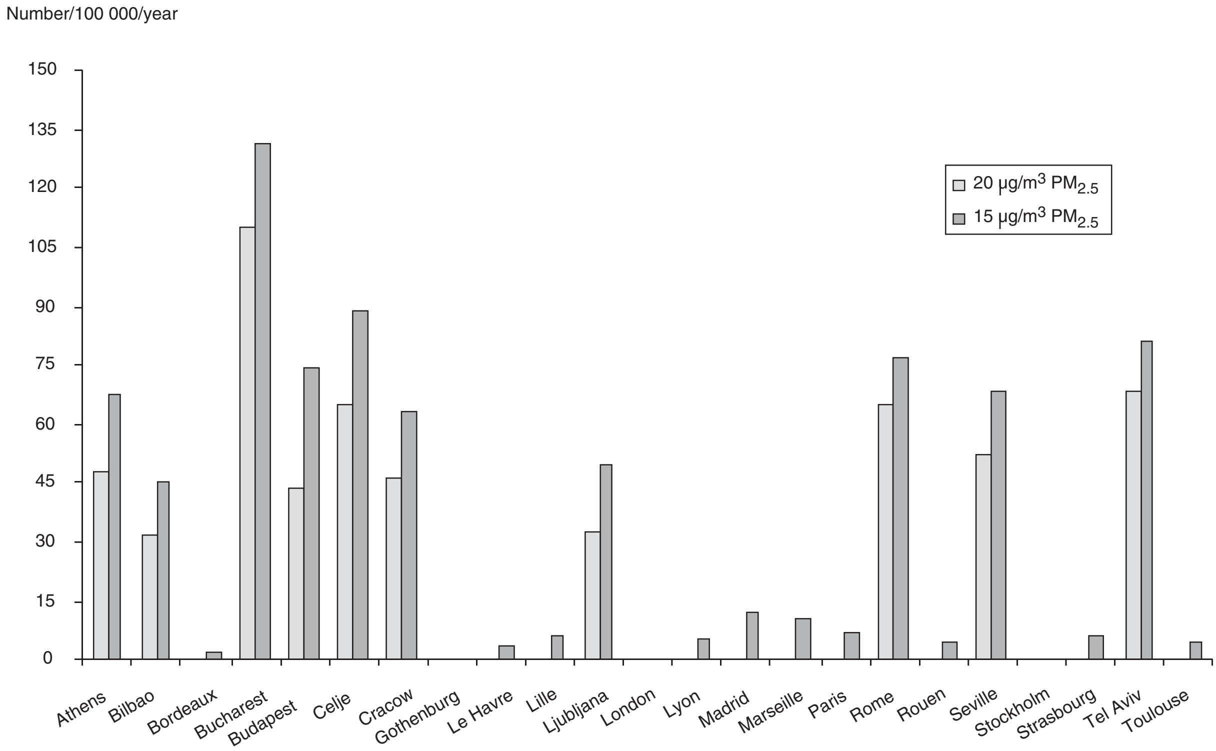
If the annual mean of converted $PM_{2.5}$ values were reduced by 3.5 µg/m^3 (equivalent to 5 µg/m^3 for PM_{10}) in the 23 cities that measured PM_{10}, all other things being equal, the consequent reduction in the number of "premature" deaths per 100 000 inhabitants would be the highest in Budapest, Celje and Bucharest.

The 23 cities, including the Swedish ones, would average 18 "premature" deaths per 100 000 inhabitants for all the cities.

For all the 23 cities, all other things being equal, the HIA estimated that 6 355 «premature» deaths could be prevented annually if long-term exposure to converted $PM_{2.5}$ levels were reduced by 3.5 µg/m^3 in each city.

$PM_{2.5}$: Long-term impact on cardiopulmonary mortality (ICD9 401-440 and 460-519)

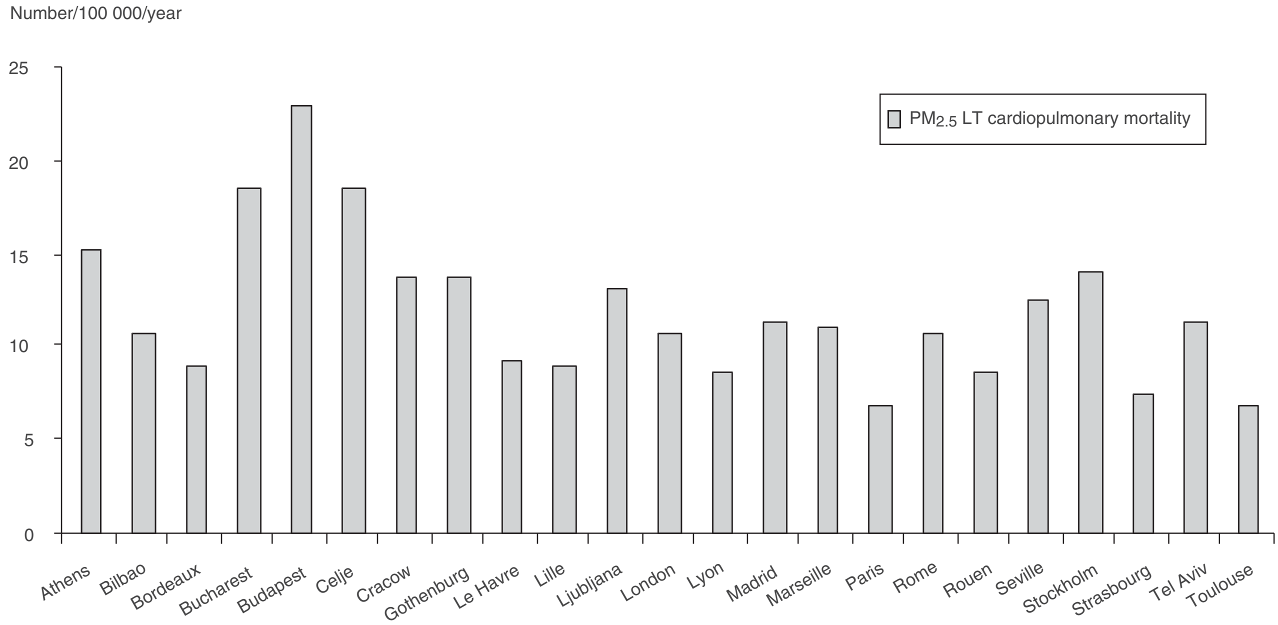
Figure 29. $PM_{2.5}$: Long-term (LT) health impact on cardiopulmonary mortality (ICD9 401-440 and 460-519). Reductions to 20 and 15 µg/m³. Number of deaths per 100 000 inhabitants



For cardiopulmonary mortality, all other things being equal, if the annual mean of converted $PM_{2.5}$ values were reduced to 20 or to 15 µg/m³ in the 23 cities that measured PM_{10}, the consequent reduction in the number of "premature" cardiopulmonary deaths per 100 000 inhabitants would be respectively: 110/130 in Bucharest, 68/82 in Tel Aviv, 65/88 in Celje, 65/77 in Rome, 52/68 in Seville, 46/64 in Cracow, 48/67 in Athens, 44/75 in Budapest, 31/45 in Bilbao and 32/50 in Ljublana. Again, all other cities would only benefit from a reduction to 15 µg/m³, excepting the Swedish cities (Gothenburg, Stockholm), which are already below these levels of $PM_{2.5}$. The 23 cities would average 22 "premature" cardiopulmonary deaths per 100 000 inhabitants for a reduction to 20 µg/m³ in converted $PM_{2.5}$ values. This average would be 32 "premature" cardiopulmonary deaths per 100 000 inhabitants if the reduction were to 15 µg/m³.

For all the 23 cities, all other things being equal, the HIA estimated that 8 053 "premature" cardiopulmonary deaths might be prevented annually if long-term exposure to converted $PM_{2.5}$ levels were reduced to 20 µg/m³ in each city. There would be 11 612 "premature" cardiopulmonary deaths if long-term exposure to converted $PM_{2.5}$ levels were reduced to 15 µg/m³.

Figure 30. $PM_{2.5}$: Long-term (LT) health impact on Cardiopulmonary mortality (ICD9 401-440 and 460-519) Reductions by 3.5 µg/m^3. Number of deaths per 100 000 inhabitants

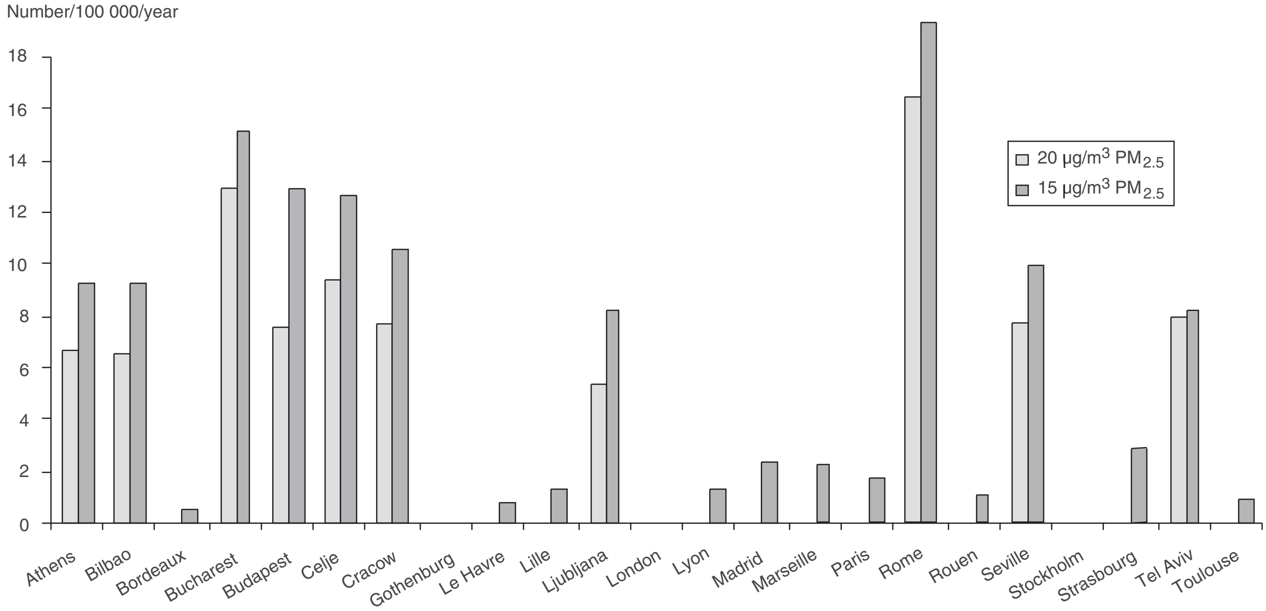


If the annual mean of converted $PM_{2.5}$ values were reduced by 3.5 µg/m^3 in the 23 cities that measured PM_{10}, all other things being equal, the consequent reduction in the number of "premature" cardiopulmonary deaths per 100 000 inhabitants would be the highest in Budapest, Celje, Bucharest and Athens. The 23 cities would average 12 "premature" cardiopulmonary deaths per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 4 199 "premature" cardiopulmonary deaths could be prevented annually if long-term exposure to converted $PM_{2.5}$ values were reduced by 3.5 µg/m^3 in each city.

$PM_{2.5}$: *Long-term impact on lung-cancer mortality (ICD9 162)*

Figure 31. $PM_{2.5}$: Long-term (LT) health impact on lung cancer mortality (ICD9 162). Reductions to 20 and 15 µg/m^3. Number of deaths per 100 000 inhabitants

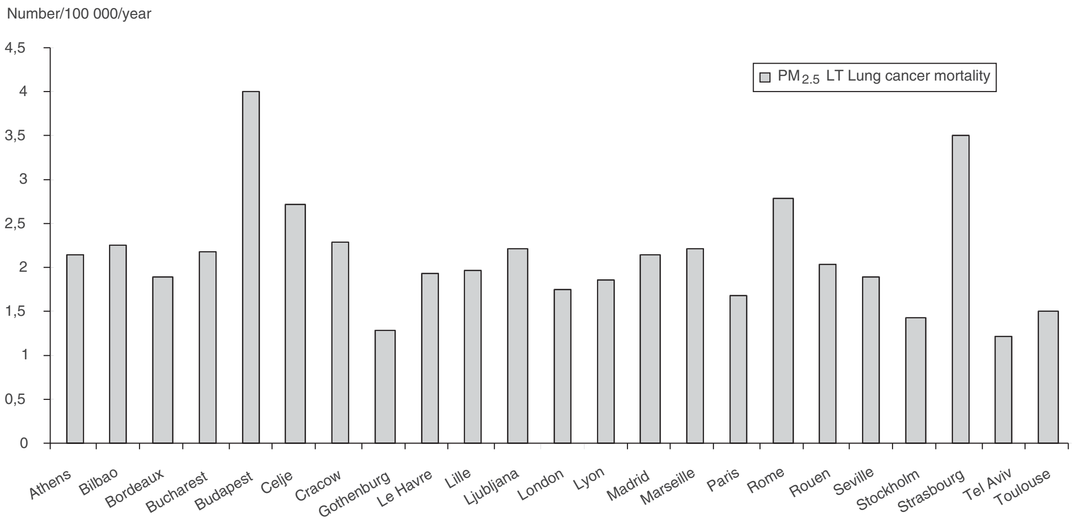


All other things being equal, if the annual mean of converted $PM_{2.5}$ values did not exceed 20 or 15 µg/m^3 in the 23 cities that measured PM_{10}, the number of "premature" lung-cancer deaths per 100 000 inhabitants would be reduced (with a certain delay) respectively by: 13/15 in Bucharest, 8/8 in Tel Aviv, 9/13 in Celje, 16/19 in Rome, 8/13 in Budapest, 8/10 in Seville and Cracow, 7/9 in Athens, 6/9 in Bilbao and 5/8 in Ljublana. All other cities would only benefit from a reduction to 15 µg/m^3, excepting Swedish cities (Gothenburg, Stockholm) and London, which are already below these levels of $PM_{2.5}$.

The 23 cities would average 4 "premature" lung-cancer deaths per 100 000 inhabitants if the annual mean of converted $PM_{2.5}$ values did not exceed 20 µg/m^3. This average would be 5 "premature" lung-cancer deaths per 100 000 inhabitants if the annual mean of converted $PM_{2.5}$ values did not exceed 15 µg/m^3.

In all the 23 cities, all other things being equal, the HIA estimated that 1 296 "premature" lung-cancer deaths might be prevented annually if long-term exposure to converted $PM_{2.5}$ levels did not exceed 20 µg/m^3 in each city. There would be 1 901 "premature" lung-cancer deaths if long-term exposure to converted PM_{10} levels did not exceed 15 µg/m^3.

Figure 32. $PM_{2.5}$: Long-term (LT) health impact on lung cancer mortality (ICD9 162). Reductions by 3.5 µg/m³. Number of deaths per 100 000 inhabitants



If the annual mean of converted $PM_{2.5}$ values were reduced by 3.5 µg/m³ (equivalent to 5 µg/m³ for PM_{10}) in the 23 cites that measured PM_{10}, all other things being equal, the consequent reduction (with a certain delay) in the number of "premature" lung-cancer deaths per 100 000 inhabitants would be the highest in Budapest, Strasbourg, Rome and Celje. The 23 cities would average 2 "premature" lung cancer per 100 000 inhabitants.

In all the 23 cities, all other things being equal, the HIA estimated that 743 "premature" lung-cancer deaths might be prevented annually if long-term exposure to converted $PM_{2.5}$ levels were reduced by 3.5 µg/m³ in each city.

For each city, the following map shows the long-term health impact on total, cardiopulmonary and lung cancer mortality for a reduction to 20 µg/m³ in $PM_{2.5}$ levels expressed in number of deaths per 100 000 inhabitants.

Map of long-term impact on total, cardiopulmonary and lung cancer mortality for a reduction to 20 µg/m^3 in $PM_{2.5}$ levels. Number of deaths per 100 000 inhabitants

$PM_{2.5}$: Expected gain in life expectancy

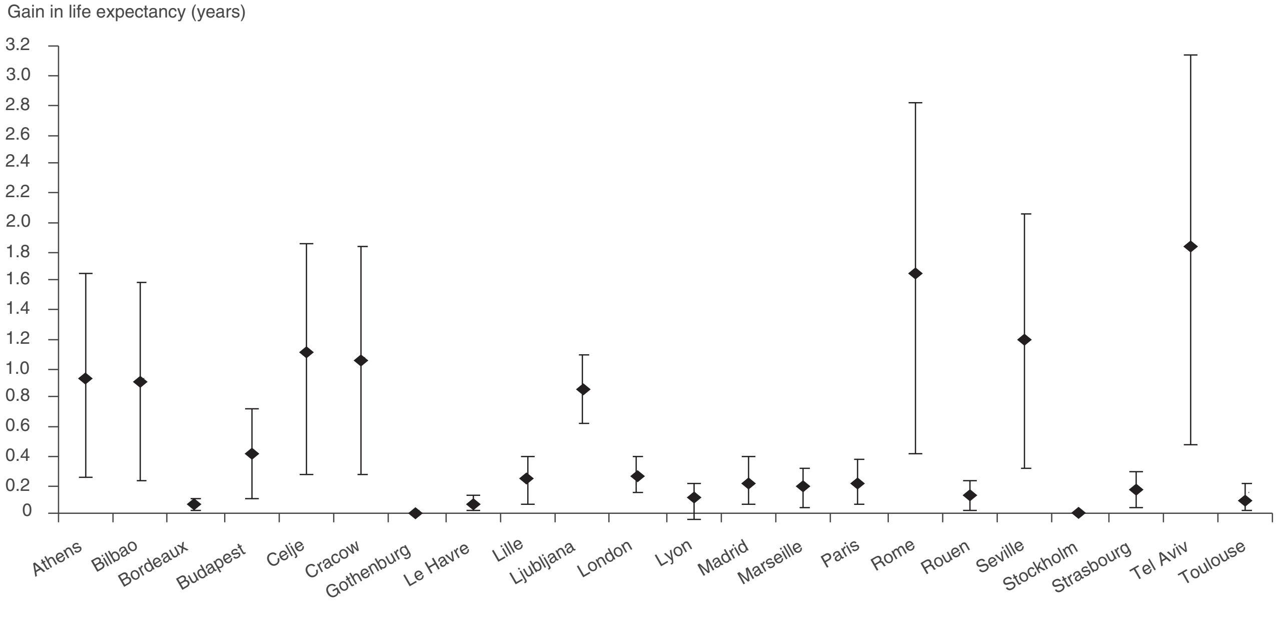
For both total and cause-specific mortality, the benefit of reducing converted $PM_{2.5}$ levels to 15 µg/m^3 is more than 30% higher than for a reduction to 20 µg/m^3. For this reason, we only presented the calculations in terms of life expectancy for the scenario where converted $PM_{2.5}$ levels would not exceed 15 µg/m^3.

For each city the following table and figure present the findings in terms of expected gain in life expectancy at 30 years of age if the annual mean of converted $PM_{2.5}$ levels did not exceed 15 µg/m^3.

Table 10. Expected gain in life expectancy at 30 years of age if the annual mean of converted $PM_{2.5}$ levels did not exceed 15 µg/m^3

City	Increase in life expectancy at age 30 Mean estimate (years)	Increase in life expectancy Low estimate (years)	Increase in life expectancy High estimate (years)
Athens	1.0	0.3	1.7
Bilbao	0.9	0.2	1.6
Bordeaux	0.1	0.0	0.1
Bucharest	2.3	0.6	3.9
Budapest	0.4	0.1	0.7
Celje	1.1	0.3	1.9
Cracow	1.1	0.3	1.8
Gothenburg	0.0	0.0	0.0
Le Havre	0.1	0.0	0.1
Lille	0.2	0.1	0.4
Ljubljana	0.6	0.2	1.1
London	0.2	0.1	0.4
Lyon	0.1	0.0	0.2
Madrid	0.2	0.1	0.4
Marseille	0.2	0.1	0.3
Paris	0.2	0.1	0.4
Rome	1.6	0.4	2.8
Rouen	0.1	0.0	0.2
Seville	1.2	0.3	2.1
Stockholm	0.0	0.0	0.0
Strasbourg	0.2	0.0	0.3
Tel Aviv	1.8	0.5	3.1
Toulouse	0.1	0.0	0.2

Figure 33. Expected gain in life expectancy at 30 years of age if the annual mean of converted $PM_{2.5}$ levels did not exceed 15 µg/m³



All other things being equal, if the annual mean of converted PM2.5 levels did not exceed 15 µg/m³, the expected gain in expected life expectancy of a 30-year-old person would range on average between 2 and 13 months, due to the reduced risk of death from all causes.

In this scenario, the gain in life expectancy would benefit all 23 cities. However, Tel Aviv, Rome and Seville followed to a lesser degree by Celje, Cracow, Athens, Bilbao and finally, Ljubljana and Budapest would show the greatest benefits. Swedish cities already present levels below 15 µg/m³.

The following figures illustrate for this last scenario the expected gain in life expectancy for successive ages in one city and then show by how much this gain would affect each age.

Figure 34 shows two curves for life expectancy in the city of Seville, taken as an example, for successive age groups:

1) Life expectancy if the annual mean of converted $PM_{2.5}$ remains as it is today in Seville.
2) Life expectancy if, all other things being equal, this annual mean did not exceed 15 µg/m³.

Figure 34. Life expectancy for current converted $PM_{2.5}$ levels and reduction to 15 µg/m³ in Seville

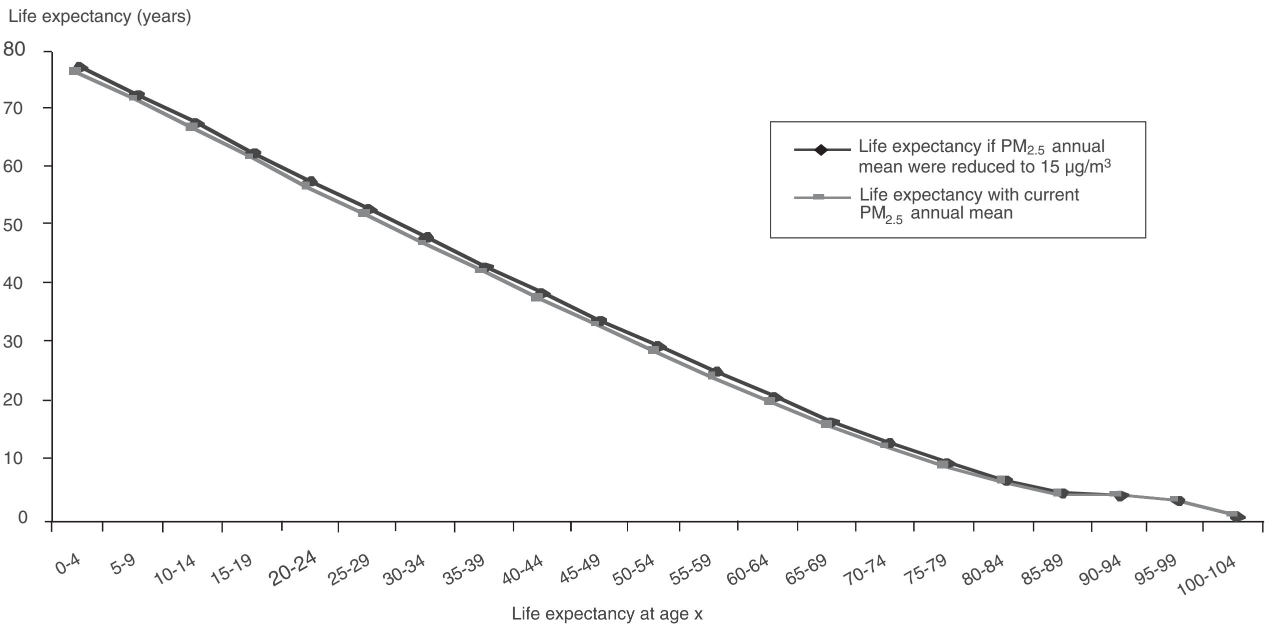
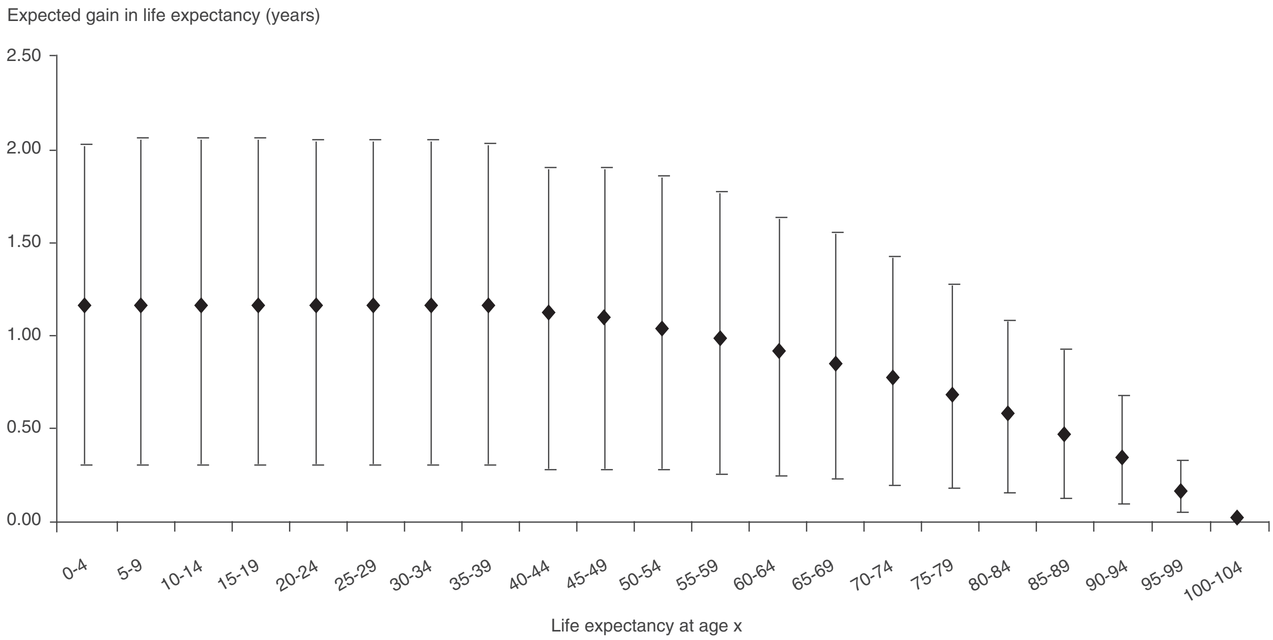


Figure 35 shows in detail the expected gain in life expectancy at each age. If, all other things being equal, the annual mean of converted $PM_{2.5}$ levels did not exceed 15 µg/m^3, the gain would remain greater than 1 year until 60 years of age and would then start decreasing.

Figure 35. Expected gain in life expectancy if $PM_{2.5}$ annual mean levels did not exceed 15 µg/m^3 in Seville



Findings in terms of years of life lost only appear in the city reports (www.apheis.net).

Interpretation of findings

This section reviews our objectives and discusses how we met them.

Objectives

The HIA part of this mainApheis-3 report has two main objectives:

1. Present a coherent methodology for local HIAs that the individual city-specific reports can use and refer to.
2. Establish a standard basis for comparing findings across cities; and report similarities and differences regarding both the application of methodologies and the HIA findings.

Causality assumption

Our HIA 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 and in the Apheis-2 scientific report.

A conservative approach

Various HIAs of the effects of air pollution focus on different pollutants and a different range of health endpoints in accordance with the purpose of the HIA.

Some HIAs seek to estimate monetary costs of the impact on health of such factors as a specific source of air pollution, or the monetary benefits of pollution reduction (ExternE 1999, 2001; Kunzli *et al.* 2000). These studies are intended to provide data for policy in order to compare the costs and benefits of a new development, or of a specific policy to control pollution. For this purpose, since it is important that the HIAs provide the most comprehensive picture possible of the impacts on health and so they use the most complete range possible of outcomes for which a risk estimate is available. Typically, as well as including mortality and hospital admissions, they also include respiratory symptoms, restricted-activity days, development of chronic bronchitis etc., i.e. they include outcomes where fewer studies support the evidence, but where impacts on health would be under-estimated if these outcomes were ignored.

Our HIA, on the other hand, seeks to provide a picture of the overall impact of air pollution on the health of the general population in urban areas in Europe. For this purpose, we chose a conservative, robust and, thus, less exhaustive approach, like the COMEAP study (1998, 2001):

- This enables us to have a strong common basis, well grounded in evidence, for comparing the health effects in different European cities – even if that common basis omits some effects where the evidence is less secure.
- It also means that, when results are discussed with policy makers locally, the scientific basis for the effects quantified is very strong.

In terms of practical implications, this strategy has some important consequences.

First, we only used exposure-response functions (E-R functions) or risk estimates that are well established.

Second, regarding the health outcomes described as associated with air pollution, we only included total and cause-specific mortality for both this general report and the city-specific reports, and hospital admissions only in city-specific reports. We did not consider many other health outcomes potentially relevant for an HIA as proposed by WHO (WHO 2001).

Third, we did not consider vulnerable subgroups of the population as defined by age or history of diseases (WHO, 2004).

And finally, regarding the air pollutants that could be considered, we limited our analysis to particulate pollution as a surrogate for the complex air-pollution mixture. There is a case for also evaluating an independent effect of ozone, but the particulate effects are the dominant ones.

We used three particulate indicators in order to provide a range of possible impacts of air pollution on health using different exposure-response functions, different cities and different age-groups. It should be noted that it is of crucial importance that HIA findings shown for different scenarios and different particulate indicators not be added together. This is because the pollutants are highly correlated, some of the impacts provided by one indicator may already be included in another indicator, and some of the impacts provided in one scenario are already included in another scenario.

Threshold considerations

Because the E-R functions we used in this HIA are linear, we did not assume any threshold in our calculations. 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 (Schwartz *et al* 2000, Daniels *et al* 2000). This viewpoint is especially well recognised with regard to particulate pollution (WHO, 2004). In particular, analyses of the effects on mortality of long-term exposure to $PM_{2.5}$ give no indication of a threshold of effects.

Instead of choosing a single reference level, our HIA proposes a range of reference levels of particulate pollution used in different scenarios.

Other methodological considerations

HIAs only provide estimates of the true health impacts, and our HIA, like other HIAs, estimates the number of events (deaths or hospital admissions) that can be attributed to exposure to particulate air-pollution in a specific city. We have expressed these numbers both in absolute terms directly related to the size of the population studied, and as rates per 100 000 inhabitants to allow comparisons between cities.

To gain a better sense of the overall uncertainty of these estimates, we followed WHO recommendations (WHO 2000, 2001) and we conducted sensitivity analyses as part of our exploration of important HIA methodological issues.

In the following pages we will describe these methodological considerations for:

- exposure assessment;
- health outcomes and baseline or background rates;
- exposure-response functions;
- statistical tools.

Exposure assessment

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.

As described in Appendix 3 on exposure assessment, the exposure measurements used in Apheis-3 were compared to and interpreted using of the Apheis Guidelines on Exposure Assessment.

Measurement intervals for air quality indicators

Because the E-R functions selected for HIA of short-term exposure use the 24-hr average measurement interval, 24-hr averages for PM_{10}, $PM_{2.5}$ and BS were recommended by the Apheis guidelines, and the

Apheis cities complied with the given recommendations for all monitoring stations. For HIAs of long-term exposure, E-R functions selected used annual levels, and so did the Apheis cities.

Number of stations and site selection

Altogether 142 monitoring stations were selected for HIAs in accordance with the Apheis site selection criteria. In a few cities, only one or two stations were used but they were background stations and thus provide a partial view of the population exposure. In three cities, 28 stations were classified as directly traffic-related and theoretically should be excluded for HIA calculations. Despite this, the data from these stations was used for HIA because: 1) local experts considered they were representative of the population's exposure in those cities; 2) E-R functions used for HIAs of short-term exposure used these direct traffic-related stations, although not the studies selected for HIAs of long-term exposure.

Measurement methods

The PM_{10}/$PM_{2.5}$/BS/TSP measurement methods were reported completely. Automatic PM_{10} measurement methods (the ß-ray absorption method and the tapered oscillating microbalance method (TEOM)) were used. $PM_{2.5}$ measurements were done only by TEOM. Reflectometry is the method commonly used to measure BS. TSP was measured by the ß-ray absorption method in one city and by gravimetric method in the other.

Correction factors

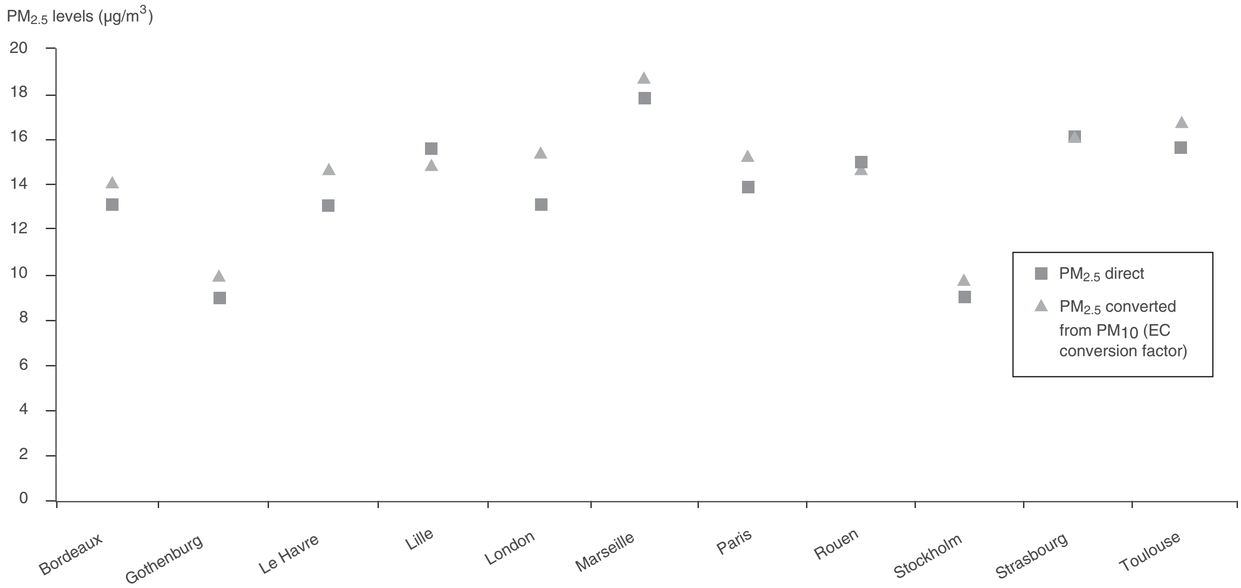
None of the cities used the European PM_{10} reference method (gravimetric method) for their PM measurements. As a reminder, for long-term HIAs of PM_{10} and $PM_{2.5}$, because the E-R functions used were taken from the ACS study that used gravimetric methods, to be consistent we had to correct the automatic PM_{10} measurements by a specific correction factor (local or, by default, European) in order to compensate for losses of volatile particulate matter. Cities where the information was available could use local correction factors. In actual fact, after consulting the reference laboratory in France, the French cities decided to use two correction factors based on comparative local measurements using gravimetric and TEOM methods: one for summer (moderate levels of PM: 1-1.18) and one for winter (increased levels of PM: 1.2-1.37). In general, local conversion factors were slightly lower than the European factor of 1.3 recommended by the EC Working Group on Particulate Matter.

Conversion factors

Besides this correction factor, conversion factors (local or European) were given for calculating PM_{10} from TSP measurements, as well as for $PM_{2.5}$ data calculated from PM_{10} measurements. As a reminder, the default factor of 0.7 for $PM_{2.5}$ was recommended by the Apheis Exposure Assessment Working Group as a mean value based on two different recent publications. First, as part of the process of revising and updating the so-called 1st European Daughter Directive, the 2nd Position Paper on Particulate Matter (draft of 20 August 2003, available for the PM Meeting in Stockholm) presents the results from 72 European locations reported by several Member states from 2001. It gives $PM_{2.5}$/ PM_{10}= 0.65 (range 0.42-0.82, se = 0.09). Second, Van Dingeren *et al.* (2004) recently published a European research activity, with a smaller number of stations (11 stations), giving the ratio = 0.73, se = 0.15 (range 0.57-0.85).

Figure 35 presents, for Apheis cities that could compare both, the annual mean levels of $PM_{2.5}$ directly measured and $PM_{2.5}$ converted from PM_{10} calculated using the European conversion factor (0.7). As we can see, except in Lille, Rouen and Strasbourg, the annual mean of $PM_{2.5}$ measured directly is lower than the annual mean levels of $PM_{2.5}$ converted from PM_{10} calculated using the European conversion factor. It could imply that the European conversion factor is a little too high. In fact, the average local conversion factor is 0.66, very close to the one proposed by the 2nd Position Paper on Particulate Matter (2003).

Figure 35. Comparaison of $PM_{2.5}$ annual mean levels direct vs converted from PM_{10} using the EC conversion factor (µg/m³)



Estimates of corrected PM_{10} and converted $PM_{2.5}$ for HIAs of long-term exposure may thus be high. We could conclude that, if there were no other uncertainties elsewhere, mortality estimates related to long-term exposure to PM_{10} and $PM_{2.5}$ could consequently be higher too. But there are many other sources of uncertainties that may contribute to under (or over) estimate the impact: transferability of E-R functions, number of air-pollution and health indicators considered for HIA, including or not including sensitive sub-groups of the population, and other sources of uncertainties that are described in this section.

Quality assurance and control (QA/QC), and data quality (DQ)

Most cities reported that QA/QC activities were implemented. All cities reported that the DQ could be assessed and validated.

We concluded that, overall, the assessment of exposure data in Apheis-3 was sufficiently reliable for our HIA purposes.

Health outcomes and baseline rates

Regarding health outcomes, Appendix 6 describes the data provided in detail.

Mortality data

The information sources for mortality data were the national, regional or local mortality registries for all the cities. Mortality rates were the highest in eastern cities in Europe.

In Apheis-3, cause-specific mortality was included besides all-causes mortality as complementary information to enrich the mortality picture. But all-causes mortality remains our first choice because it is more robust, not subject to misclassification and easier to obtain. In addition to the number of cases, life-expectancy calculations were made using total mortality in people of 30 years of age.

Given that most of the cities applied a quality-control programme and given the low percentage of missing data for all-causes mortality, we consider that erroneous entries in the selection of cause of death did not affect the comparability of the data between cities.

Hospital admissions data

To estimate the acute effects on hospital admissions of short-term exposure to air pollution, we have selected hospital admissions for residents of each city with discharge diagnoses of respiratory diseases (ICD9: 460-519; ICD10: J00-J99) and cardiac diseases (ICD9: 390-429; ICD10: I00-I52). Whenever possible we only used emergency admissions as being more specifically related to air pollution, and we used discharge diagnoses for all-cases because they are more reliable.

All the cities obtained the data from registries. The completeness of the registries on hospital admissions was quite high, being 95% or more in 18 of the 22 cities. We didn't know this percentage in two cities (London and Tel Aviv). Barcelona and Valencia had a slightly lower level of completeness. In Apheis-2, French cities (Bordeaux, Lyon, Le Havre, Lille, Marseille, Paris, Rouen, Strasbourg and Toulouse) only included public hospital admissions, while the completeness has been 100% in most of these cities in Apheis-3.

All the registries run a quality-control programme, and completeness of the diagnosis of the cause of admission was quite high, with a percentage of missing data of 1% or lower in 19 of the 22 registries. We didn't know this percentage in three cities (London, Tel Aviv and Valencia).

For cities with emergency admissions, respiratory admissions cluster closely. Cardiac admissions show greater variability, but the extreme difference (Stockholm against Valencia) shows a factor of more than two. In the literature, within western Europe a north-south gradient is described for cardiovascular diseases and even more striking for ischaemic heart disease, with some "reverse" inequalities in southern Europe (Mackenbach *et al*, 2001).

The main problem for comparability remains the difference in the availability of information in the registries, because some cities used emergency admissions, while others that lacked this information used total admissions. The information sources used in Barcelona, Bilbao, Budapest, Gothenburg, London, Madrid, Seville, Stockholm and Valencia allowed selecting emergency admissions. Yet for Bordeaux, Celje, Le Havre, Lille, Ljubljana, Lyon, Marseille, Paris, Rome, Rouen, Strasbourg, Tel Aviv and Toulouse, it was not possible to distinguish between emergency and total admissions.

Methodologically speaking, statistical analyses of the APHEA-2 cities showed no significant heterogeneity in the estimated RR of hospital admissions between cities that reported general hospital admissions and those that reported emergency hospital admissions only (Atkinson 2001, Le Tertre 2002). This might seem surprising initially but in fact is very reasonable. General admissions include both planned and emergency admissions, and when controlling for season we also control for general trends for both, leaving emergency admissions and some background noise.

This does raise an important issue for HIA if general admissions are used rather than emergency ones and if the same RR is applied. We should investigate the possibility of using a correction factor from emergency admissions and apply it to general admissions. There is a need to examine this and other approaches to determine how best to handle the difficult situation of HIAs when baseline data are unknown, or missing, or collected using different conventions.

The analysis of health data quality and availability concludes that, for local use in each city, the selected data was 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, such comparability was limited for the incidence of hospital admissions, because some cities used emergency admissions while others used total admissions, and the incidence rates from these two types of admissions (Figure 5) do not appear to be fully comparable. Consequently, we only present data for hospital admissions and the consequent HIAs in the city-specific reports, and our study still stresses the need to promote the use of more-uniform hospital admissions data in Europe.

Choosing the exposure-response functions

HIAs of short-term exposure

Two HIAs of short-term exposure

For the first time in Apheis, we conducted two HIAs of short-term exposure using two types of exposure-response functions: for a very short-term exposure (usually 1 or 2 days) and for a cumulative exposure (up to 40 days). Our objective was to better understand the effects of particulate pollution on health over time for short-term exposures.

For the very short-term exposure, we used a new exposure-response function developed by Apheis-3 for all-ages respiratory admissions (Appendix 2). We also used exposure-response functions newly developed by WHO from a meta-analysis of time series and panel studies of particulate matter (PM) **http://www.euro.who.int/document/E82792.pdf.**

For the cumulative short-term exposure (up to 40 days), in Apheis-3 we also used Zanobetti's (2002, 2003) estimates using distributed-lag models that showed the cumulative effect was more than twice that found using only 2 days of follow-up.

HIA of short-term exposure on respiratory admissions for all ages

In Apheis-2 the HIA was performed for respiratory admissions > 65 years because it is well-known that acquired susceptibility from chronic diseases increases with age (WHO 2004). Nevertheless, below 65 years air pollution also has an impact on health. We then decided to study the impact of particulate pollution on respiratory admissions for all ages. Because in the literature there was no E-R function for all-ages respiratory admissions, it was decided in Apheis-3 to provide this new E-R function (see Appendix 4) and calculate the consequent health impact.

Transferability of E-R functions for short-term exposure

The question of transferability of E-R functions is not a matter of concern for short-term exposure since most of the Apheis cities are some of the cities where the E-R functions were estimated.

Sensitivity analysis using different types of estimates

As stated briefly in the "Methods" section, most HIAs, including Apheis HIAs, use overall estimates from multi-centre studies. But in some cases, people doing an HIA in a particular city where an epidemiological study has been conducted providing local E-R functions prefer to use city-specific estimates. The Apheis statistical advisory group conducted a sensitivity analysis in some cities to address this issue, using different effect estimates (observed city-specific, shrunken city-specific, pooled, mean of shrunken city-specific and adjusted for effect modifiers) to calculate the number of "premature" deaths in each city.

The study concluded that, although the sum for 21 European cities of the deaths attributable to PM_{10} is not strongly influenced by the method used to estimate RRs, this is not true at the city level. Applied to a single city, the different estimates tested present benefits and limits, and based on these limitations the authors recommend using the shrunken estimate in cities for which this option is available. This shrunken estimate has the property to derive the overall estimate at the local level by combining information from the city-specific estimate and the overall one and can be considered as a weighted mean between these two estimates. The shrunken estimate also reduces the variability of the local estimate by incorporating information from other cities. The shrunken-estimates approach has already been explored and applied to air pollution (Post *et al*, 2001). A key disadvantage of such an estimate is that it can only be applied in cities that formed part of the initial analysis. The use of this type of estimate will be proposed at the city level in the next Apheis HIA. A full description of this analysis appears in Appendix 5.

HIAs of long-term exposure

In Apheis-3, long-term HIAs were conducted in terms of number of "premature" deaths for PM_{10} and $PM_{2.5}$ and in terms of expected gain in life expectancy for $PM_{2.5}$.

For long-term exposure to particulate pollution, European E-R functions were still not available at the time the study was conducted.

Transferability of E-R functions for long-term exposure

In Apheis-3, for $PM_{2.5}$, we used an update of the ACS study (Pope, 2002) covering 1.2 million adults in 50 states that 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 for PM_{10}. But the question of transferability of estimates between the U.S. and Europe raises uncertainties, since the particulate mixtures and populations can differ between the two continents.

Also relevant for transferability are differences in methods used in the U.S. and Europe for exposure measurement, e.g., $PM_{2.5}$ gravimetric vs automatic methods. We used a correction factor for PM_{10} observed values to compensate for losses of volatile particulate matter. But, on the other hand, the application of this correction factor may be another source of uncertainty in our HIAs.

We should also be cautious if the E-R functions used were extrapolated to a city with particulate levels beyond the range of the original study. This also applies for HIAs of short-term exposure. On the other hand, the general linearity of the E-R functions within the ranges studied gives some reassurance that extrapolation beyond these ranges should not be seriously misleading.

The question of transferability is unlikely to be a concern for the health outcomes we used, since they are limited to total and very broad cause-specific mortality.

Statistical tools

Short-term and long-term number of cases

For our HIA's statistical method, we used WHO guidelines (WHO 2001) as a starting point and also developed our own standardised statistical and HIA guidelines (Medina *et al.* 2001).

Calculations for short- and long-term number of cases were conducted using an Excel spreadsheet (Appendix 7) developed by the French surveillance system on air pollution and health, PSAS9 (Le Tertre *et al.* 2002).

When building our own E-R functions on respiratory admissions for all ages, we used the APHEA 2 methodology (Katsouyanni *et al* 2001) taking into account the problems with GAM raised by NMMAPS (Dominicci 2002) and investigating the sensitivities of the estimated pollution effects by using alternative smoothing techniques, parametric and non-parametric, and by using a range of smoothing parameters. These analyses are described in detail in Appendix 4.

Gain in life expectancy and years of life lost

For the first time in Apheis, we calculated the gain in life expectancy and years of life lost (YoLL). For this purpose we used the WHO-ECEH AirQ 2. 2. 2. software based on the methods summarized by Miller BG in WHO, 2001.

As explained in the "Methods" section, life expectancy calculations are based on the following considerations: the survival curve for a birth cohort predicts the temporal pattern of deaths in the cohort. Expected life from birth can be calculated by summing the life years over all period and dividing by the size of the starting population. Conditional expectation of life, given achieving a certain age, can also be calculated by summing the years of life at that age and later, and dividing by the number achieving that age (Miller BG in WHO, 2001).

Life expectancy with zero mortality for one cause can be used to indicate the relative importance of an illness. A life table is calculated assuming the complete elimination of a particular cause, and the resulting hypothetical life expectancy is compared with the actual life expectancy (Romeder and McWhinnie, 1977). The greater the difference, the greater is the relative importance of the cause. In air-pollution HIAs, a similar approach can be used, and actual life expectancy can be compared with the hypothetical life expectancy obtained for the baseline scenario. For that purpose, hazard rates must be predicted in the baseline scenario. In Apheis we assumed the same proportional hazard reduction for every age-group, and calculated hazard rates of the baseline scenario by dividing the actual hazard rates by the corresponding relative risk.

In general, our HIA aimed at providing an average effect for the whole population because, as stated by Künzli, (2000), a relatively minor deterioration in the average of the outcome for the whole population may reflect an important shift in the proportion of seriously affected individuals within a population. Indeed, our HIA did not focus on sensitive subgroups defined by their history of disease or their age. However, as an example of the potential gain in life expectancy if $PM_{2.5}$ levels were reduced, calculations were made for an adult of 30 years.

Years of life lost calculations were also conducted using AirQ. However, since YoLL calculations express the same kind of information as gain in life expectancy, it was decided not to include them in this main report. Instead they appear in each city report for total and cause-specific mortality.

Conclusions and recommendations

What's more important: Long-term or short-term? Number of deaths or gain in life expectancy?

Long-term vs. short-term

When interpreting the findings on annual mortality, we should remember that the main effects of air pollution are associated with long-term exposure. Most of the acute effects on mortality are included in effects of long-term exposure and represent around 15% of these chronic effects, when judged in terms of the number of attributable cases. But not all short-term health impacts are included in the long-term impacts (Medina *et al.,* in press, Kunzli *et al.,* 2001). It was interesting to note that the cumulative short-term impact over up to 40 days was more than twice that found using only 2 days of exposure follow-up (Zanobetti *et al.* 2002), showing that air pollution does not simply displace mortality by a few days. Consequently, omitting E-R functions from time series would lead to under-estimating the short-term impact on mortality.

Number of deaths vs. gain in life expectancy

Attributable cases are often interpreted as the preventable fraction, meaning those that would have been prevented had exposure been removed. However, caution should be used with such an interpretation. First, the benefit of removing a particular exposure can only rarely be estimated. The benefit may be achieved much later than predicted, or not to the full extent predicted. In our case, lower air pollution levels would take years to be fully achieved. Second, the attributable risk estimation does not take competing risks into account. Removing one risk factor, e.g., air pollution, will increase the relative importance and contribution of other risks and causes of morbidity and mortality. Accordingly, for multicausal diseases it is well known that the sum of attributable cases across several risk factors does not add up to 100% but may be larger. Nevertheless, recent intervention studies (Heinrich *et al,.* 2002, Hedley *et al.,* 2002, Clancy *et al.,* 2002, Friedman *et al.,* 2001) do indicate the reduction in mortality and morbidity after decreases in air pollution.

For the time being, expressing mortality findings in terms of "premature" deaths per year is an easy-to-understand way of communicating health/mortality impacts. It gives a picture at one point in time. Another way of expressing mortality findings is in terms of expected gain in life expectancy, which provides a more dynamic picture.

The magnitude of the problem

What is the contribution of particulate pollution to the total burden of mortality in the Apheis cities? One way of assessing the magnitude of the problem is to calculate within the total number of deaths observed and reported by each city the percentage of "premature" deaths attributable to reducing PM levels to 20 µg/m^3.

In our HIA for PM_{10}, exposure has focused on very short-term, cumulative short-term (raw PM_{10} levels) and long-term effects (corrected PM_{10} levels). All other things being equal, when only considering very short-term exposure, the proportion of all-causes mortality attributable to a reduction to 20 µg/m^3 in raw PM_{10} levels would be 0.9% of the total burden of mortality in the cities measuring PM_{10}. This proportion would be greater for a cumulative short-term exposure up to 40 days (1.8%). For long-term exposure to corrected PM_{10} levels, it would be 7.2%.

For BS, only very short-term exposure (raw levels) was considered. All other things being equal, the proportion of all-causes mortality attributable to a reduction to 20 µg/m^3 in BS levels would be 0.7% of the total burden of mortality.

Lastly, for long-term exposure to $PM_{2.5}$ converted from corrected PM_{10}, all other things being equal, the proportion of all-causes mortality attributable to a reduction to 20 µg/m^3 in converted $PM_{2.5}$ levels would be 4% of the total burden of mortality.

As we can see, the contribution to the total burden of mortality of short-term, cumulative short-term and long-term exposure to particulate air pollution is not negligible. Public health will be better served if we recognise not only that air pollution exposure is hazardous, but also determine the magnitude of this hazard.

Implications for policy making: air pollution indicators and limit values

PM vs. BS

There is substantial toxicological and epidemiological evidence of the effects of PM on mortality and morbidity. And it has been highlighted that primary, combustion-derived particles have the highest toxicity (WHO 2004). PM_{10}, BS and $PM_{2.5}$ are important indicators of PM, and respective HIA findings show that the estimated impacts are significant. However, because these three pollutant indicators are highly correlated, HIA findings must not be added together.

PM_{10} levels are already regulated by the European Commission, and the Position Paper on Particulate Matter, prepared for the CAFE programme, postulates using $PM_{2.5}$ as a principal metric to assess PM exposure. Unfortunately, black smoke regulation has ceased, and no European Directive is planned for BS by 2005 or by 2010. Nevertheless, this air-pollution indicator, which has been measured for many years in most European cities, represents small black particles (less than 4 µm in size) with measurable health effects and may be considered as a good proxy for traffic-related air pollution closely related to diesel engine exhaust in urban areas (WHO 2003).

Given the evidence currently available, policymakers should consider the air-pollution mixture as a whole for setting standards, and not favour some air-pollutant indicators over others.

PM_{10}: Meeting 2005 and 2010 European limit values

The year 2005 is almost here, and European the annual limit value of 40 µg/m^3 for PM_{10} is still exceeded in a few Apheis cities in southern and eastern Europe, although 18 of the 23 cities that measured PM_{10} already meet the annual cut-off of 40 µg/m^3. However, excepting the two Swedish cities, the 2010 annual limit value of 20 µg/m^3 for PM_{10} is exceeded in most Apheis cities, although London and 8 of the 9 French cities show levels close to 20 µg/m^3. Incentives to reduce PM_{10} levels in the short and medium terms are needed to help further reduce air-pollution levels. A coordinated initiative by European legislators and national and local policy-makers could help achieve this goal.

$PM_{2.5}$: 20 or 15 µg/m^3 for the European limit values?

Our HIA provides new evidence for the ongoing discussions that will set limit values for $PM_{2.5}$ as part of the CAFE legislation process for the European Commission : (**http://europa.eu.int/comm/environment/air/café/index.htm**). In Apheis-3, for both total and cause-specific mortality, the benefit of reducing $PM_{2.5}$ levels to 15 µg/m^3 is more than 30% greater than for a reduction to 20 µg/m^3. Thus, for public-health reasons, our HIA recommends 15 µg/m^3 as the limit value for $PM_{2.5}$. However, because a significant health impact will be expected even at 15 µg/m^3, further reductions in pollution are advised as seen in the 3.5 µg/m^3 scenario.

Implications for communicating Apheis' findings better to policy makers

As a reminder, the Apheis programme seeks to meet the information needs of individuals and organizations concerned with the impact of air pollution on health in Europe; and most importantly the needs of those individuals who influence and set policy in this area on the European, national, regional and local levels.

Doubts about the ability of Apheis' scientific reports alone to meet the needs of this key audience led us to develop a communications strategy based on learning this audience's needs directly from its members.

Our research showed in particular that:

- Policy advisors and makers are generally unlikely to use the scientific reports we develop as is, contrary to scientists.
- Policy advisors and makers comprise scientific and policy users and each of these groups has different problems to solve, different ways of processing information, different levels of scientific knowledge and different cultures, meaning each group has different information needs.
- A long, complex chain comprising many players leads from the scientists to whom we distribute our reports directly, and who use them, to the policy makers who ultimately have the greatest effect on public health, but who only receive our reports indirectly and use them rarely, if at all.

Based on this evidence, we concluded that Apheis needs to act proactively to:

- Apply the above knowledge to the way it shapes and delivers its information and messages.
- Develop a range of communications tools that goes beyond our comprehensive scientific reports to include summary reports, brochures, presentations and Q&As whose focus, content and form are tailored to the separate information needs of scientific and policy users.
- Ensure that the information needed by policy advisors and makers actually reaches them.

Taking these steps will greatly enhance the way Apheis communicates with the key audiences that set policy on air pollution in Europe, and will thus help Apheis contribute better to improving public health.

Conclusion

Apheis-3 established a good basis for comparing methods and findings between cities, and explored important HIA methodological issues.

To provide a conservative overall picture of the impact of urban air pollution on public health in Europe, like its predecessor Apheis-2 the Apheis-3 project used a limited number of air pollutants and health outcomes for its HIAs.

Apheis-3 added more evidence to the finding in Apheis-2 that air pollution continues to pose a significant threat to public health in urban areas in Europe. And it added further support to WHO's view that "it is reasonable to assume that a reduction of air pollution will lead to considerable health benefits." And, at least for particulate pollution, our findings support WHO's already strong recommendation for "further policy action to reduce levels of air pollutants including PM, NO2 and ozone" (WHO 2004).

Future steps

The Apheis communications strategy will be implemented when funds are allocated to developing the different communications tools recommended for each of our target audiences.

While continuing the development of HIAs of outdoor air pollution, Apheis will join the ENHIS project (Environment and Health Information System) of the WHO-European Centre for Environmental Health (ECEH) co-sponsored by the European Commission and ENHIS's partners.

In this new project, Apheis will coordinate health impact assessment issues; it will test and adapt, in new cities and for new environmental risk factors, the methodology developed by Apheis; and Apheis will establish interactions with other kinds of impact assessments. The ultimate goal of this new phase of Apheis' work is to provide a global picture of the environmental burden of disease in Europe.

Special thanks

Last but not least, the huge amount of work behind these pages is the fruit of the generous and constructive input from all the members of the Apheis network. We wish to extend our special thanks and appreciation to all of them.

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Appendix 1

Developing An Apheis Communications Strategy

Prepared by Michael Saklad, Saklad Consultants
in conjunction with Sylvia Medina and Antoni Plasència

August 14, 2002

Background

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

To meet this objective, during its first year, 1999-2000, Apheis created five advisory groups in the fields of public health, health-impact assessment, epidemiology, exposure assessment and statistics. These groups drafted guidelines that define the best indicators for epidemiological surveillance of the effects of air pollution on public health in Europe, and provide a standardized protocol for data collection and analysis.

During this time, Apheis also conducted preliminary work to determine which entities in each of its 12 member countries were best able to implement an epidemiological surveillance system; understand how the different entities could work together on the local, national and European levels; and assess each entity's ability to implement, during the programme's second year, the guidelines drafted by the advisory groups. This preliminary work concluded that: most centres comply with the guidelines, and can provide basic, standardised reports on a periodic basis; and that some centres can provide advanced reports on complementary specific issues on a periodic basis.

During its second year, 2001, among other tasks Apheis is testing an epidemiological surveillance system in 26 cities in 12 European countries that will use the above guidelines to gather and analyse pertinent data. The findings will appear in a Summary Report.

Objective

Today, as the next step in fulfilling its mission, Apheis wishes to make its findings available to its different audiences, and facilitate the comprehension and dissemination of those findings.

Preliminary to doing so, however, Apheis first wishes to explore and understand how best to meet the information needs of the many European audiences concerned with the impact of air pollution on public health.

In specific, Apheis wishes to understand what those information needs are; whether the information contained in its Summary Report meets those needs; what other types of information are required to meet those needs; and what is the best form for presenting the necessary information.

Unfortunately, various considerations prevent investigating all its many audiences at this time. Consequently, as the objective of this project Apheis has chosen to explore and understand how best to meet the information needs of a single European audience, that of “government decision and policy makers.”

Methodology

Target audiences and research sites

Audiences concerned with the impact of air pollution on public health include such varied groups as: government decision and policy makers; the media that inform and influence government decision and policy makers and other audiences; environmental and health professionals who perform a similar role; industry and transport sectors, which include manufacturing industries and automotive manufacturers that directly or indirectly pollute the atmosphere; health-care providers who serve the needs of the public; vulnerable members of the population who seek to meet their special needs; and members of the general population.

Given various budgetary and time constraints, to meet the stated objective of this proposal Apheis has chosen in a first phase to conduct in-depth research on the information needs and behaviour of a single, key target audience from among the large number of target audiences that require information on the impact of air pollution on public health.

From all the potential target audiences that deserve investigation, we have chosen government decision and policy makers, since through its actions this audience probably has the greatest impact of all the target audiences on improving public health.

To gain the best possible understanding of the chosen target audience, we have decided to concentrate our investigations on members of this audience in a single country.

We believe that conducting this research in one country, the U.K., and specifically in one city within that country, London, that together have long experience in the area of air pollution and public health and in its communications aspects, will enable us to form a rich, clear and concise picture of the thought and communications processes, information needs and best practices for meeting the information needs of our chosen target audience.

We propose treating this research as a core case study.

At the same time, we recognize the limitations of conducting research in a single country. Indeed, cultural, historical, regional, environmental or other reasons may prevent our findings concerning the audience in this country from being directly applicable to the same target audience in other Apheis countries or to other key target audiences.

To make the findings of our core case study more useful by all Apheis members, and to respond to the important wishes expressed by the Apheis group, we propose enriching the findings of the core case study with the findings of a complementary case study conducted in a southern European city where levels of air pollution are high and people are just becoming aware of its damaging impact on public health. This complementary case study would be modelled on the first, and would seek to validate and broaden its findings.

Addition of the second city, it should be noted, will depend on final funding from the European Commission.

To further enrich the findings of these case studies and make them even more useful by all Apheis members, we propose asking all the member centres to provide comments and feedback on applicability of the case studies for developing local communications content and tools, and to indicate concerns and issues that pertain to such local work.

Deliverable

We would like the deliverable for this project to serve as an information bank or resource on which each Apheis centre can draw to inform and develop communications tools that meet the information needs of the chosen target audience in its own country.

For this purpose, Apheis proposes providing its members with a multipart deliverable that will include the findings of the two case studies and the local feedback, as outlined above, augmented by two other key parts: previous learnings; and a template.

We propose organizing the deliverable as follows:

Part A) Previous learnings: A report and synthesis of conceptual models, frameworks and/or current knowledge in the area of risk communication that pertain directly to the project's objective of meeting the information needs of all key target audiences concerning the impact of air pollution on public health.

Part B) Core case study: A case study conducted in London that reports the methodology used to explore the communications processes and to identify the information needs of the chosen target audience in the chosen country and city, and that reports best practices identified for understanding and meeting those needs. The case study would use targeted research as described in this proposal, possibly informed by the learnings identified in Part A.

Part C) Complementary case study: A case study conducted in a southern European city, and modelled on the core case study, that seeks locally to validate and enrich the findings of the core case study.

Part D) Local feedback: A summary of feedback and comments on the case studies and on local issues and concerns submitted by the various Apheis centres.

Part E) Template: Based on the case studies and local feedback from the Apheis centres, a report on considerations and best practices for identifying and meeting the information needs of the chosen target audience.

Subgroups to be investigated within the target audience

For the case studies, it should be noted that, while members of the chosen target audience can be grouped together under the single rubric of government decision and policy makers, this audience in fact comprises many key subgroups that merit investigation. Among others, these subgroups include combinations of the following:

- Individuals who make decisions directly regarding public policy
- Individuals who influence the making of such decisions
- Individuals active on the European, national, regional and local levels
- Individuals who recognize the benefits of reducing air pollution to improve public health and advocate such moves
- Individuals who reject, deny or question the benefits of reducing air pollution to improve public health, and who actively or passively oppose such moves
- Individuals who require information of a technical nature
- Individuals who require information of a nontechnical nature.

To obtain the best possible picture of our chosen target audience, for the core case study we propose conducting 28 interviews with individuals who combine the above characteristics in the following subgroups.

Subgroup of government decision and policy makers

By this subgroup we mean individuals in government who make policy decisions such as a European minister; a country's president or prime minister; a region's administrator; or a city's mayor.

Interviewing such key individuals would be highly informative, but unfortunately we can't reasonably expect to reach such busy people. Hence, we have decided to forgo interviews with this subgroup in favour of gathering information from the next subgroup, which directly influences this first group.

Subgroup of direct advisors to government decision and policy makers

This subgroup comprises those individuals closest to government decision and policy makers, and includes their direct advisors and members of their close political entourage. In these capacities, individuals in this subgroup advise the decision and policy maker directly, or the decision and policy maker consults them directly for opinions and recommendations.

To get a representative view of this subgroup, we propose conducting eight interviews that include a cross section of individuals from the European level; the national level; and the regional or local level.

We would like to obtain a good balance between those individuals who favour reducing air pollution to improve public health, and those who are sceptical of the benefits of reducing air pollution or oppose doing so.

And we would like to focus on individuals who require technical information.

Government decision and policy influencers

These influencers include representatives from three key subgroups: industry and transport; public health; and the environment.

Contrary to the previous subgroup, members of these subgroups are not direct political advisors to government decision and policy makers or members of such individuals' close political entourage.

However, they are members of European, national, regional or municipal government bodies who consult with, advise or otherwise influence the government decision and policy makers or members of their political entourage.

- *Subgroup of industry and transport sectors*

In this subgroup, we include manufacturing industries and automotive manufacturers that directly or indirectly pollute the atmosphere.

To get a representative view of this subgroup, we propose conducting six interviews that include a cross section of individuals from the European level; the national level; and the regional or local level.

We would like to get equal representation from both manufacturing industries and automotive manufacturers.

And we would like to get equal representation from individuals who require technical information and from individuals who require nontechnical information.

We expect that most individuals in this segment will be sceptical of the benefits of reducing air pollution or oppose doing so.

- *Subgroup of the public health sector*

To get a representative view of this subgroup, we propose conducting seven interviews that include a cross section of individuals from the European level; the national level; and the regional or local level.

And we would like to get equal representation from individuals who require technical information and from individuals who require nontechnical information.

While most individuals in this segment will be favourable to reducing air pollution, we would also like to interview at least two individuals who are sceptical of the benefits of reducing air pollution or oppose doing so.

- *Subgroup of the environment sector*

Our wishes for this sector are the same as for the public-health sector.

Again, we propose conducting seven interviews that include a cross section of individuals from the European level; the national level; and the regional or local level.

And we would like to get equal representation from individuals who require technical information and from individuals who require nontechnical information.

While most individuals in this segment will again be favourable to reducing air pollution, we would also like to interview at least two individuals who are sceptical of the benefits of reducing air pollution or oppose doing so.

Topics to be investigated

Apheis will conduct one-on-one, in-person, in-depth interviews with key members of subgroups of the chosen target audience of government decision and policy makers, as described above, with a larger number of interviews conducted for the core case study (28) than for the complementary case study (10).

This research will seek to learn, analyse and report on the following topics ideally, among others:

- What are the information needs of the target audience as end users concerning the impact of air pollution on public health
- What is the decision-making process of the target audience, how does the process work, and who else participates in the process
- Who specifically uses information on the impact of air pollution on public health. This includes the target audience itself as end users; and those individuals with whom the target audience communicates or whom it informs on the subject as part of the decision-making process, who require

and request such information from the target audience, and who are thus end users of the information in their own right

- How do the different individuals use that information
- For what purposes do they use that information
- What key messages or information are needed by specific groups of government decision and policy makers to raise their awareness of and encourage them to act on the impact of air pollution on public health
- What are the risks inherent in providing certain types of messages and information to certain groups, and what needs to be done to minimize these risks
- What other pitfalls need to be identified and avoided
- Which types of communications tools meet the information needs of the target audience, which don't, and why
- What sources do the different individuals draw on to obtain information on air pollution and its impact on public health
- What types of information do they seek from these sources
- How useful are these sources and the information they provide
- How well does the Apheis Summary Report meet the information needs of the different members of the target audience; is its content clear and understandable; is it relevant; is it usable
- What may be lacking in the content of the Summary Report and in how that content is presented to meet those various needs better, what needs to be changed, and how
- What is the best mechanism for delivering to the different members of the target audience the information they seek, and at what frequency.

Working group

Michael Saklad will design and track the project; review and advise on the methodology, findings, analysis and deliverable; and in general advise Rene van Bavel and ourselves on the project from a communications perspective to ensure its deliverable meets our target goals.

Rene van Bavel will implement the communications project.

Appendix 2

Description of Tasks

Apheis Communications Strategy Project

Prepared by Michael Saklad, Saklad Consultants
In conjunction with Sylvia Medina and Antoni Plasència

October 7, 2002

Background

As outlined in the project description entitled "Developing An Apheis Communications Strategy," the communications goals of the Apheis programme during its third year call for understanding how Apheis can best meet the needs of chosen target audiences who seek information on the impact of air pollution on public health.

In specific, Apheis wants to identify what those individual information needs are; test the usefulness of its second-year report and the information it contains in meeting those needs; identify what other types of information are required to meet those needs; and recommend best practices each centre can use to develop communications tools that meet the information needs of each target audience.

To meet these objectives, the final deliverable for the Apheis Communications Strategy Project will consist of a report on which both the European Commission and each Apheis centre can draw to develop effective communications tools.

The Apheis Communications Strategy Project, to be executed by April 2003, will comprise five successive parts, hereafter called "phases."

This document details the tasks involved in each phase; the chronological order in which the tasks will be performed; and who will perform the tasks.

The Apheis Communications Strategy Project has been designed by Michael Saklad, communications strategy consultant, in conjunction with Sylvia Medina and Antoni Plasència.

Phase A: Previous learnings and project design

During this phase, René van Bavel and Michael Saklad will familiarize themselves with key scientific and political issues in the area of air pollution and its impact on public health; with the processes by which individuals in the chosen target audiences gather information on this subject, and make and influence decisions concerning it; and with the nature of information Apheis can convey to its chosen target audiences currently and in the future.

Apheis project comanagers Sylvia Medina and Antoni Plasència will brief René and Michael by phone or in writing on these subjects and provide them with relevant background information.

René will then conduct desk research on conceptual models, frameworks and/or current knowledge in the area of risk communication directly applicable both to the project's design and methodology and to meeting the information needs of the chosen target audiences on the impact of air pollution on public health.

He will then prepare a short synthesis of his findings that will outline their applicability to design of the project and meeting information needs. The synthesis will form part of the project's preliminary and final reports.

Michael will read the synthesis to understand the learnings and their applicability to the project, and comment as needed.

Based on this information and on the project description outlined in “Developing an Apheis Communications Strategy” and in this document, Michael and René will refine the design of the overall project to ensure it meets the stated objectives.

Phase B: Core case study: Design of questionnaires, execution of study, and drafting of preliminary report

As outlined in “Developing An Apheis Communications Strategy,” to gather information on its chosen target audiences, during Phases B and C of this project Apheis will interview a total of 32 (revised from 38) members of the following three subgroups of government decision and policy makers and influencers:

- Direct advisors to government decision and policy makers
- Influencers from the public-health sector
- Influencers from the environment sector

(Note that budgetary reasons forced us to reduce the total number of subjects to be interviewed from 38 to 32, which caused us to remove the subgroup of industry and transport sectors originally planned for inclusion.)

During Phase B, the core case study, Apheis will interview 22 subjects from the three chosen subgroups in London and in other cities where European-level decisions are made relating to the situation in London or the U.K. Then during Phase C, the complementary case study, Apheis will interview 10 subjects from the same three subgroups in Madrid and Barcelona, but with greater emphasis on the first subgroup of direct advisors to government decision and policy makers.

The deliverable for Phase B will consist of a preliminary report on the work conducted in Phase A and on the core case study conducted in Phase B. Among others, the report will include the following sections.

Executive Summary

Project Description

- Background on the project
- Description of the project's objectives

Methodology

- Description of the project's methodology
- Synthesis of conceptual models, frameworks and/or current knowledge in the area of risk communication, and description of their applicability to project design

Findings

- General description of the three subgroups, their roles in making and influencing decisions in the area of air pollution and its impact on public health, and their information needs
- Separate detailed descriptions of each “target communications audience” identified. (As described below, these audiences, identified for targeting of the communications tools to be developed by the Apheis centres, are defined by their members' common information needs. These audiences may thus not exactly match the three subgroups studied, but will probably comprise members from across the individual subgroups.) For each target communications audience, the descriptions will cover:
    - *How its members think, feel and act concerning the impact of air pollution on public health*
    - *For what purposes they require information in this area*
    - *How they gather that information, analyze it, and use it themselves for their different needs and when communicating with others in the decision-making or -influencing process*

- Who else they share information with, and what the needs are of those other information users

- What types and levels of information they require for their different needs

- In what form do they wish to receive that information (how it should be organized, preferred types of collateral and design), and with what frequency

- What key messages or information would they like to have to raise awareness of the impact of air pollution on public health

- What risks are inherent in providing certain types of messages and/or information to them or to the general public, and what needs to be done to minimize these risks

- What other pitfalls need to be identified and avoided from a communications perspective

- What sources do they draw on to obtain information on air pollution and its impact on public health

- What types of information do they seek from these sources

- How useful are these sources and the information they provide

- Which types of communications tools meet their information needs, which don't, and why

- How useful is Apheis' second-year report in meeting their information needs; is its content clear, relevant, complete, and presented and framed in a way that meets their needs; what may be lacking; what needs to be changed.

• Summary of minicase studies provided by Apheis centres on their local communications experiences

Recommendations

• Summary of findings, and recommendations and best practices for identifying and defining individual target communications audiences and their common information needs

• Summary of findings, and recommendations and best practices for developing communications tools that meet the information needs of each specific target communications audience

To develop the content of the preliminary report, as part of this core case study, René will conduct in-person, taped interviews with members of the three chosen subgroups in London and in other cities where European-level decisions are made. René will subsequently analyze and summarize this information for inclusion in the preliminary report

To avoid influencing the subjects' responses, the interviews will identify the subjects' information needs before testing the usefulness of Apheis' second-year report in meeting those needs

As a reminder, as outlined in “Developing An Apheis Communications Strategy,” members of the subgroups Apheis has chosen to interview will include combinations of the following characteristics:

• Individuals who make decisions directly regarding public policy

• Individuals who influence the making of such decisions

• Individuals active on the European, national, regional or local levels

• Individuals who recognize the benefits of reducing air pollution to improve public health and advocate such moves

• Individuals who reject, deny or question the benefits of reducing air pollution to improve public health, and who actively or passively oppose such moves

• Individuals who require information of a technical nature

• Individuals who require information of a nontechnical nature

Developing a single communications tool that can effectively meet the needs of people with such diverse characteristics and, thus, a multiplicity of differing information needs is virtually impossible

For this purpose, within and across the subgroups we want to reach, Apheis will seek to identify individual target communications audiences whose members share similar information needs

With knowledge of such audiences and their common needs, it will later be easy for the Apheis centres to develop separate, focused communications tools tailored to the specific information needs of each audience.

Note that Ross Anderson, at the London Apheis centre, will identify the subjects to be interviewed in London in the three subgroups described in more detail in “Developing An Apheis Communications Strategy” and having the characteristics described there.

Previously, Sylvia Medina will have prepared an introductory letter on the project for the subjects to be interviewed.

Ross will then brief René and Michael on the individual subjects to be interviewed in London, and Ross or someone he recommends will also brief René and Michael on the pollution and political situations in London.

Michal Kryzanowski, Emile de Saeger and Marc Séguinot, at DG SANCO at the European Commission, will identify the subjects to be interviewed in other cities where European-level decisions are made relating to the situation in London or the U.K., again in the three subgroups described in "Developing An Apheis Communications Strategy." And they will also brief René and Michael on the individual subjects to be interviewed at the European level and on the pollution and political situations for the European level as those situations relate to London or the U.K.

Apheis assistant Claire Sourceau, with the help of the comanagers, will start making all the appointments as soon as possible, and she will start sending each subject a package containing the introductory letter, a statement ensuring the subject's anonymity, a confirmation of the appointment date, time and place, and a copy of the second-year report.

Ross, Michal, Emile and Marc should keep in mind that we will need to make about 25 percent more appointments than the number of subjects actually required, due to cancellations and other problems that routinely occur.

To enrich the research findings in London, Madrid and Barcelona and make them as useful as possible by all Apheis members, the project comanagers will solicit feedback and comments from the Apheis centres on local communications experiences in the form of minicase studies.

These should report on local experience gained when disseminating the HIA findings in the second-year Apheis report, when disseminating information on air pollution and public health from other sources, or both.

In particular, the comanagers will ask the centres to provide communications minicase studies in English that cover:

- The local pollution situation
- The political situation surrounding the local pollution situation (the stakes, the interests, the players)
- What information the three subgroups of direct advisors to government decision and policy makers, influencers from the public-health sector and influencers from the environment sector wanted from the centres
- What information the centres gave them
- How the decision makers and influencers used this information
- Who they communicated this information to or shared it with, and what those pass-on readers used the information for
- How well decision makers and influencers said the centre met their information needs (information type, level, quality, completeness, presentation; what was lacking).

Note that, since the purpose of the Apheis Communications Strategy Project is to understand the information needs of the target subgroups and how best to meet them, we are seeking communications minicase studies rather than technical success stories on reductions in air pollution. Further to discussions at our January meeting in Paris, however, we propose including the latter success stories in the second-year report when possible.

René will prepare a summary of the communications minicase studies. Michael will read the studies and René's summary, and comment as needed.

Preliminary to conducting the interviews, Michael will design the interview questionnaires for the different chosen target subgroups in order to gather data for the report sections listed above.

Concerning the interviews and relevance of the research to other cities and countries, as stated in "Developing An Apheis Communications Strategy," conducting research in London will enable us to tap into the city's long experience in the area of air pollution and public health and related communications aspects. At the same time, most change in pollution levels has already been achieved in London, and little new information today will make for more than incremental change.

To make data gathered in London more relevant to Apheis centres in cities and countries where discussions about air pollution and public health are in earlier stages, when Ross recruits subjects to be interviewed he will seek to locate people familiar with earlier reductions in pollution levels or having contributed to that change. And research in Phase B will ask London subjects to reconstruct the past when possible, and learn from them what information they required when pollution levels were higher.

When possible, presentation and analysis of data will be illustrated by highlights and quotes from specific interviews, and will note variations within the target communications audiences and feedback from the Apheis centres.

Michael will review the preliminary report and make recommendations, when needed.

René will then revise the report and send it to both comanagers, who will forward it to the participating Apheis centres for review and comments.

Phase C: Complementary case study: Design of questionnaires, execution of study, and revision of preliminary report

To the extent possible given the limited sample of 10 subjects, the work in Phase C will seek to validate the findings of Phase B in a setting with different political and pollution characteristics, and enrich the findings with local experiences. For this purpose, Phase C will comprise complementary research conducted in Madrid among national and regional decision makers and influencers, and in Barcelona among regional and local decision makers and influencers.

Since Phase C will build on the findings of Phase B, Phase C will be conducted after the field work and analysis of the findings in Phase B have been completed, rather than being conducted concurrently with Phase B.

The Apheis centres in Madrid and Barcelona will be responsible for identifying the subjects to be interviewed in the same three subgroups as in Phase B and having the characteristics described in "Developing An Apheis Communications Strategy"; briefing René on the individual subjects when possible; making the appointments; and briefing René on the local pollution and political situations.

Claire Sourceau, with the help of the comanagers, will send a package to each subject containing an introductory letter on the project (which Antoni Plasència and Mercedes Martinez will have translated into Spanish), a statement ensuring the subject's anonymity, a confirmation of the appointment date, time and place, and a copy of the second-year report. Concerning the latter, Mercedes and Toni will have translated into Spanish the city reports for Madrid and Barcelona. The Apheis centres in Madrid and Barcelona will need to make about 25 percent more appointments than the number of subjects actually required, due to cancellations and other problems that routinely occur.

René will concurrently draft a new set of questionnaires for Phase C. Michael will review and contribute to the questionnaires as needed.

René will interview the 10 subjects in Madrid and Barcelona.

After gathering and analyzing the data, René will incorporate a report on Phase C's findings in the preliminary report prepared after Phase B, and revise the report accordingly.

Michael will review the new preliminary report and make recommendations, as needed.

At the end of Phase C, René will present this new report to both comanagers for review, comments and possible revision.

Phase D: Local feedback: Feedback from the Apheis centres

During Phase D the project comanagers will submit the preliminary report from Phase C to the various Apheis centres for review and request their feedback.

In particular, the comanagers will ask the centres to comment in writing on local experiences, issues and concerns that may diverge from the report's findings, analysis and recommendations, and on actionability of the recommendations for developing their local communications content and tools.

René and Michael will review the feedback from the Apheis centres.

Phase E: Finalization of communications report

During Phase E, René will analyze local feedback, and incorporate his analysis and Michael's comments in the communications report.

Michael will review and make recommendations, as needed, on the report to ensure its recommendations are actionable by the European Commission and by the Apheis centres.

Appendix 3

Quality Control of exposure data (Hans Guido Müecke, Emile de Saeger)

Exposure Assessment

Hans-Guido Mücke and Emile De Saeger

In order to harmonise and compare the information relevant to exposure assessment of 26 Apheis cities in 12 countries a questionnaire was prepared by the Exposure Assessment Advisory Group (enclosed Annex 3). The following text summarises and interprets the findings of this group.

I. Table A

Annexed table A gives an overview on the air monitoring information compiling the results of questions 1 to 13 and 15.

Air monitoring stations

In total 174 PM_{10} /$PM_{2.5}$/BS/TSP measurements were operated at 147 air monitoring stations (partly multi component measurements), which were selected by the cities as exposure relevant and appropriate for calculating health impact assessments (HIA).

a) PM_{10}

PM_{10} was measured in 21 cities, which selected and evaluated 84 stations (48%) as exposure and HIA relevant.

b) $PM_{2.5}$

Nine cities measured $PM_{2.5}$ at 15 stations (9%), using the same site as for PM_{10} measurements.

c) Black Smoke (BS)

Sixteen cities measured BS at 63 exposure-relevant stations (36%).

d) Total suspended particulates (TSP)

Only two cities evaluate 12 TSP monitoring stations (7%) as appropriate for HIA.

As mentioned before, due to the fact that in twenty seven cases multiple measurements of PM_{10} and/or $PM_{2.5}$ and/or BS were done in parallel at the same site, 147 stations were finally considered for HIA evaluation (see table B).

Measurement methods

a) PM_{10}

The applied automatic PM_{10} measurement methods can be distinguished into the ß-ray absorption method (in 5 cities at 22 stations) and the tapered oscillating microbalance method (TEOM, which was applied in 16 cities at 55 stations).

b) $PM_{2.5}$

$PM_{2.5}$ measurements were done only by TEOM in 9 cities at 15 stations.

c) BS

Reflectometry is the commonly used measurement method of BS (in 16 cities at 63 stations).

d) TSP

TSP is measured by using ß-ray absorption method in one city, the second city uses the gravimetric method.

II. Tables B and C

Annexed tables B and C summarise the results of question 14 of Annex 3, which considered the classification types of exposure and HIA relevant air monitoring stations by measured pollutant (PM_{10}, $PM_{2.5}$, BS or TSP).

Classification of monitoring stations

Table B gives an overview of the classification of altogether 147 exposure and HIA relevant PM_{10}/$PM_{2.5}$/BS/TSP monitoring stations in all 26 Apheis cities.

The evaluation of table B is collated in table C. Due to parallel measurements (at 8 stations parallel measurements were done for PM_{10} and BS, at 11 stations PM_{10} and $PM_{2.5}$, and at 4 stations PM_{10}, $PM_{2.5}$ and BS were measured in parallel) the total number of exposure relevant monitoring sites in this respect is 174 (100%). In the majority of cases 118 monitoring stations (68%) are classified as urban residential. 32 stations (18%) were classified as traffic-related, 12 stations (7%) as sub-urban, followed by commercial (6%) and others (1%).

With regard to the requirements of the first Daughter Directive 1999/30/EC it can be concluded that about 80% of the reported air monitoring sites (classified as urban residential, commercial and sub-urban) can be considered as appropriate for HIA.

III. Table D

Annexed table D summarises the results of question 16 and 17 of Annex 3, which considered the use of correction or conversion factors for PM_{10} and $PM_{2.5}$.

PM_{10} correction factor

Twenty of 23 cities reported that they correct their PM_{10} data by a specific factor in order to compensate losses of volatile particulate matter occurring within automatic PM_{10} measurements (ß-attenuation and TEOM). Fourteen cities used a local correction factor with the advise of the local air pollution network; six cities used 1.3 European default correction factor (recommended by the EC working group on Particulate Matter; see: http://europa.eu.int/comm/environment/air/pdf/finalwgreporten.pdf), because no local factor was available. The remaining three cities do not apply a correction factor; two of them calculated PM_{10} from TSP.

$PM_{2.5}$ conversion factor

Twenty two cities reported on using of a conversion factor (ranging between 0.5 and 0.8) if $PM_{2.5}$ data have been calculated from PM_{10} measurements. Nine cities used a local conversion factor with the advise of the local air monitoring network. Twelve cities used 0.7 as default conversion factor, because no local factor was available. The default factor of 0.7 was recommended by the Apheis Exposure Assessment working group as a mean value resulting of two different recent publications. First, within the process of the revision and update of the so-called 1st European Daughter Directive the 2nd Position Paper on Particulate Matter (draft of 20 August 2003, available for the PM Meeting in Stockholm) presents the results from 72 European locations reported by several Member States from 2001 (page 73). It gives $PM_{2.5}$/ PM_{10} = 0.65 (range 0.42-0.82, se=0.09). Second, Van Dingeren *et al.,* (2004) published recently a European research activity, with a smaller number of stations, giving the ratio=0.73, se=0.15 (range 0.57-0.85).

One city applied monthly specific factors (between 0.3 and 0.63), and one city used real $PM_{2.5}$ measurement data.

IV. Interpretation and Conclusion

In the following chapter, the results of Annex 3 are compared to and interpreted in function of the Apheis Guidelines on Exposure Assessment.

Air quality indicators (PM_{10}, $PM_{2.5}$, BS and TSP)

The measurement interval of 24hour averages for PM_{10}, $PM_{2.5}$ and BS comply with the given recommendations for all monitoring stations. This occurred for the TSP measurements in two cities too.

Site selection

Altogether 142 monitoring stations (82%) are in accordance with the Apheis site selection criteria. It has to be considered that 32 stations are classified in a way that they theoretically should be excluded for further HIA calculations (in three cities 28 stations are classified as directly traffic-related).
Despite this, the data of these stations should be used for HIA, because there are still some uncertainties in the interpretation of used local classifications yet.

Number of stations

The number of reported HIA relevant stations varies broadly from city to city (ranging from 1 up to 23 for PM_{10}, and from 1 up to 11 for BS). It might be that in some specific cases only one or two stations for large cities could not reflect the population exposure correctly, and will maybe underestimate the exposure of the total urban population.

Measurement methods and factors

The PM_{10}/$PM_{2.5}$/BS/TSP measurement methods were reported completely. Concerning the use of TEOM the answer of the used probe temperature was given in ten of sixteen cases. Because the TEOM probe temperature can be changed there might be an unknown uncertainty. None of the cities used the European PM_{10} reference method (gravimetric method) for their PM measurements. For the purpose of long-term HIA on $PM_{2.5}$, because the exposure-response functions which was used are issued from a publication that used gravimetric methods (Pope *et al.,* 2002), we had to correct the automatic PM_{10} measurements (ß-attenuation and TEOM) by a specific correction factor (local or European) in order to compensate losses of volatile particulate matter. Besides this correction factors, conversion factors (local or European) were given for calculating PM_{10} from TSP measurements, as well as for $PM_{2.5}$ data calculated from PM_{10} measurements. The application of these correction and conversion factors may be another source of uncertainty in our HIAs.

Quality assurance and control (QA/QC), and data quality (DQ)

Most cities reported that QA/QC activities are implemented, which is not happened in two cities. All cities reported that the DQ could be assessed as validated.

As an overall conclusion, it can be stated that the Apheis Guidelines on Exposure Assessment are already in use in the centres with different degree of application. One big challenge of Apheis is the interaction of local and/or national environmental and health authorities. With regard to the broad variety of responsibilities in Europe the Apheis cities were able to contact the relevant environmental institutions to collate and pass reliable results for the exposure and health impact assessment of PM_{10}, BS and partly for $PM_{2.5}$ too.

References:

Pope A, Burnett R. Thun M *et al.,* Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA. 2002;287:1132-1141.

EC (2002). Guidance to member states on PM_{10} equivalent monitoring and intercomparisons with the reference method. (http://europa.eu.int/comm/environment/air/pdf/finalwgreporten.pdf).

Van Dingenen R., Raes F., Putaud J.P. *et al.,* A European aerosol phenomenology - 1: physical characteristics of particulate matter at kerbside, urban, rural and background sites in Europe. Atmospheric Environment 38 (2004); 2561 – 2577.

Appendix 3. Table A. Air Monitoring information ([1]Total area, [2]Area covered by air network, [3]4 week days (Monday-Thursday))

City	Area [1] (km²)	Area [2] (km²)	Popul. (Mio.)	PM 10	PM2.5	BS	TSP	PM 10 HIA	PM2.5 HIA	BS HIA	TSP	Interval	QA/QC	DQ	Method
Athens	350	350	3.0	8				6				cont.	yes	valid.	ß-attenuation
						3				2		24 h	yes	valid.	reflectometry
Barcelona	99		1.5			20	2			5		24 h	no	valid.	normalised smoke
Bilbao	117	117	0.7	5				4				cont	no	valid.	ß-radiation absorption
						6				6		24 h	no	valid.	reflectometry
Bordeaux	560	283	0.6	7				4				24 h	yes	valid.	TEOM
						4				4		24 h	yes	valid.	reflectometry
Bucharest[3]	238	180	2.0				5				4	24 h	yes	valid.	gravimetric
Budapest	524	524	1.8				8				8	cont.	yes	valid.	ß-ray-operation
Celje	265	400	0.05	1				1				cont.	yes	valid.	TEOM (50°C)
						1				1		24 h	yes	valid.	reflectometry
Cracow	320	320	0.7	5				4				24 h	yes	valid.	ß-gauge-monitor
						11				11		24 h	yes	valid.	reflectometry
Dublin	113	113	0.5	3								24 h	yes	valid.	
						14				6		24 h	yes	valid.	reflectometry
Göteborg	282	282	0.5	4	1			1	1			cont.	yes	valid.	TEOM (50°C)
Le Havre	199	199	0.2	3	2			3	2			cont.	yes	valid.	TEOM (50°C)
						6				2		24 h	yes	valid.	reflectometry
Lille	612	612	1.1	7	2			6	2			cont.	yes	valid.	TEOM (50°C)
						3				2		24 h	yes	valid.	reflectometry
Ljubljana	902	400	0.3	2				2				cont.	yes	valid.	TEOM (50°C)
						3				3		24 h	yes	valid.	reflectometry
London	1600	1600	6.9	11	2			1	1			cont.	yes	valid.	TEOM
						8				1		24 h	yes	valid.	reflectometry
Lyon	500	132	0.8	5	2	1	1	2		1		cont.	yes	valid.	TEOM
Madrid	606	606	2.9	25				23				cont.	yes	valid.	TEOM
Marseille	355	355	0.8	4	2			3	2			cont.	yes	valid.	TEOM (50°C)
						4				2		24 h	yes	valid.	reflectometry
Paris	762	762	6.2	7	1			7				hourly	yes	valid.	TEOM
						10				10		24 h	yes	valid.	reflectometry
Rome	1495	320	2.2	4				2				cont.	yes	valid.	ß-gauge monitor
Rouen	320	320	0.4	2	2			2	2			cont.	yes	valid.	TEOM (50°C)
						7				3		24 h	yes	valid.	reflectometry
Sevilla	141	90	0.5	10				6				cont.	yes	valid.	ß-radiation-attenuation
Stockholm	500	500	1.2	4	3			1	1			cont.	yes	valid.	TEOM (50°C)
Strasbourg	304	304	0.5	5	3			3	2			cont.	yes	valid.	TEOM (50°C)
Tel Aviv	171	52	1.1	2				2				cont.	yes	valid.	TEOM
Toulouse	713	635	0.7	3	2			2	2			cont.	yes	valid.	TEOM (50°C)
Valencia	100	47	0.7	1			5					24 h	yes	valid.	ß-ray-atomic-absorption
						15				3		24 h	yes	valid.	reflectometry
Sum				**128**	**22**	**116**	**21**	**85**	**15**	**62**	**12**				

Appendix 3. Table B. Specifications of HIA relevant air monitoring stations

City	Site	Classification	Pollutant
Athens	Aristotelous	traffic	PM_{10}
	Goudi	traffic	PM_{10}
	Lykovrisi	sub-urban	PM_{10}
	Marousi	traffic	PM_{10}
	Peiraias	traffic	PM_{10}
	Zografou	sub-urban	PM_{10}
	Athinas	traffic	BS
	Patision	traffic	BS
Barcelona	Llull	residential	BS
	Paris/Urgell	residential	BS
	Pl. Universitat/Balmes	commercial	BS
	P°. Zona Franca	residential	BS
	Sants	commercial	BS
Bilbao	Barakaldo-San Eloy	residential	BS
	Barakaldo	residential	PM_{10}
	Bilbao-Sanidad	residential	BS
	Erandio-Arriaga	residential	BS
	Getxo-Las Arenas	residential	BS
	Mazarredo	urban/residential	PM_{10}
	Santurtzi-Ayuntamiento	residential	BS
	Sestao-Plaza	residential	BS
	Portugalete-Nautica	sub-urban	PM_{10}
	Getxo-Algorta	residential	PM_{10}
Bordeaux	Grand-Parc	urban/residential	PM_{10}
	Talence	urban/residential	PM_{10}
	Floirac	sub-urban	PM_{10} + BS
	Bassens	sub-urban	PM_{10} + BS
	Place de la victoire	urban residential	BS
	IEEB	urban residential	BS
Bucharest	ISPB	residential	TSP
	Policolor	residential/traffic/industrial	TSP
	Sintofarm	residential/traffic/industrial	TSP
	Romaero	residential/traffic	TSP
Budapest	Laborc street	residential	TSP
	Szena square	residential/commercial	TSP
	Déli street	residential/commercial	TSP
	Baross square	residential/commercial	TSP
	Kosztolanyi square	residential/commercial	TSP
	Erzsebet square	residential/commercial	TSP
	Gergely square	residential	TSP
	Ilosvai square	residential	TSP
Celje	Hospital	urban/residential	PM_{10} + BS
Cracow	Kurczaba Str	residential	PM_{10}
	Rynek Glowny	residential	PM_{10}
	Bulwarowa Str	residential	PM_{10}
	Krowodrza	residential	PM_{10}
	Rynek Podgorski	residential	BS
	Krolewska Str	residential	BS
	Jagiellonskie	residential	BS
	Kapielowa	residential	BS
	Szwedzka Str	residential	BS
	Brozka Str	residential	BS
	Wyslouchow Str	residential	BS
	Basztowa Str	residential	BS
	Syrokomli Str	residential	BS
	Prasnicka Str	residential	BS
	Miechowity Str	residential	BS
Dublin	Royal Dublin Society	sub-urban	BS
	Mountjoy Square	residential	BS
	Clontarf	sub-urban	BS
	Finglas	sub-urban	BS
	Herbert Street	residential	BS
	Bluebell	sub-urban	BS
Göteborg	Femman, Nordstan	commercial	PM_{10} + $PM_{2.5}$
Le Havre	Ecole Herriot	residential	PM_{10} + $PM_{2.5}$ + BS
	Mare Rouge	urban/residential	PM_{10} + $PM_{2.5}$
	Les neiges	residential/industrial	BS + PM_{10}
Lille	Croix	residential	BS
	Wattrelos	residential	BS
	Marcq-en-Baroeul	residential	PM_{10}
	Lille-Rives	residential	PM_{10}
	Tourcoing	residential	PM_{10}
	Lomme	residential	PM_{10} + $PM_{2.5}$
	Villeneuve d'Ascq	residential	PM_{10}
	Faidherbe	traffic	PM_{10} + $PM_{2.5}$

Ljubljana	HMZ	urban/residential	PM_{10} + BS
	Figovec	commercial/residential	PM_{10} + BS
	Moste	residential	BS
London	Bloomsbury	residential	PM_{10} + $PM_{2.5}$
	London City	commercial	BS
Lyon	Croix Luizet	residential	PM_{10}
	Bossuet	residential	PM_{10}
	Puits Gaillot	residential	BS
Madrid	Glorieta Carlos V	traffic	PM_{10}
	Plaza Del Carmen	traffic	PM_{10}
	Marqués De Salamanca	traffic	PM_{10}
	Esquelas Aguirre	traffic	PM_{10}
	Ramón y Cajal	traffic	PM_{10}
	Plaza De Castilla	traffic	PM_{10}
	Paseo de Rcoletos	traffic	PM_{10}
	Plaza de Espana	traffic	PM_{10}
	Barrion del Pilar	traffic	PM_{10}
	Plaza Doctor Maranon	traffic	PM_{10}
	Plaza Luca de Tana	traffic	PM_{10}
	Cuatro Caminos	traffic	PM_{10}
	Plaza Manuel Bacerra	traffic	PM_{10}
	Vallecas	traffic	PM_{10}
	Plaza Fernandez Ladreda	traffic	PM_{10}
	Paseo de Pontones	traffic	PM_{10}
	Villa Verde	others	PM_{10}
	Gta. Marqués De Vadillo	traffic	PM_{10}
	Alto Extremadura	traffic	PM_{10}
	Moratalaz	traffic	PM_{10}
	Isaac Peral	traffic	PM_{10}
	Alcala	traffic	PM_{10}
	Casa De Campo	sub-urban	PM_{10}
Marseille	Saint Louis	residential	PM_{10} + $PM_{2.5}$ + BS
	Cinq Avenues	residential	PM_{10} + $PM_{2.5}$
	Thiers/Noailles	residential	PM_{10}
	Saint Marguerite	residential	BS
Paris	Paris 12	residential	PM_{10}
	Bobigny	residential	PM_{10}
	Issy-les-Moulineaux	residential	PM_{10}
	Tremblay	residential	PM_{10}
	Paris 18	residential	PM_{10} + BS
	Paris Tour St Jacques	residential	BS
	Paris 7	residential	BS
	Paris 8	residential	BS
	Paris 14	residential	BS
	Gennevilliers	residential	PM_{10} + BS
	Ivry	residential	BS
	Vitry	residential	PM_{10} + BS
	Montreuil	residential	BS
	Saint Denis	residential	BS
Rome	Fermi	traffic	PM_{10}
	Magna Grecia	traffic	PM_{10}
Rouen	Bois Guillaume	urban/residential	BS
	Palais de Justice	urban/residential	PM_{10} + $PM_{2.5}$ + BS
	Sotteville	urban/residential	PM_{10} + $PM_{2.5}$ + BS
Sevilla	Ranilla	residential	PM_{10}
	Reina Mercedes	residential	PM_{10}
	Principes	others	PM_{10}
	Enramadilla	residential	PM_{10}
	Macarena	residential	PM_{10}
	Torneo	residential	PM_{10}
Stockholm	Rosenlundsgatan	commercial/residential	PM_{10} + $PM_{2.5}$
Strasbourg	Strasbourg Centre	residential	PM_{10} + $PM_{2.5}$
	Strasbourg Est	residential	PM_{10} + $PM_{2.5}$
	Strasbourg Nord	residential	PM_{10}
Tel Aviv	SL	residential	PM_{10}
	TM	commercial/residential	PM_{10}
Toulouse	Lycée Berthelot	urban/residential	PM_{10} + $PM_{2.5}$
	CCIT	traffic	PM_{10} + $PM_{2.5}$
Valencia	Viveros	residential	BS
	Cruz Cubierta	residential	BS
	Cemeterio	residential	BS

Appendix 3. Table C. Classification types of exposure (HIA) relevant air monitoring stations

Type	PM_{10}	$PM_{2.5}$	BS	TSP	Sum
Traffic	28	2	2	-	32 (18%)
Kerbside	-	-	-	-	
Building line	-	-	-	-	
Commercial	4	2	4	-	10 (6%)
Urban residential	44	11	50	12	118 (68%)
Sub-urban	6	-	5	-	12 (7%)
Rural	-	-	-	-	
Industrial	1	-	1	-	2 (1%)
Others (e.g. public gardens)	2	-	-	-	2 (1%)
Total	**84**	**15**	**63**	**12**	**174 (100%)**

Appendix 3. Table D. Use of corrections factors for PM_{10} and $PM_{2.5}$

Cities	PM_{10} measurement data corrected			Conversion factor
	no	yes	factor	$PM_{2.5}$ calculated from PM_{10}
Athens	x			0.3 to 0.63^{+}
Bilbao		x	1.2 $^{\#}$	0.7
Bordeaux	x			0.67
Bucharest	x $^{\$}$			0.7
Budapest	x *			0.7
Celje	x			0.7
Cracow		x	1.25 §	0.8
Göteborg		x	1.3	0.66
Le Havre		x	1^{s}; 1.253^{w}	0.7
Lille		x	1.185^{s}; 1.271^{w}	
Ljubljana	x			0.7
London	x			
Lyon		x	1.221^{w}	0.7
Madrid		x	1.0 $^{\#}$	0.51
Marseille	x			0.65
Paris		x	1^{s}; 1.37^{w}	0.7
Rome	x			0.7
Rouen		x	1^{s}; 1.221^{w}	0.7
Sevilla		x	1.13	0.7
Stockholm		x	1.2 $^{\#}$	0.65
Strasbourg		x	1.3	0.7
Tel Aviv	x			0.5
Toulouse		x	1^{s}; 1.2^{w}	0.65

Barcelona, Dublin and Valencia are not considered inhere, because they do not calculate HIA for PM_{10}

$^{\$}$: PM_{10} data calculated from TSP measurements (PM_{10} = TSP x 0.6)
*: PM_{10} data calculated from TSP measurements (PM_{10} = TSP x 0.58)
$^{\#}$: derived from parallel PM_{10} measurements within the city
§: PM_{10} local factor
$^{+}$: range of $PM_{2.5}$ conversion factor, because month-specific factors are used
^{s}: summer
^{w}: winter

Appendix 4

New E-R function for respiratory hospital admissions (Richard Atkinson, HR Anderson et al.)

Analysis of all-age respiratory hospital admissions and particulate air pollution within the Apheis programme

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Introduction

In recent years there have been numerous studies published which investigate the short-term health effects of air pollution. Many of these studies are of an ecological time series design where daily indicators of the health status of a population, such as daily numbers of hospital admissions and daily number of deaths, have been linked to daily concentrations of outdoor air pollution. These studies have been influential in identifying the potentially toxic effects of ambient pollution and in contributing evidence to the case for stringent abatement strategies [1-5].

Associations between particulate air pollution and hospital admissions for respiratory causes have been investigated in numerous publications. Some have grouped admissions for all respiratory causes together [6,7] whilst others have considered specific diagnoses such as asthma or COPD [8-10]. Furthermore, studies vary in the age ranges selected for analysis. Because of the heterogeneous nature of respiratory diseases across age groups, analyses for all respiratory causes in all-ages are less common than in age- and cause-specific groups. However, from a policy perspective this "catch-all" all-age category is most useful.

The Apheis programme involves members from 12 countries and 26 cities, of which nine have available daily counts of hospital admissions and daily concentrations of outdoor particulate air pollution. The Apheis 3 programme included an analysis of all-age respiratory admissions with the express purpose of determining relative risks estimates that could be used in a health impact assessment exercise.

In this chapter we describe this analysis and present both the city-specific and summary estimates for the effects of PM_{10} (particles with a mean aerodynamic diameter less than 10 microns) and Black Smoke (BS) on all-age, all-respiratory hospital admissions. Two-pollutant models investigating potential confounding between PM_{10} and ozone were also run.

Methods

Respiratory hospital admissions data

Nine cities were able to supply daily counts of hospital admissions for respiratory diseases. They were: Barcelona, Budapest, Gothenburg, London, Madrid, Paris, Rome, Stockholm and Valencia. Where possible emergency, rather than general, hospital admissions for respiratory disease were specified. ICD 9/10 (International Classification of Diseases Version 9/10) codes 460-519 and J00-J99, coded on discharge, defined admissions for respiratory causes.

Air pollution and meteorological data

Daily PM_{10} measures were available from eight of the nine cities and BS measures from 4. Daily average temperature and daily average humidity in each city was also collected.

Statistical methods

Poisson regression was used to model the dependencies of daily counts of admissions on daily pollution concentrations. Other variables included in the models were terms to account for potential confounding factors such as seasonal patterns in the numbers of asthma events, meteorological conditions, respiratory epidemics and social factors e.g. day of week. The details of this analysis followed those employed by the APHEA 2 project (Air Pollution and Health: A European Approach) [11].

The key elements of their approach are 1) the use of non-parametric smoothing techniques (LOWESS) within a Generalised Additive Model (GAM) framework, 2) use of the partial autocorrelation function to guide selection of smoothing parameters to control for seasonality, 3) investigation of same day and lagged effects, linear or non-linear, of temperature and humidity, 4) control for day-of-week effects, bank holidays and any other unusual events (e.g. thunderstorms) using dummy variables.

The modelling procedure was carried out for each city-specific admissions series in turn. As a result the “core” models for each time-series were not necessarily the same.

The average of the same day (as the health event) and the previous days (lag 1) particle measures were used in the analysis. This reflects the aim of the study to investigate the short-term heath effects of exposure to air pollution. To assess the sensitivity of the PM_{10} and BS effect estimates to confounding by other pollutants the single-pollutant models were supplemented with a second set of two pollutant models incorporating ozone (average of lag 0 and lag 1).

Results from each model were expressed as relative risks, together with 95% confidence intervals, and are calculated for 10 µg/m^3 increases in PM_{10}. Once all of the city-specific estimates had been calculated fixed- and random-effects summary estimates were then calculated [12].

Recent studies have questioned the validity of GAMs and LOWESS smoothing for these types of analyses. It has been shown that in some situations the algorithms implemented in the software can result in biased effect estimates and under-estimation of standard errors [13-15]. In practice, these biases may have little impact on the effect estimates, nor their standard errors [16]. None-the-less the sensitivities of the estimated pollution effects were investigated in a sample of the cities (Barcelona, London, Paris, Rome and Stockholm) using penalised splines with the equivalent degrees of freedom as used in the GAM models.

Results

Table 1 gives the details of the city populations, time period for which data were available and the median and maximum number of daily admissions. The table also indicates if the admissions were emergency or general admissions. The shortest time period for which data were available was 3 years and the longest was 9 years. The median number of respiratory admissions in each city ranged from 6 per day in Gothenburg to 142 per day in London.

Table 2 gives summary statistics for PM_{10}, BS and ozone concentrations recorded in each city. Median daily concentrations of PM_{10} and BS ranged from 11.7 to 52.9 µg/m^3 and 9.3 to 36.5 µg/m^3. The highest concentration of particles was observed in Rome where the maximum single day concentration of PM_{10} reached 152 µg/m^3. This contrasts with Gothenburg were the highest recorded daily average was 44.7 µg/m^3.

Median daily average temperature ranged from 7.6 °C in Stockholm to 16.1 °C in Barcelona. Results of the city-specific analysis for PM_{10} are shown in table 3 and illustrate graphically in figure 1. Estimates are relative risks, together with 95% confidence intervals, and are calculated for 10 μg/m^3 increases in PM_{10}. Also shown in table 3, and figure 1, are the fixed- and random-effects summary estimates. All of the individual city PM_{10} estimates are positive. The magnitude of these estimates ranged from 1.0025 (95% CI 0.9914, 1.0137) in Budapest to 1.0441 (1.0072, 1.0823) in Gothenburg. The fixed- and random-effects summary estimates were 1.0102 (1.0078, 1.0125) and 1.0114 (1.0062, 1.0167) respectively.

When daily ozone concentrations were added to the models the PM_{10} estimates tended to increase, the two exceptions were Stockholm and Gothenburg (table 4 and figure 2). Consequently, the fixed- and random-effect summary relative risks for PM_{10} increased to 1.0154 and 1.0193 respectively.

The results for BS are given in table 3 and illustrated in figure 3. Two estimates were positive and two negative. The fixed- and random-effects summary relative risks were close to 1.

The sensitivity of the results to different methods of controlling for seasonality was investigated. When the method of smoothing for seasonality was changed from LOWESS to penalised splines the results were found to be largely unaffected in the sample of cities studied. Original fixed- and random-effect estimates for the five cities re-analysed were 1.1 (0.8, 1.4) and 1.4 (0.7, 2.0) and the corresponding results from the re-analysis were 1.1 (0.8, 1.5) and 1.5 (0.6, 2.3).

Discussion

In this study a standard approach to data collection and analysis has been applied in nine European cities with a total population of almost 25 million. The results show a consistent positive association between particulate air pollution as measured by PM_{10} and hospital admissions for respiratory diseases across all ages. In this study we found no evidence of an association between BS and all-age respiratory admissions, summary estimates were very close to unity. For PM_{10}, the single pollutant model summary estimates (fixed and random) were robust to the inclusion of measures of ozone into the models.

One of the main motivations for this study was to provide robust estimates of the effects of particulate air pollution on respiratory admissions across all ages, a combination of diseases and ages not frequently studied. As part of a systematic review of published time series studies conducted at St. George's Hospital Medical School in London a database of effect estimates from time series studies has been created. This database was interrogated for results for PM_{10} and BS and all-age all-respiratory admissions. From the published world literature, to February 2002, 12 estimates of the effect of PM_{10} on all-age, all-respiratory admissions and 3 of BS were identified. The former was dominated by the 8-city Italian study, the others being London, West Midlands, Paris and Drammen. The summary estimate for these 12 estimates was 1.017 (1.011, 1.024) for a 10 μg/m^3 increase in PM_{10}. This compares with the summary estimate derived from the present analysis of 8 cities of 1.0114 (1.0062, 1.0167). Only three estimates for BS were found (London, West Midlands and Paris) and were not meta-analysed.

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Table 1. Summary statistics for respiratory hospital admissions

City	Population ('000s)	Study period	No of days	Emergency/ General Admissions	Median (n/day)	Max. (n/day)
Barcelona	1.644	1/1/1994 – 31/12/1996	1096	Emergency	18	51
Budapest	1.931	1/1/1997 – 31/12/2000	1461	Emergency	29	114
Gothenburg	299	1/1/1997 – 31/12/2000	1461	Emergency	6	24
London	6.900	1/1/1992 – 31/12/2000	3288	Emergency	142	459
Madrid	2.938	1/1/1998 – 31/12/2000	1096	Emergency	35	99
Paris	6.100	1/1/1992 – 30/9/1996	1735	General	73	177
Rome	2.775	1/1/1998 – 31/12/2001	1410	General	51	124
Stockholm	1181	6/3/1997 – 31/12/2000	1316	Emergency	20	57
Valencia	746	1/1/1996 – 30/11/1999	1430	Emergency	9	32

Table 2. Summary statistics for environmental variables

City	PM_{10} (µg/m³)			BS (µg/m³)			Ozone (µg/m³)			Daily Average Temperature (°C)		
	n	Median	Max.	n	Median	Max.	n	Median	Max.	n	Median	Max.
Barcelona	1096	52.9	150.4	1096	35.8	122.5	1096	57.5	171.3	1096	16.1	28.1
Budapest	1461	27.3	115.4				1405	60.5	147.0	1461	13.1	31.2
Gothenburg	1461	11.7	44.7				1461	56.2	182.5	1461	7.8	22.0
London	3078	23.0	103.0	3288	9.3	70.0	3142	15.5	85.4	2914	11.1	26.7
Madrid	1092	34.4	108.9				1092	35.6	106.9	1096	13.4	30.2
Paris	1732	19.9	94.3	1735	18.3	149.3	1735	29.3	185.5	1735	12.3	29.4
Rome	1410	47.4	152.0				1410	82.9	232.7	1410	15.8	30.3
Stockholm	1316	12.1	60.1				1249	63.8	124.0	1316	7.6	25.0
Valencia				1423	36.5	124.5	1401	40.4	73.4	1430	18.7	30.3

Notes
1. Rome ozone concentrations are 1 hour measures
2. Paris PM_{13} measures
3. London ozone concentrations in ppb

Table 3. City-specific and summary estimates for all-age respiratory hospital admissions and PM_{10} /BS

City	PM_{10}			BS		
	RR	LCL	UCL	RR	LCL	UCL
Barcelona	1.0189	1.0098	1.0281	1.0007	0.9876	1.0139
Budapest	1.0025	0.9914	1.0137			
Gothenburg	1.0441	1.0072	1.0823			
London	1.0086	1.0049	1.0124	0.9983	0.9922	1.0045
Madrid	1.0046	0.9969	1.0125			
Paris	1.0045	0.9980	1.0111	1.0062	1.0013	1.0113
Rome	1.0142	1.0095	1.0189			
Stockholm	1.0433	1.0222	1.0649			
Valencia				0.9934	0.9814	1.0056
FE	1.0102	1.0078	1.0125	1.0032	0.9997	1.0068
RE	1.0114	1.0062	1.0167	1.0030	0.9985	1.0075

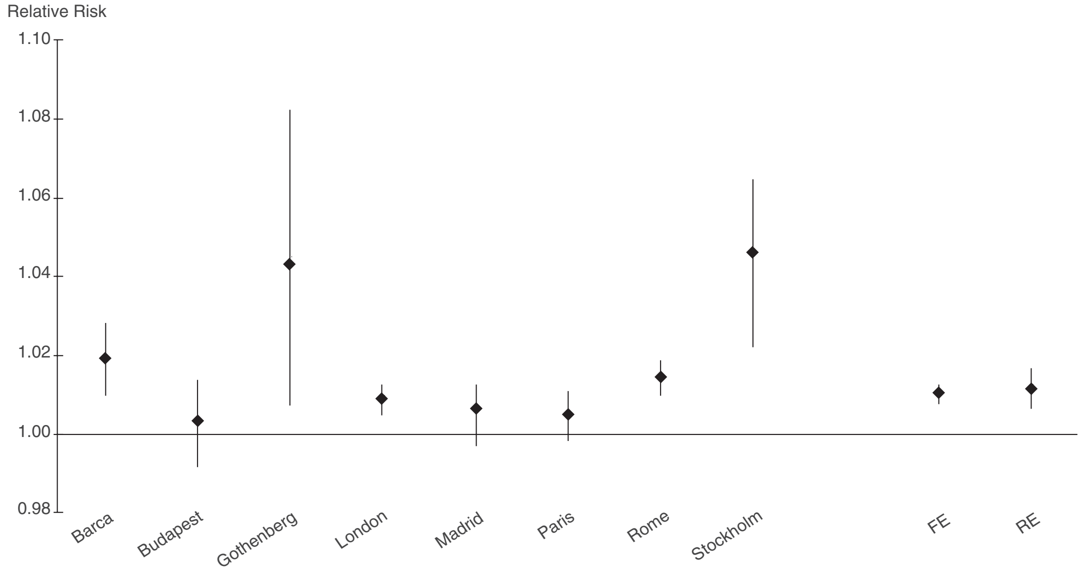
Notes
1. Estimates are relative risks (RR) per 10 µg/m³ increase in PM_{10} or BS
2. LCL and UCL are upper and lower 95% confidence intervals

Table 4. City-specific and summary estimates for all-age respiratory hospital admissions and PM_{10} controlling for ozone

City	PM_{10}		
	RR	LCL	UCL
Barcelona	1.0193	1.0101	1.0285
Budapest	1.0026	0.9915	1.0139
Gothenburg	1.0413	1.0043	1.0798
London	1.0089	1.0051	1.0126
Madrid	1.0048	0.9963	1.0133
Paris	1.0043	0.9977	1.0108
Rome	1.0149	1.0101	1.0196
Stockholm	1.0430	1.0199	1.0666
Valencia			
FE	1.0103	1.0080	1.0127
RE	1.0154	0.9992	1.0318

Notes
1. Estimates are relative risks (RR) per 10 μg/m^3 increase in PM_{10}
2. LCL and UCL are upper and lower 95% confidence intervals

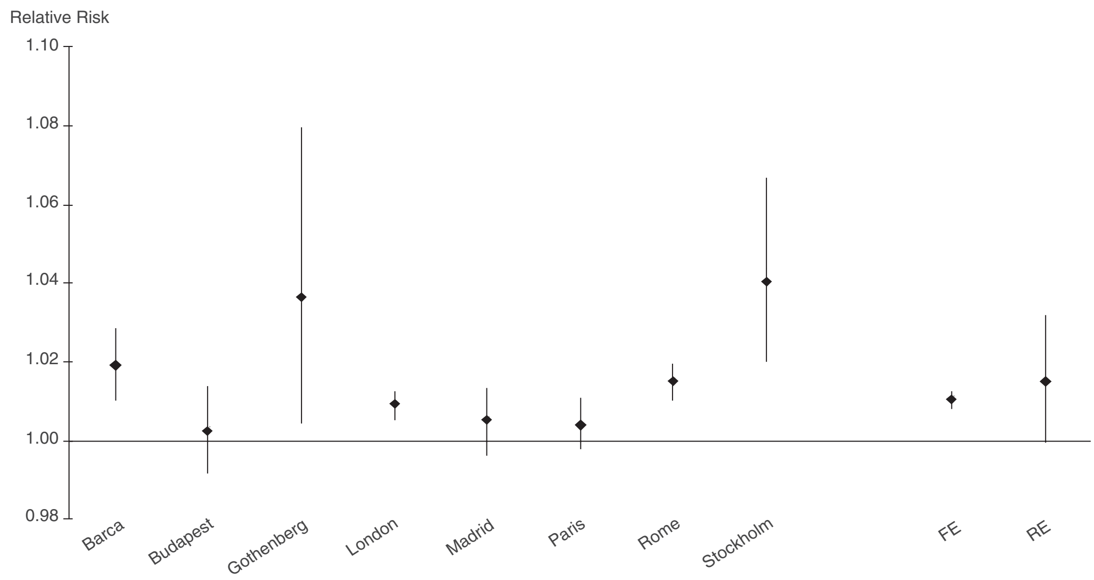
Figure 1. City-specific and summary estimates for all-age respiratory hospital admissions and PM_{10}



Legend

Figure 1 shows the relative risks (and 95% confidence intervals) associated with increases of 10 μg/m^3 in PM_{10} concentrations. Estimates for individual cities are given together with summary effect estimates (fixed effects (FE) and random effects (RE)).

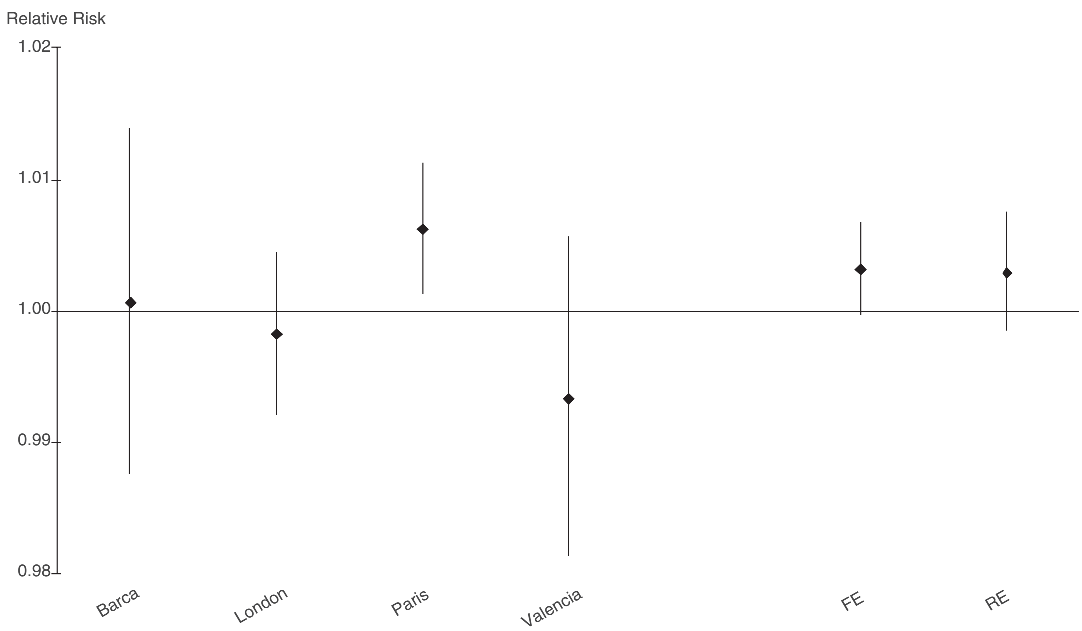
Figure 2. City-specific and summary estimates for all-age respiratory hospital admissions and PM_{10} controlling for ozone



Legend

Figure 2 shows the relative risks (and 95% confidence intervals) associated with increases of 10 μg/m^3 in PM_{10} concentrations controlling for ozone. Estimates for individual cities are given together with summary effect estimates (fixed effects (FE) and random effects (RE)).

Figure 3. City-specific and summary estimates for all-age respiratory hospital admissions and BS



Legend

Figure 3 shows the relative risks (and 95% confidence intervals) associated with increases of 10 μg/m^3 in BS concentrations. Estimates for individual cities are given together with summary effect estimates (fixed effects (FE) and random effects (RE)).

Appendix 5

Sensitivity analysis on shrunken estimates (Alain Le Tertre, Giota Touloumi, Joel Schwartz)

Empirical Bayes and adjusted estimates approach to estimating the relation of mortality to exposure of PM_{10}

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Abstract

In the framework of the Apheis program (Air Pollution and Health: a European Information System), a health impact assessment of air pollution in 26 European cities was performed for Particles of an aerodynamic diameter less than or equal to 10 µm (PM_{10}). For short-term effects, it was based on overall estimates from the Aphea-2 project (Air Pollution and Health: a European Approach). These city specific risk assessments require city specific concentration-response functions, raising the question of which concentration-response is most appropriate. We compared several estimates derived from the city-specific analyses in cities that were part of the Aphea-2 project, as well as on a city that was not included in Aphea-2 but was part of the Apheis project. These estimates were the local estimate, the adjusted estimate based on two significant effect modifiers in a meta-regression, and an empirical Bayes estimate (shrunken) and its underlying distribution. The shrunken and adjusted estimates were used to improve the estimation of city-specific concentration-response function. From these different estimates, attributable numbers of death per year were calculated. The advantages and limits of these different approaches are discussed.

Abstract: 183 words

Text: 2344 words

Introduction

In the last decade, a number of epidemiological studies have shown that ambient air pollution adversely affects human health even at levels lower than current national standards [1]. Particulate matter is the pollutant that has most consistently been associated with short short-term effects in mortality. Risk analyses based on these results have already been published [2,3,4,5]. Typically, an overall estimate (based on a meta-analysis) is used for all cities, assuming that the Exposure-Response relationship is the same everywhere. Many studies are using an overall estimate derived from multi- cities studies, such as Aphea-1 [1] or Aphea-2 (Air Pollution and Health: an European Approach) [6], or NMMAPS (National Mortality and Morbidity Air Pollution Study) [7], or derived from the literature. Overall estimates are computed using a random- effect approach that takes into account the heterogeneity of the effects among cities/studies. The observation of heterogeneity (not always significant) suggests that the use of a single estimate in each city is not appropriate. In many cases, people doing a risk assessment in a particular city where a study has been done have preferred to use a city city-specific estimate.

In general, it is naïve to assume that the city–specific effect estimate is better than the overall one just because it is derived from the city of interest. If for the specific outcome and pollutant of interest, there is no evidence of heterogeneity, then it is likely that the variations of city specific effect estimates about the overall mean are purely stochastic. In that case, the overall effect estimate should be used. Often, however, significant heterogeneity between city-specific estimates will be present. Even in such cases though, the city specific effect estimate may not be the best one.

In the presence of heterogeneity, city-specific estimates vary about the overall effect estimate for two reasons: a) due to true heterogeneity in the estimates, and b) due to additional stochastic error. A city specific estimate that reflects the first source of variation, but not the second is then required. This is obtainable by using a shrunken estimate.

True variation in the exposure-response estimate among cities presumably reflects differences (e.g. sources of particles, ventilation characteristics of housing, health of population) that are in principal identifiable. Meta-regression is an approach that seeks to identify the sources of such heterogeneity. An alternative city-specific estimate is obtained by using the slope predicted for that city by a meta-regression on effect modifiers. This approach has the added advantage that it can be applied to risk assessment in cities that were not part of the original studies, and therefore do not have city specific estimates. In the Aphea-2 study of the effect of PM_{10} on total mortality it was found that annual level of NO2 and annual temperature mean at the city level both act as effect modifiers explaining a substantial part of the observed between cities heterogeneity in Europe.

In the framework of the Apheis program (Air Pollution and Health: a European Information System-www.apheis.net)[4,5], a health impact assessment of air pollution in 26 European cities was performed. For short-term effects, it was based on overall estimates from the Aphea-2 project but the issue of using alternatively city-specific estimates raised and the Apheis statistical advisory group conducted an analysis to address this issue.

In this paper we will demonstrate, in 21 European cities that were part of the Aphea-2 project and one that was not, but was part of Apheis[4], the impact of choosing different approaches to estimate short-term air pollution effect on the attributable number of deaths.

Methods

In multi-city studies the data analysis is implemented in two stages. In the first stage data from each city are analysed separately whereas in the second stage evidence across cities are combined using meta-regression techniques. Briefly, daily counts of deaths from each city were assumed to come from a non-stationary overdispersed Poisson process. The exposure-response function is then assumed to be exponential and follow

$$\ln\left(E(y_t^c)\right) = \sum_{i=1}^{m} \beta_i^c Z_t^c + \beta_p^c P_t^c$$

with $E(y_t^c)$ denoting the mean daily counts of the relevant health outcome in city c, Z_{it}^c the independent covariates other than PM_{10}, P_t^c daily levels of PM_{10}- in city c and β_i^c and the corresponding parameters to be estimated.

City specific PM_{10} estimates were combined using the method developed by Berkey [8]. In summary, a random effects model regressing the estimates from each city against potential effect modifiers was performed. The model assumptions are:

$$\hat{\beta}_p^c \sim N(\mu_p^c, \sigma_{W,c}^2)$$
$$\mu_p^c \sim N(X^c\alpha, \sigma_B^2)$$

and hence

$$\hat{\beta}_p^c \sim N(X^c\alpha, \sigma_{W,c}^2 + \sigma_B^2)$$

where $\hat{\beta}_p^c$ is the estimated PM_{10} effect estimate in city c and $\sigma_{W,c}^2$ and σ_B^2 are the within city c and the between cities variances respectively. It should be noted that $\sigma_{W,c}^2$ is estimated in the first stage analysis. For details about APHEA-2 first stage and second stage analysis, refer to Touloumi [9] *et al.*

The Empirical Bayes shrunken estimate was derived following Longford [10]. Lets $\bar{\beta}$ be the pooled over all cities estimate, without regressing on any effect modifier ($X^c\alpha = \bar{\beta}$ in this case). The shrinkage estimator is the conditional expectation of the city mean μ_p^c given the observed mean $\hat{\beta}_p^c$. The variance matrix of $(\mu_p^c, \hat{\beta}_p^c)$ is:

$$\begin{pmatrix} \sigma_B^2 & \sigma_B^2 \\ \sigma_B^2 & \sigma_B^2 + \sigma_{W,c}^2 \end{pmatrix}$$

Therefore,

$$E(\mu_p^c | \hat{\beta}_p^c; \overline{\beta}, \sigma_B^2, \sigma_{W,c}^2) = \overline{\beta} + \frac{\sigma_B^2}{\sigma_B^2 + \sigma_{W,c}^2}(\hat{\beta}_p^c - \overline{\beta})$$

(1)

with variance

$$Var((\mu_p^c | \hat{\beta}_p^c; \overline{\beta}, \sigma_B^2, \sigma_{W,c}^2) = \sigma_B^2(1 - \frac{\sigma_B^2}{\sigma_B^2 + \sigma_{W,c}^2}) = \frac{1}{\sigma_B^{-2} + \sigma_{W,c}^{-2}}$$

(2)

We also followed the approach proposed by Post [11] *et al.*, who estimated the underlying distribution of β for the United States as an equally weighted mixture of the shrunken estimates derived in the previous step. The aim was to use all available information from the APHEA-2 studies to apply the overall estimate on a city not part of the original analysis.

We also calculated meta-regression based adjusted estimates derived from the APHEA-2 study. The two effect modifiers found to explain a substantial part of the observed heterogeneity were annual mean of NO2 and annual mean temperature. Therefore, for each city we predicted the coefficient for PM_{10} based on the model:

$$E(\hat{\beta}_p^c | \mathrm{NO}_2, Temp) = \overline{\beta}' + \beta_1' NO_2 + \beta_2' Temp$$

(3)

Regression coefficients and associated variance-covariance matrix were provided by the APHEA-2 project.

We used the above described effect estimates (observed city-specific, shrunken city-specific, pooled, mean of shrunken city-specific and adjusted for effect modifiers) to calculate the attributable number of deaths in each city. The Relative Risk (RR) is expressed in our analysis as $RR_{\Delta x} = \exp(\beta \times \Delta x)$ where Δx represents a change by x µg/m^3 in the daily PM_{10} levels. To estimate attributable number of deaths we first need to define the baseline exposure from which incremental mortality is estimated. Lets $\overline{Y}$ be the annual mean of daily mortality, which reflects the impact of mean daily PM_{10} levels, $\overline{x}$. The baseline mortality incidence Y_F at the no-effect PM_{10} level x0 can then be estimated as:

$$Y_F = \overline{Y} \times \left(1 - \frac{RR_{\Delta(x0-\overline{x})} - 1}{RR_{\Delta(x0-\overline{x})}}\right)$$

The attributable number of deaths when the PM_{10} levels increase from x0 to x1 is:

$$AR = Y_F \times (RR_{\Delta(x1-x0)} - 1)$$

We have a priori decided for this exercise to set the x0 level equal to 10 µg/m^3.

Results

Table 1 shows the city specific estimated regression coefficients and their standard errors for the effect of each 1 µg/m^3 increase in PM_{10} levels on total mortality, as reported in the Aphea-2 project. Shown are also the annual mean of daily temperature and NO2 levels. The coefficients ranged from -0.00056 in Erfurt to 0.00153 in Athens.

The annual temperature exhibited a range of around 14°C with the minimum value observed in Helsinki and the maximum in Tel Aviv. Stockholm was the cleanest city in terms of NO2 levels with an annual mean of 26 µg/m^3 whereas Milano showed the highest levels with annual mean of 94 µg/m^3.

There was significant between cities heterogeneity in the PM_{10} effect estimates and therefore the pooled effect was calculated based on a random effects mode[8]. The overall estimate was 0.000607 (SE=0.000104). We then calculated the shrunken estimators in each location following equations (1) and (2). Figure 1 shows the estimated density for each of the shrunken estimators (i.e. in each city). Superimposed on them is the estimated distribution of the population averaged slope, based on the random effects meta-analysis, and the estimated distribution of the Empirical Bayes estimates across all the cities. We clearly see the departure from the population mean estimate in cities with extreme estimates. The underlying distribution of Empirical Bayes estimates displays the same mean as the pooled estimate, but it is also more flat, reflecting the heterogeneity between cities. Consequently the corresponding 95% credible interval for the Relative Risk for total mortality associated with a 10 µg/m^3 increase in PM_{10}, 0.996, 1.016, is larger than the one derived from the overall estimate 1.004, 1.008. We also applied equation (3) to calculate the adjusted for temperature and NO2 estimate in each city.

Figure 2 shows the city-specific Relative Risks and its 95 Confidence Interval of mortality for a 10 µg/m^3 increase in daily PM_{10} levels as estimated using the shrunken estimates. Shown are also the local estimates of the RRs as well as the adjusted for temperature and NO2 ones. For comparison, the overall estimate provided by the RE model is also shown. As expected the shrunken estimates is located between the local and the overall estimates as it can be considered as a weighted mean of these two estimates.

Except in four cities, Helsinki, Stockholm, Tel Aviv and Teplice, the adjusted estimates are close to the shrunken ones. This concordance is due to the fact that temperature and NO2 annual means tend to explain the observed heterogeneity between the local estimates.

In Table 2, the attributable to PM_{10} exposure number of deaths calculated using the various estimates for the mortality-PM_{10} RR are shown. A reduction of the annual PM_{10} mean from the observed value to 10 µg/m^3 was assumed in each city. There is substantial variability in the attributable numbers of deaths at the city level depending on the choice of the RR estimate. The calculated number of deaths using the shrunken estimates or those adjusted for temperature and NO2 ranged from half (in Erfurt and in Stockholm) to double (in Athens and in Rome) the one using the overall RR estimate. However, the sum over all cities number of deaths estimated using shrunken or the adjusted estimates of RR is larger than the one estimated using the overall RR estimate only by around 15%.

Discussion

In this study we have shown that although the sum over all 21 European cities of the deaths attributable to PM_{10} is not strongly influenced by the method used to estimate RRs this is not true at the city level. Applying a shrunken estimate in Athens or in Erfurt would lead to almost 100% more deaths or 100% less death respectively than those calculated with the overall estimate. The heterogeneity observed in these cities is not in favor of applying a single estimate. Neither does it militate for applying the city specific estimate, as that estimation would also lead to over or underestimating the shrunken estimates by 70 and 430% respectively.

We also applied the overall, adjusted and estimated underlying coefficients on a city, Cracow in Poland, not part of the APHEAphea-2 study, but part of the Apheis project. The overall or estimated underlying estimates gave 202 deaths per year compared to 146 for the adjusted approach. More interesting was the difference in the 95% confidence interval around these estimates: while the overall show an extremely narrow confidence interval (134, 272), the estimated one showed a much larger interval (-128, 537), as did the adjusted one (96, 195). This indicates that excessive certainty may be suggested by naïve approaches to risk assessment.

The shrunken estimates approach has already been explored and applied in the case of air pollution(11). The shrunken estimates have the nice property that they derive the estimate at the local level by combining information from the city specific estimate and the overall one. It also reduces the variability of the local estimate by incorporating information from other cities. A key disadvantage of such an estimate is that it can only be applied in cities part of the initial analysis.

The adjusted estimate also provides a more local estimate as it takes into account potential effect modifiers. It also reduces uncertainties around the estimate. It is more widely applicable as one just needs to have information on these two effect modifiers to calculate it. The two particular effect modifiers (NO2 and temperature) that have been identified so far for the PM_{10} mortality relationship, should be seen as surrogates for different pattern of air pollution or exposure of the population but they could also be just the best, on a statistical point of view, set of covariates explaining the heterogeneity. The temperature effect could be a surrogate of the ventilation rate between cities. In that case we could not apply annual temperature as effect modifier on a city with a high rate of air conditioned houses(12). This is not common in Europe, but quite common in warmer climates in the United States. The use of this adjusted estimate should be limited to cities presenting similar characteristics to those initially observed. The discrepancy between the shrunken and the adjusted estimates, found in some cities as Stockholm, highlights the limit of such indicator, useful to explore the reasons of the heterogeneity, not to explain them.

The use of the local estimate is subject to too much noise to be really effective. The two derived city-specific estimates could be alternatively used depending of the data availability. For cities in the initial study, both give similar results. One can still prefer the shrunken one as it doesn't make any inference on the relation with potential effect modifiers. For cities with available data on effect modifiers, the adjusted estimate has some nice properties but requires careful attention to use it.

Applied on a single city, the overall estimate does not adequately reflect the heterogeneity present in the data. We have shown that this could be better taken into account by deriving an estimated underlying distribution that represents the dispersion observed between cities. Both of these techniques are an improvement in reducing the uncertainties surrounding pollutant coefficient, but are still affected by the uncertainties around the initial estimates of these coefficients.

Based on the limitations of each of these different estimates, we recommend the use of the shrunken estimate in cities for which this option is available. For the other, it is less straightforward as the adjusted reflects a local situation but require strong assumptions, the estimated reflects a general situation with greater uncertainties.

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Table 1. Local estimates for total mortality PM_{10} regression coefficients with their associated standard errors and annual mean of daily temperature and NO_2 levels in cities participating in the APHEA-2 study

City	PM_{10} coefficient	SE	Annual Temperature	Annual NO_2
Athens	0.00153	0.00028	17.8	74.0
Barcelona	0.00093	0.00018	16.4	68.6
Basel	0.00041	0.00044	10.7	38.2
Birmingham	0.00028	0.00026	9.6	45.9
Budapest	0.00029	0.00046	10.5	76.3
Cracow	0.00013	0.00035	8.3	43.5
Erfurt	-0.00056	0.00039	8.8	39.5
Geneva	-0.00010	0.00047	9.5	44.9
Helsinki	0.00032	0.00043	6.1	32.6
London	0.00069	0.00017	11.8	60.7
Lyon	0.00135	0.00053	12.4	63.0
Madrid	0.00053	0.00024	14.5	70.0
Milano	0.00116	0.00019	13.7	93.5
Paris	0.00043	0.00023	12.0	52.8
Prague	0.00012	0.00018	9.9	57.5
Rome	0.00128	0.00027	16.7	87.7
Stockholm	0.00039	0.00086	7.5	25.7
Tel Aviv	0.00064	0.00026	20.4	69.7
Teplice	0.00064	0.00034	8.8	32.4
Torino	0.00105	0.00017	14.3	75.9
Zurich	0.00042	0.00037	10.9	40.1

Table 2. Attributable number (95% CI) of deaths for a reduction of the annual mean PM_{10} from the observed value to 10 μg/m^3 calculated under various estimates for corresponding relative risk

City	Local estimates			Shrunken estimates			Adjusted estimates			Overall estimate		
	N	CI-	CI+	N	CI-	CI+	N	CI-	CI+	N	CI-	CI+
Athens	1305	823	1795	1035	647	1428	882	667	1098	524	347	703
Barcelona	708	427	994	664	411	922	684	521	849	467	308	628
Basel	29	-30	89	37	-3	76	16	-1	33	42	28	56
Birmingham	91	-74	257	125	-12	263	92	28	156	195	129	261
Budapest	260	-548	1092	434	-87	963	651	387	918	545	361	730
Cracow	43	-172	265	112	-49	276	63	-10	138	193	127	259
Erfurt	-58	-135	22	4	-50	60	17	-7	41	61	40	82
Geneva	-5	-47	38	15	-12	43	13	3	22	28	19	38
Helsinki	20	-31	71	30	-5	64	-3	-22	16	37	25	50
London	797	401	1196	782	421	1146	673	508	838	701	464	938
Lyon	138	31	249	90	27	154	66	52	81	63	42	84
Madrid	326	40	617	341	97	588	506	414	600	373	247	500
Milano	517	349	687	471	320	623	490	338	645	274	181	367
Paris	323	-18	667	361	68	656	369	248	490	460	305	615
Prague	103	-198	410	179	-92	457	377	218	539	505	333	679
Rome	1239	718	1774	1032	605	1468	1123	887	1361	596	394	800
Stockholm	24	-79	128	35	-7	78	-5	-25	15	37	25	50
Tel Aviv	251	52	455	248	83	417	423	268	580	238	158	320
Teplice	157	-8	327	155	31	281	17	-51	86	149	99	200
Torino	500	338	666	468	319	620	430	346	515	295	194	396
Zurich	59	-41	162	72	-1	146	37	5	70	85	56	113
Total	**6829**	**1797**	**11962**	**6690**	**2713**	**10729**	**6922**	**4773**	**9091**	**5868**	**3881**	**7870**

Figure 1. Probability densities of PM_{10} shrunken coefficients for mortality in each of 21 cities, of the population mean slope (estimated by the random effects model), and the distribution of the Empirical Bayes estimates

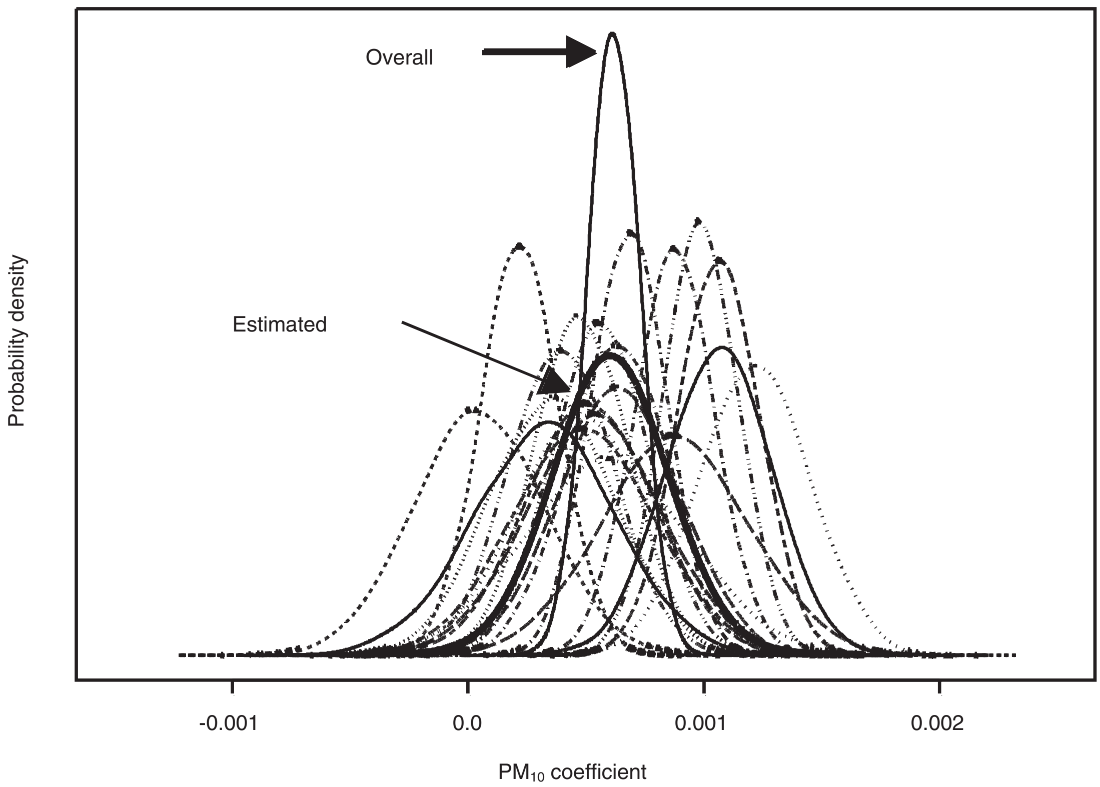
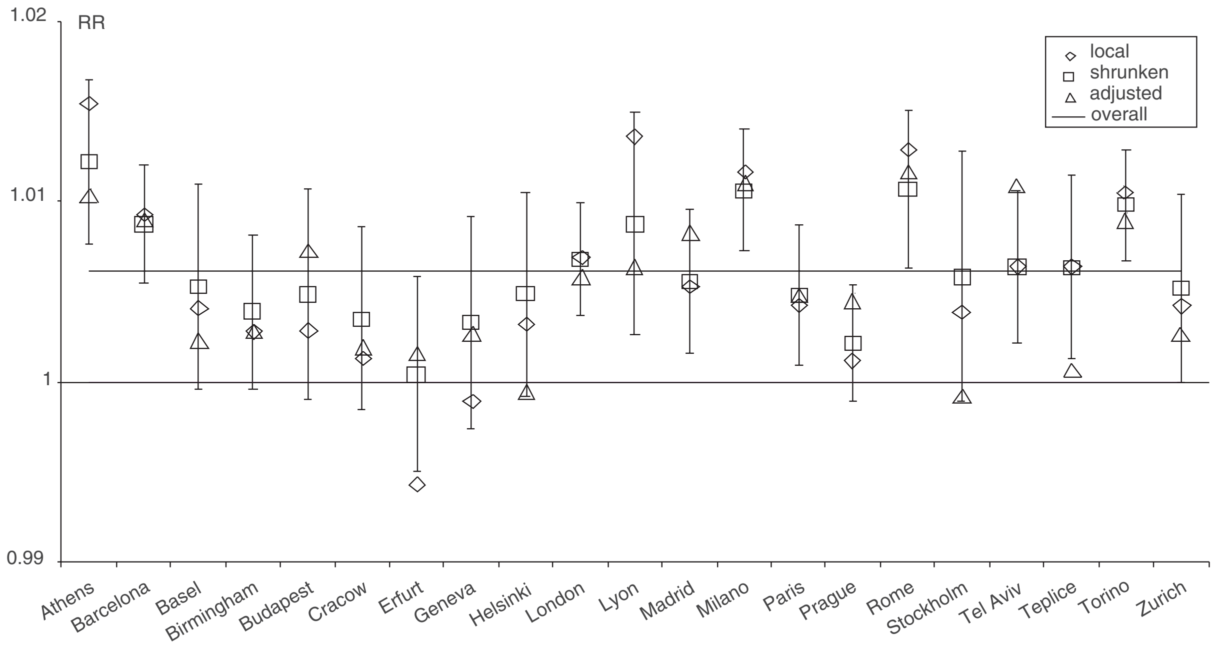


Figure 2. City-specific shrunken estimates (95% CI) of Relative Risk for mortality per 10 µg/m^3 increase in PM_{10} levels. Shown are also local and adjusted for effect modifiers (NO_2 and temperature) estimates. The overall effect as estimated by the Random Effects model is also shown



Appendix 6

Quality Control of health outcomes (Belén Zorrilla, Elena Boldo[1] and Mercedes Martínez)

Mortality data

In Apheis 2, to estimate the acute effects of short-term exposure to air pollution on premature mortality, we used the daily mean number of deaths among residents of each city out of the total mortality, excluding external causes of death (ICD9: <800; ICD10: A00-R99). In Apheis-3, in addition to this indicator we used the daily mean number of deaths from cardiovascular mortality (ICD9: 390-459; ICD10: I00-I99) and respiratory mortality (ICD9: 460-519; ICD10: J00-J99).

On the other hand, to estimate the chronic impact of long-term exposure to air pollution on premature mortality, we used total mortality excluding external causes of death (ICD9: <800; ICD10: A00-R99), cardiopulmonary mortality (ICD9: 401-440 and 460-519; ICD10: I10-I70 and J00-J99) and lung cancer mortality (ICD9: 162; ICD10: C33-C34). In addition for life expectancy calculations, we used total mortality (ICD9: 0-999; ICD10: A00-Y98) in people 30 years old and more.

The information sources for mortality data were the national, regional or local mortality registries for all the cities. The year used in each city depended on the availability of the data. Death registration was complete in all of them. The completeness of the data for the basic cause of death was 99% or more in 22 of the 24 cities. We didn't know this percentage in two cities (Athens and Bucharest). Tel Aviv had a 4.6% of missing data in basic cause death and London 3% (Table 1).

Due to the fact that most of the cities applied a quality control programme and the low percentage of missing data in basic cause of death, we consider that erroneous entries in the selection of cause of death did not affect the comparability of the data.

Hospital admissions data

To estimate the acute effects of short-term exposure to air pollution on hospital admissions, we have selected hospital admissions for residents in each of the cities with discharge diagnosis of respiratory diseases (ICD9: 460-519; ICD10: J00-J99) and cardiac diseases (ICD9: 390-429; ICD10: I00-I52). Whenever possible only emergency admissions were selected and discharge diagnosis has been used in all cases.

All the cities obtained the data from registries. The completeness of the registries of hospital admissions was quite high, 95% or more in 18 of the 22 cities. We didn't know this percentage in two cities (London and Tel Aviv). Barcelona and Valencia had a slightly smaller level of completeness. Athens, Bucharest, Cracow and Dublin have not estimated the impact on hospital admissions (Table 2). In Apheis 2, the nine French cities (Bordeaux, Lyon, Le Havre, Lille, Marseille, Paris, Rouen, Strasbourg and Toulouse) only included public hospital admissions, while the completeness has been 100% in most of these cities in Apheis 3.

All the registries run a quality control programme and completeness in the diagnosis for the cause of admission is quite high, with a percentage of missing data of 1% or lower in 19 of the 22 registries. We didn't know this percentage in two cities (London and Tel Aviv).

The main problem for comparability was the differences in the availability of information in the registries because some cities used emergency admissions, while others that lacked this information used total admissions. The information sources used in Barcelona, Bilbao, Budapest, Gothenburg, London, Madrid, Seville, Stockholm and Valencia allowed selecting emergency admissions. Yet, for Bordeaux, Celje, Le Havre, Lille, Ljubljana, Lyon, Marseille, Paris, Rome, Rouen, Strasbourg, Tel Aviv and Toulouse, it was not possible to distinguish between emergency and total admissions. Therefore hospital admissions data from these cities and those cities able to select only emergency admissions are not comparable.

[1] Elena Boldo was supported by a grant from the Regional Ministry of Health, Madrid Regional Government, Spain (Orden 566/2001).

Table 1. Characteristics of the information sources for mortality data

City	Type of source	Year	Source	Quality control programme	% Missing data in basic cause death	ICD	Codification Manual	Codification Automatic
Athens	Register	2001	National statistical Service of Greece	-	-	9	100%	
Barcelona	Register	2000	Barcelona city council	Yes	0%	9	100%	
Bilbao	Register	2000	Mortality Register of the Basque Autonomous Community	Yes	0%	10	100%	
Bordeaux	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Bucharest*	Register	2000	Medical Statistics Centre. Ministry of Health and Family and National Institute of Statistics	-	-	10	-	
Budapest	Register	2000	Central Statistical Office, Budapest	Yes	0%	10	100%	
Celje	Register	2000	Institute of Public Health of the Republic of Slovenia	Yes	0%	10	100%	
Cracow	Register	2000	Department of Epidemiology and Preventive Medicine of the Jagiellonian University Collegium Medicum	Yes	0.14%	10	100%	
Dublin	Register	2000	National Register, Central Statistics Office	Yes	0%	9	100%	
Gothenburg	Register	2000	National Registry	Yes	0.8%	10	100%	
Le Havre	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Lille	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Ljubljana	Register	2000	Institute of Public Health of the Republic of Slovenia	Yes	0%	10	100%	
London	Register	2001	Office for National Statistics	Yes	3%	9	-	100%
Lyon	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Madrid	Register	2000	Registro de Mortalidad. Instituto de Estadística. Comunidad de Madrid	Yes	0.18%	10	40%	60%
Marseille	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Paris	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Roma	Register	2001	Mortality Information System (SIM)	Yes	<0.1%	9	100%	
Rouen	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Seville	Register	2000	Mortality Register of Andalusia	Yes	0%	9	100%	
Stockholm	Register	2000	National Registry	Yes	0.8%	10	100%	
Strasbourg	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Tel Aviv	Register	1998	Department of Information. Ministry of Health	Yes	4.6%	9	100%	
Toulouse	Register	1999	Institut national de la santé et de la recherche médicale (CépiDC)	Yes	0%	9	100%	
Valencia	Register	2000	Mortality Register of the Valencian Community	Yes	0%	10	55%	45%

* Bucharest: cardiac mortality and cardiopulmonary mortality data belong to the year 1999. Lung cancer mortality data belong to the year 1997.

Table 2. Characteristics of the information sources for hospital admissions data on cardiac and respiratory diseases

City	Type of source	Year	Source	ICD	Quality control	Completeness (%)	% Missing data cause admission	Type of hospital admissions: Total	Type of hospital admissions: Emergency
Barcelona	Register	2000	Minimum set of Basic Hospital Data	9	Yes	70	0.2		X
Bilbao	Register	2000	Hospital Discharge Register. Basque Autonomous Community	9	Yes	99.9	0.3		X
Bordeaux	Register	2000	PMSI	10	Yes	100	0	X	
Budapest	Register	2000	Centre for Healthcare Information of the Ministry of Health, Social and Family Affairs	10	Yes	100	0		X
Celje	Register	2000	Institute of Public Health of the Republic of Slovenia	10	Yes	100	0	X	
Gothenburg	Register	2000	National Hospital Discharge Register	10	Yes	> 99	1		X
Le Havre	Register	2000	PMSI	10	Yes	100	0	X	
Lille	Register	2001	PMSI	10	Yes	100	0	X	
Ljubljana	Register	2000	Institute of Public Health of the Republic of Slovenia	10	Yes	100	0	X	
London	Register	2001	Health Episodes Statistics	10	Yes	-	-		X
Lyon	Register	2000	PMSI	10	Yes	100	0	X	
Madrid	Register	2001	Minimum set of Basic Hospital Data (CMBD). Consejería de Sanidad y Consumo. Comunidad de Madrid	9	Yes	95	0	X	X
Marseille	Register	2001	PMSI	10	Yes	>98	0	X	
Paris	Register	2001	PMSI de l´Assistance publique des hôpitaux de Paris	10	Yes	>98	0	X	
Roma	Register	2001	Hospital Information System (SIO)	9	Yes	96	0.1	X	
Rouen	Register	2000	PMSI	10	Yes	100	0	X	
Seville	Register	1999	Minimum set of Basic Hospital Data. Andalusia Health Service	9	Yes	100	0.34		X
Stockholm	Register	2000	National Hospital Discharge Register	10	Yes	> 99	1		X
Strasbourg	Register	2000	PMSI	10	Yes	100	0	X	
Tel Aviv	Register	1998	Department of Information. Ministry of Health	10	Yes	-	-	X	
Toulouse	Register	2000	PMSI	10	Yes	100	0	X	
Valencia	Register	2000	Minimum set of Basic Hospital Data	9	Yes	90	0		X

Athens, Bucharest, Cracow and Dublin have not estimated the impact on hospital admissions

Appendix 7

Essential steps in HIA calculations and PSAS-9 excel spread sheet (Florian Franke, Laurence Pascal, the PSAS-9 team and Elena Boldo)

An estimate of the impact can be based on the calculation of the attributable proportion (AP), indicating the fraction of the health outcome, which can be attributed to the exposure in a given population (provided there is a causal association between the exposure and the health outcome). With the population distribution of exposure determined in the exposure assessment stage, and the identified exposure - consequence function, one can calculate the attributable proportion using the formula:

$$AP = \sum \{ [RR(c) - 1] * p(c)\} / \sum [RR(c) * p(c)] \quad [1]$$

where: $RR(c)$ - relative risk for the health outcome in category c of exposure

$p(c)$ - proportion of target population in category c of exposure

Knowing (or, often, assuming) a certain underlying frequency of the outcome in the population, I, the rate (or number of cases per unit population) attributed to the exposure in the population can be calculated as:

$$IE = I * AP$$

Consequently, the frequency of the outcome in the population free from the exposure can be estimated as:

$$INE = I – IE = I * (1 – AP) \quad [2]$$

For a population of a given size N, this can be converted to the estimated number of cases attributed to the exposure, NE = IE * N.

Knowing the (estimated) incidence in non-exposed population and relative risk at a certain level of pollution, it is also possible to estimate an excess incidence (I+(c)) and excess number of cases (N+(c)), at a certain category of exposure:

$$I+(c) = (RR(c) – 1) * p(c) * INE \quad [3]$$

$$N+(c) = I+(c) * N \quad [4]$$

Air Pollution and Health

Health Impact Assessment

French HIA software (PSAS-9)

Version 3.0

User's book

Department of Health and Environment – Institut de veille sanitaire

Adaptation and translation: December 2003

1. Background

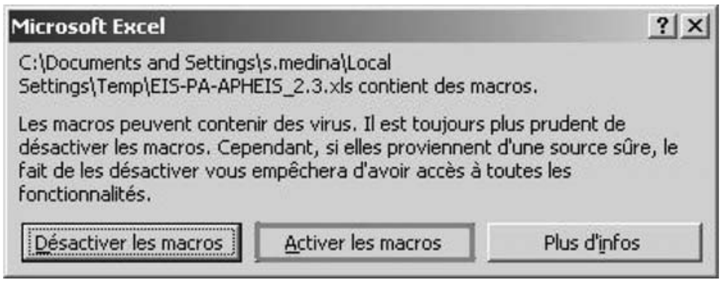
The French HIA software (EIS-PA from the PSAS-9 programme) is a support tool to carry out health impact assessments (HIA) of urban air pollution according to the methodology recommended by the Institut de veille sanitaire (InVS).
The EIS-PA software allows carrying out an automated and standardized HIA for various air pollution indicators and health indicators, and according to various scenarios.

2. Format

Warning : Once the data are entered, the size of this program might be big. Therefore, the time required to open, save and close this program might be relatively long.

2.1. Using Excel 2000

When opening the program, the following window may be displayed. Click on "Activer les macros" ("Activate the macros") to continue.



2.2. Content

The EIS-PA has been adapted for Apheis use. Therefore, for Apheis purposes some columns are masked at the screen but not when printing.

Then, **when printing : 1) select what do you want to print; 2) Print selection.**

EIS-PA-APHEIS is an excel file with 25 sheets,

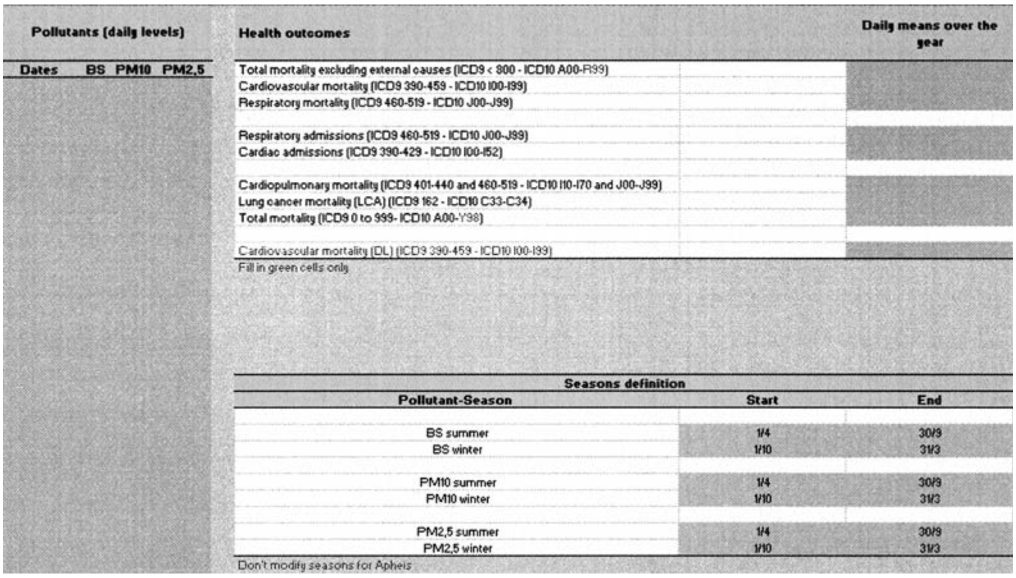
- A « Data » sheet with the data needed for the HIA,
- A « AP descriptive findings» sheet with the specifications of the exposure indicators,
- 23 sheets for the short and long-term HIA findings.

NB: the excel sheets have different formulas that require data from some of the cells. **It is therefore extremely important not to add or erase lines, columns or cells or make any copy and paste that will change the calculation sheets . However, you can copy and paste to import your dates, air pollution data and health outcomes <u>only</u> in the green cells.**

3. « Data » sheet

This sheet allows entering the required data for the HIA of sheets number 2 to 25.

- The data must be **entered or pasted into the green parts** of the sheet,
- The excel file recognises "," as the indicator for decimals.
- The light blue parts have values by default that can be altered by the user
- **The white parts have values or calculation results that cannot be altered,**
- Column titles are in the yellow parts.



3.1. Air pollution exposure indicators

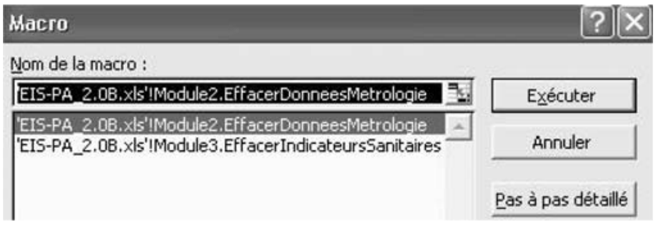
The chosen indicators are the ones decided by Apheis 3 and for which there are informed exposure-response functions, i.e. Black Smoke (BS), particles less than 10 µm (PM_{10}), particles less than 2.5 µm ($PM_{2.5}$).

For the purpose of Apheis, the calculation sheet allows entering a year of data. **Be aware that for the HIA you must select a full year of data**.

Also be aware that for the leap year 2000, the user has to calculate by hand the % of missing values because by default, the calculation of % of missing values requires that data is entered for periods of 365 days. For the leap year the calculation is on 366 days.

NB : on this « data » sheet, you should paste the daily series of the various pollution indicators built from the measuring urban stations selected for the HIA in Apheis (see Apheis 1 report) by the following procedure :

1. Before pasting the pollutant data, delete the existing data, if any, by using, from the menu bar, the function called "Tools/Macro/Macros/". The window called "Macro" is displayed. Select the macro 'EIS-PA_2.0B.xls'! Module2. EffacerDonneesMetrologie (Delete metrological data) and click on "Executer" ("Execute").



2. First, **enter or paste** your series for **the dates alone**. Paste into « A3 cell » the series of date, without the column titles, from the studied period chosen for your HIA. To do so, from the menu, **always** choose «Edition/special paste/values».

3. Then paste your series for the air pollution indicators without the column titles (from the menu, choose «Edition/special paste/values».

	A	B	C	D
1	Pollutants (daily levels)			
2	Dates	BS	PM10	PM2,5
3	1/1/2000		45,8	
4	2/1/2000		41,6	
5	3/1/2000		50,9	
6	4/1/2000		51,9	
7	5/1/2000		66,4	
8	6/1/2000		36,9	
9	7/1/2000		55,5	
10	8/1/2000		51,1	
11	9/1/2000		33,5	

- In cell « B3 », the series for the BS indicator
- In cell « C3 », the series for the PM_{10} indicator
- In cell « D3 », the series for the $PM_{2.5}$ indicator

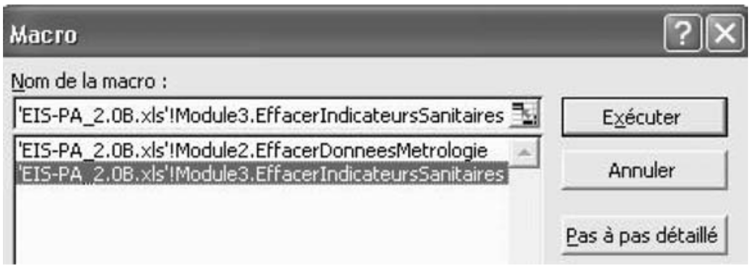
4. If the studied periods are different for some of the indicators, remember to paste the data in the cell of the corresponding first date of the pollution indicator series.

	A	B	C	D
1	Pollutants (daily levels)			
2	Dates	BS	PM10	PM2,5
3	1/1/2000		45,8	
4	2/1/2000		41,6	
5	3/1/2000		50,9	
6	4/1/2000		51,9	
7	5/1/2000		66,4	
8	6/1/2000		36,9	
9	7/1/2000		55,5	
10	8/1/2000		51,1	
11	9/1/2000		33,5	
12	10/1/2000		13,0	9,1
13	11/1/2000		26,1	18,2
14	12/1/2000		62,1	43,5
15	13/1/2000		63,4	44,4
16	14/1/2000		16,0	11,2
17	15/1/2000		17,3	12,1
18	16/1/2000		14,6	10,2
19	17/1/2000		53,0	37,1

3.2. Health Outcomes

1. Before entering the health outcomes data, delete the existing data, if any, by using

« Tools/ Macro/ Macros/ » from the menu bar. The window called "Macro" is then displayed. Select the macro « 'EIS- PA_2.0B.xls'! Module3. Effacer Donnees Sanitaires (Delete health data"» and click on "Executer" ("Execute").



2. The daily average number of health events for each health outcome (in the green area) must be entered or pasted.

Health outcomes		Daily means over the year
Total mortality excluding external causes (ICD9 < 800 - ICD10 A00-R99)		
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)		
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)		
Respiratory admissions (ICD9 460-519 - ICD10 J00-J99)		
Cardiac admissions (ICD9 390-429 - ICD10 I00-I52)		
Cardiopulmonary mortality (ICD9 401-440 and 460-519 - ICD10 I10-I70 and J00-J99)		
Lung cancer mortality (LCA) (ICD9 162 - ICD10 C33-C34)		
Total mortality (ICD9 0 to 999- ICD10 A00-Y98)		
Cardiovascular mortality (DL) (ICD9 390-459 - ICD10 I00-I99)		
Fill in green cells only		

3.3. The studied seasons

You don't have to do anything in this window for Apheis. You don't need to change the values but for other purposes, you may change the summer and winter starting and ending dates entered by default according to the ones you have chosen for your study. Only the days and months corresponding to the beginning and end of the season should be entered, not the year.

Seasons definition		
Pollutant-Season	Start	End
BS summer	1/4	30/9
BS winter	1/10	31/3
PM10 summer	1/4	30/9
PM10 winter	1/10	31/3
PM2,5 summer	1/4	30/9
PM2,5 winter	1/10	31/3

3.4. The reference levels for the various short-term HIA scenarios

Default values have already been entered for each of the scenarios chosen in Apheis 3 but they can be changed, once the scenarios have been done, to produce a figure showing the relative impact of air pollution peaks (see section 5.2) or if you want to test a different scenario.

NB : As you test several scenarios, in order to keep the findings, remember to save the folder under another name before changing the reference value.

3.4.1. Scenario 1

Short term (ST) HIA Reference level Scenario 1 (reduction of all values above X to X µg/m3)		
Pollutant	Value (X)	
BS	20,0	
PM10	20,0	
no more PM2,5 short-term		

3.4.2. Scenario 2

Short term (ST) HIA Reference level Scenario 2 (reduction of all values above X to X µg/m3)		
Pollutant	Value (X)	
BS	50,0	
PM10	50,0	
no more PM2,5 short-term		

3.4.3. Scenario 3

Short term (ST) HIA Reference level Scenario 3 (reduction of all values by X µg/m3)		
Pollutant	Value (X)	
BS	5,0	
PM10	5,0	
no more PM2,5 short-term		

3.5. The reference levels for the various long-term HIA scenarios

Long Term HIA and PM2,5	
Scenario	Value
Scenario 1 : reduction of annual mean value to 15 µg/m3	15,0
Scenario 2 : reduction of annual mean value to 20 µg/m3	20,0
Scenario 3 : reduction of annual mean by 3,5 µg/m3	3,5
Long Term HIA and PM10	
Scenario	Value
Scenario 1 : reduction of annual mean value to 20 µg/m3	20,0
Scenario 2 : reduction of annual mean value to 40 µg/m3	40,0
Scenario 3 : reduction of annual mean by 5 µg/m3	5,0

3.6. Calculation of the number of days with air pollution by 10 µg/m^3 exposure category

This part of the « Data » sheet shows the number of days for each pollutant by year, by season and by 10 µg/m^3 exposure category. **These data allow creating figures in the "AP descriptive findings" sheet and therefore must not be altered.**

Categories 10 / Number of days

Exposure category	BS year	BS summer	BS winter	PM10 year	PM10 summer	PM10 winter	PM2,5 year	PM2,5 summer	PM2,5 winter
0 à 10	0	0	0	3	1	2	0	0	0
10 à 20	0	0	0	67	35	32	0	0	0
20 à 30	0	0	0	81	38	43	0	0	0
30 à 40	0	0	0	72	51	21	0	0	0
40 à 50	0	0	0	64	33	31	0	0	0
50 à 60	0	0	0	38	13	25	0	0	0
60 à 70	0	0	0	24	6	18	0	0	0
70 à 80	0	0	0	11	6	5	0	0	0
80 à 90	0	0	0	3	0	3	0	0	0
90 à 100	0	0	0	2	0	2	0	0	0
100 à 110	0	0	0	0	0	0	0	0	0

3.7. Relative risks of the exposure/response functions

The various **relative risks** used in this software and found in the columns BG to BI are the ones decided for Apheis 3 and **must not be altered for the Apheis HIA.** They are automatically imported for the calculations in the findings sheets.

RR — Increase of : 10 µg/m3

Pollutant	health outcome	Lower	Central	Upper	Reference papers
BS	Total mortality ICD < 800 (CT)	1,004	1,006	1,009	Richard Atkinson
	Cardiovascular mortality (CT)	1,002	1,004	1,007	Richard Atkinson
	Respiratory mortality (CT)	0,998	1,006	1,015	Richard Atkinson
	Respiratory admissions (CT)	0,9985	1,003	1,0075	APHEIS 3

N.B. In addition, in the "Data" sheet, each of **the following cities** must fill in the RR for the PM_{10} shrunken estimate (SE) total mortality scenario from the following table:

City	RR	95% CI -	95% CI +
Athens	1,01217711	1,00765085	1,0167237
Barcelona	1,00873408	1,00544448	1,01203443
Budapest	1,00483458	0,99902889	1,010674
Cracow	1,0035059	0,99845954	1,00857776
London	1,00680869	1,0036713	1,00995588
Madrid	1,00556222	1,00158519	1,00955503
Paris	1,00477747	1,00090073	1,00866923
Rome	1,01068873	1,00631745	1,01507899
Stockholm	1,0058063	0,99890154	1,01275879
Tel-Aviv	1,00635149	1,00212599	1,0105948

Example for Madrid:

			RR	
		Lower	Central	Upper
PM10 (shrunken estimates-SE)	Total mortality < 800 (CT)	1,0016	1,0056	1,0096

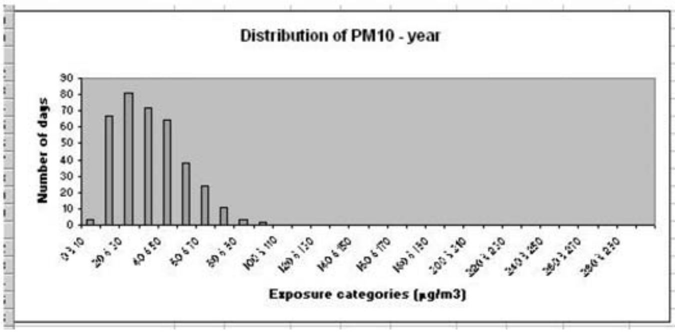
4. «AP descriptive findings» sheet

This sheet shows various descriptive results on pollution indicators for the entire studied period. Once copied, the figures can be inserted into the word documents using the function «Edition/ paste special/ image» from the menu.

- The tables with the distribution of exposure indicators;
- The figures showing the distribution of the various exposure indicators by categories of 10 µg/m^3;

Distribution of air pollution indicators for the study period

	BS year	BS summer	BS winter	PM10 year	PM10 summer	PM10 winter	PM2,5 year	PM2,5 summer	PM2,5 winter
Number	0	0	0	365	183	182	0	0	0
Minimum				9	9	9			
Percentile 5				15	15	16			
Percentile 25				22	21	23			
Median				34	33	37			
Percentile 75				47	43	51			
Percentile 95				69	64	72			
Percentile 98				76	72	83			
Maximum				95	78	95			
Daily mean				37	34	39			
standard error				17	15	19			
% missing values	100,00%	100,00%	100,00%	0,00%	0,00%	0,00%	100,00%	100,00%	100,00%



5. HIA findings sheets

The results of the HIA for sheets 2 to 25 are automatically calculated from data contained in the “Data” sheet (there is no more $PM_{2.5}$ short-term).

There are 25 findings sheets for the HIA. Each sheet corresponds to the HIA results of a combination “pollution indicator – health indicator”. The title of the sheet is always displayed as following: **Type of HIA – pollution indicator – health indicator.**

The sheets are classified according to the health indicator in the following order :

- SHORT TERM
  1. Total mortality (excluding external causes)
  2. Cardiovascular mortality
  3. Respiratory mortality
  4. Respiratory admissions
  5. Cardiac admissions
  6. Distributed lag (DL) total mortality
  7. Distributed lag (DL) cardiovascular mortality
  8. Distributed lag (DL) respiratory mortality
  9. Shrunken estimates (SE) total mortality
- LONG TERM
  1. Total mortality
  2. Cardiopulmonary mortality
  3. LCA mortality

5.1. Summary description of data

Summary description of data is presented in tables for:

- Distribution of the air pollution indicator,
- Number of cases,
- Study period,
- Relative risk used.

Health impact assessment (HIA) - short term (ST)

			Daily mean number of cases	Total number of cases	Study period (days)
Air pollution indicator	PM10		102,8	37522	365
Period:	year				
Health outcome	Respiratory admissions				

Air pollution indicator (µg/m3)	Value		Relative risk lower	Relative risk central	Relative risk upper
Percentile 5	15,0		1,0062	1,0114	1,0167
Percentile 25	22,3				
Percentile 50	33,7		**β lower**	**β central**	**β upper**
Percentile 75	46,9				
Mean	36,6		0,000618086	0,001133551	0,001656209

5.2. HIA findings

1. The last table shows the HIA findings for the various chosen scenarios for the studied period.

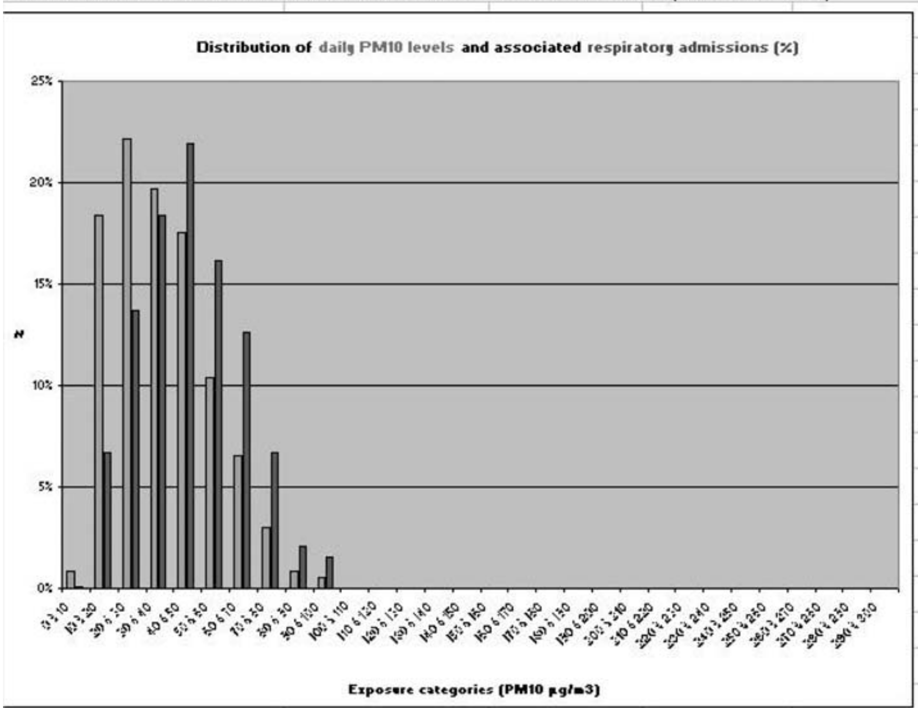
HIA findings, number of attributable cases (NAC) for each scenario PM10 - Respiratory admissions

FINDINGS		For the study period NAC	95% CI	
Scenario 1: Number of cases* for air pollution levels above 20	20,0	734,84	397,30	1082,98
Scenario 2: Number of cases* for air pollution levels above 50	50,0	114,84	62,27	168,72
Scenario 3: Reduction in the number of cases* if air pollution levels are reduced by 5 µg/m3	5,0	205,77	112,05	301,04

**all other things being equal*

2. The figure above the table should not be used for the scenarios. It should be used to show the relative impact of air pollution peaks during a few days compared to daily exposure to lower levels of air pollution over longer periods. To obtain this figure you have to replace values in cells AA42, AA43 and AA44 in "Data" screen by a baseline air pollution level (e.g.:5 µg/m^3).

Distribution of PM10 levels and associated number of cases (scenario 1 ST)



The figure shows daily exposure levels and associated percentage of respiratory admissions divided into 10 µg/m^3 categories. You can see that only 4% of the associated health impact is attributable to levels of PM_{10} higher than 80 µg/m^3. Ninety six percent of the health impacts are observed for lower levels of PM_{10}.

Appendix 8

Some AirQ definitions and AirQ summary help
(Elena Boldo, Emilia Maria Niciu, Michal Krzyzanowski)

Hereafter are some AirQ definitions. For more details on AirQ calculations see (**http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20040428_2**)[2].

Life-Table Formulas used by AirQ

Formulas used by the life-table part of AirQ 2.1.0 are based on /1/ and /2/.

Definitions:

m: mid-year population,

d: number of deaths,

e: entry population,

h: hazard rates,

s: survival probability. e, h, and s are computed based on empirical m's and d's.

For a single cohort (no migration), moving from year i to year i+1:

(1) e_i := m_i + 0.5*d_i (half of the people die in the first half of the year)

(2) hazard rate: h = d/m

(3) all e_i persons are alive at the beginning of year i, d_i die over that year, thus the probability to survive year i is s_i = 1 - d_i/e-i, or with the help of (1)

(4) s_i = (2-h_i)/(2+h_i).

(5) e_(i+1) = s_i * e_i

(6) m_i = Years of Life in year i.

Hazard rates are calculated from empirical data using equation (2). With this, survival probabilities can be expressed and then the evolution of entry and mid-year population (= Years of Life) can be computed.

Estimation of yearly values

If age groups in the input data on population and mortality consist of more than one year, AirQ has to estimate yearly values .. As an example, a data table with 3-years intervals is investigated here. Mid-period population values are sums of three mid-year population values (which are not known):
(i) M = m_1 + m_2 + m_3 and D = d_1 + d_2 + d_3
(ii) H = D/M = (d_1 + d_2 + d_3) / (m_1 + m_2 + m_3) is the weighted annual hazard rate over the three-years interval, and S = (2-H)/(2+H) is the weighted annual survival rate, it is not the probability to survive 3 years! (To see this, consider the special case of all three yearly hazard rates being equal, i.e.
h_i = h, and d_i = h * m_i, which results in H = h.)

[2]More information about HIA can be found in the WHO documents "Quantification of Health effects of Exposure to Air Pollution" (http://www.euro.who.int/document/e74256.pdf) and "Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide" (http://www.euro.who.int/document/e79097.pdf).

Relative risks

Relative risks are usually expressed as ”increased risks per given increase in pollution level”, i.e. RR > 1.0 and

(7) h_higher_pollution_level = RR * h_reference_level

AirQ usually views it the other way round:
(7.A) h_reference_level = RR-1 * h_higher_pollution_level

RR is a function of the difference in pollution level:

(8) RR(x) = exp (b * (x - x_reference))

With b being derived from empirical studies (valid in the range [x_low, x_high], which must be entered on the Calc screen).
In principle, (8) can be used also for cases in which ”x” is less than x_reference, representing a drop in pollution level (RR < 1.0), resulting in increased life expectancies. In fact, AirQ assumes that computation of increases in life expectations as a function of falling pollution levels is the prime interest. In order not to confuse with minus signs in the exponent, AirQ applies formula (7) in the following manner:

(7.B) h_annualMean = exp (b * (x_annualMean - x_reference)) * h_reference

h_annualMean : given, computed from empirical age-distribution
x_annualMean: from measurements, entered on Calc or Infos screen
x_reference: entered on Calc screen
h_reference: computed, i.e.

(7.C) h_reference = h_annualMean / exp (b * (x_annualMean - x_reference))

Definition of Years of Life Lost (YoLL):

(*) YoLL = Years of Life (reference) - Years of Life (basic data).
If the pollution level of reference is less than the pollution level of basic data (i.e. the empirical measurements as they are entered), YoLL is a positive quantity. It can also be viewed as the number of life-years gained, if pollution level drops from the current to the reference level. YoL values are computed using the mid year population values (see description of formulas). Values are computed relative to the first year of simulation.

Expected Life Remaining (ELR):

ELR(at AGE) = Sum (from AGE until end) YoL / number of people at AGE.

The table presents the ELR for the “reference” pollution levels, calculated with the hazard rates adjusted by the RR associated with the observed pollution levels. Since the RR will be different for total and cause-specific mortality, the ELR displayed in the tables will vary accordingly.

ELR lost = ELR (reference) - ELR(basic data). The list may be displayed in one, five, or ten years steps.
Note: The ELRs will change if YoL weights are different from 1.0 (see calculation sheet).

Years of Life Lost:
“Years of Life Lost for starting year of simulation” compares the absolute numbers of YoL based on the initial distribution. Formulas:

YoL (*first year*) = *Sum* (*age range*) YoL and

Normalized values (per 100 000 population):

*YoL_norm(first year) = 100 000 * Sum (age range) YoL / Sum (age range) Entries (first year)*

Calculations for specific causes of death (e.g. Lung Cancer -LCA)
Algorithm: In the presence of air pollution, the number of deaths due to LCA and cardiopulmonary reasons are both affected decreasing population at risk. For doing the propagation (entry populations, hazards, and Years-of-Life/mid period population), the following formula are used:

(* *) hreference = hcardio+LCA = helse + RRcardio * hcardio+ RRLCA * hLCA

Of interest are the Years-of-Life-Lost due to LCA:
YLLLCA := YLLCA+cardio - YLcardio

or for Cardio:

YLLcardio := YLLCA+cardio - YLLCA. In General:
YLLspecial cause A := YLspecial cause A+ special cause B - YLspecial cause B

In the calculation of lower and upper boundaries of the estimates, the program uses RRlower and RRupper for the analysed cause of death only, without considering the error covariance structure.

References:
/1/ EUR/01/5026342, Appendix 2: "Life-table methods for predicting and quantifying long-term impacts on mortality".
/2/ Kenneth J. Rothman, Sander Greenland: "Measures of Disease Frequency"

How to use AirQ
AirQ example : YoLL

The Air Quality Health Impact Assessment Tool (AirQ) is a specialized software that enables the user to assess the potential impact on human health of exposure to a given air pollutant in a defined urban area during a certain time period.

This AirQ example consists in estimating the Years of Life Lost for different effects (all causes of death, cardiopulmonary mortality and LCA mortality) of a city (Madrid, Spain) which can be attributed to the ambient air pollution with $PM_{2.5}$, during one year of air quality monitoring.

AirQ is essentially a sequence of screens in which information can be entered and estimated health impacts are calculated and displayed. The user should go through the following sequence:

1. **Start the program**: click twice on the AirQ icon on your desktop or on the file airq.exe in the default directory (where you have installed it) and the next screen appear:

Then, press OK button and the AirQ 2.0 Main Screen appears:

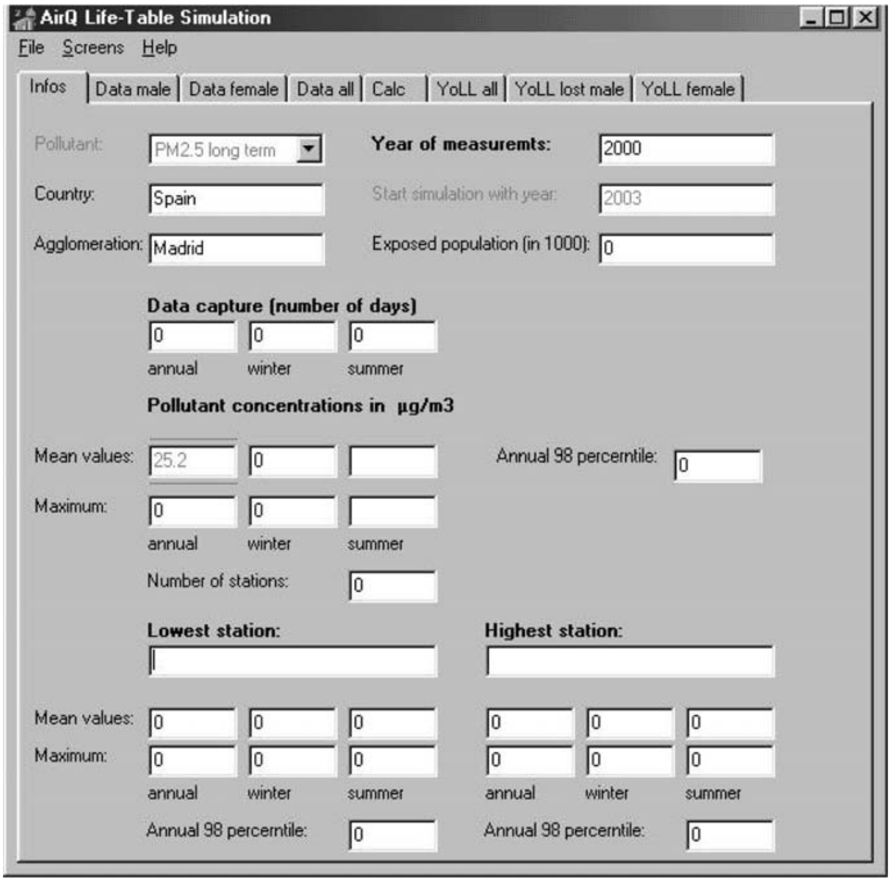
For Life-tables calculation, press *Enter LT data* button and *AirQ Life-Table Simulation* screen appears where basic data have to be filled in different screens. The flow is from left to right, starting with data entry on the *Info sheet*, continuing with entering *population data*, selecting and entering the parameters on the *Calc sheet for* performing calculations, and finally viewing results on the *Years of Life Lost sheets*.

The life table implementation of AirQ is a one calculation at a time application (impact estimates for one pollutant on one health outcome). The items of the working sheets are stored in a single "life-table file" with save (temporary saving) or save as from the file menu of AirQ, as a TXT file that can be retrieved later. This can be re-imported with the open input/result command of AirQ.

2. Infos sheet

This sheet holds primarily data for information purposes only. The user has to fill in the necessary data (*country, agglomeration, year of measurements, start simulation with year, exposed population, data capture, physical values and number of stations*) and to select an air pollutant (*pollutant*) for the assessment of its impact on the health outcome in the program. Nevertheless, in this sheet, only the red items have to be filled in for calculations.

If the population exposure profile was estimated by daily averaging of the data from more than one monitoring station, the following additional statistics for the *lowest stations* profile and the *highest stations* profile should be entered to allow better description of the population exposure, i.e. annual and seasonal mean values and 98 percentile.



Data capture (number of days):

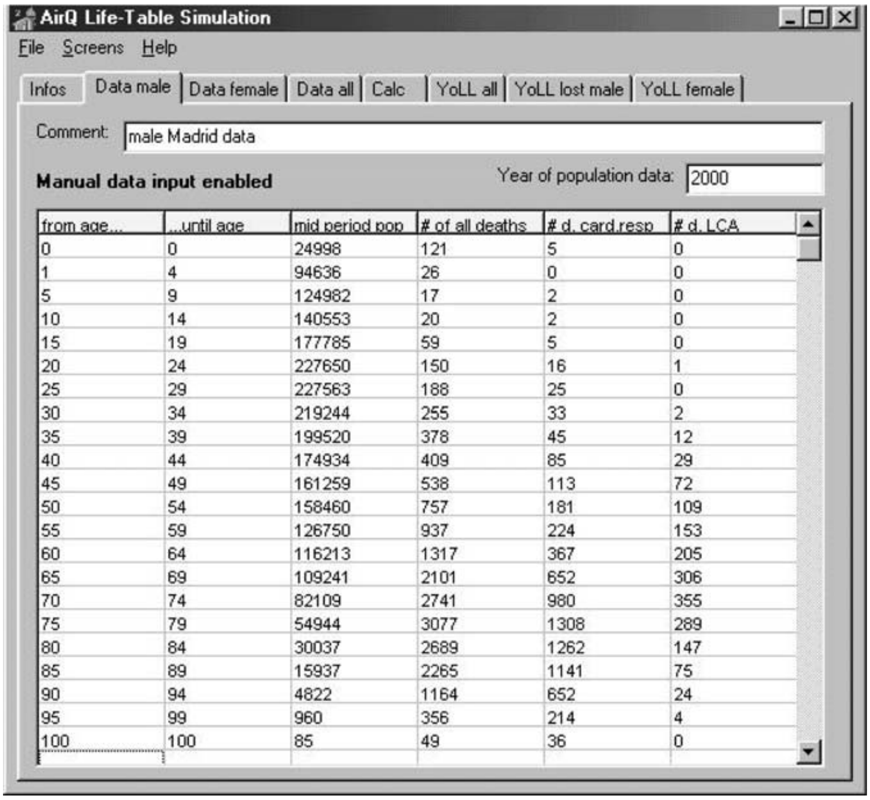
Year: *calendar year* (1 January-31 December)
Seasons: *winter* – from January to March and from October to December inclusive
summer – from April to September inclusive.

Attention!

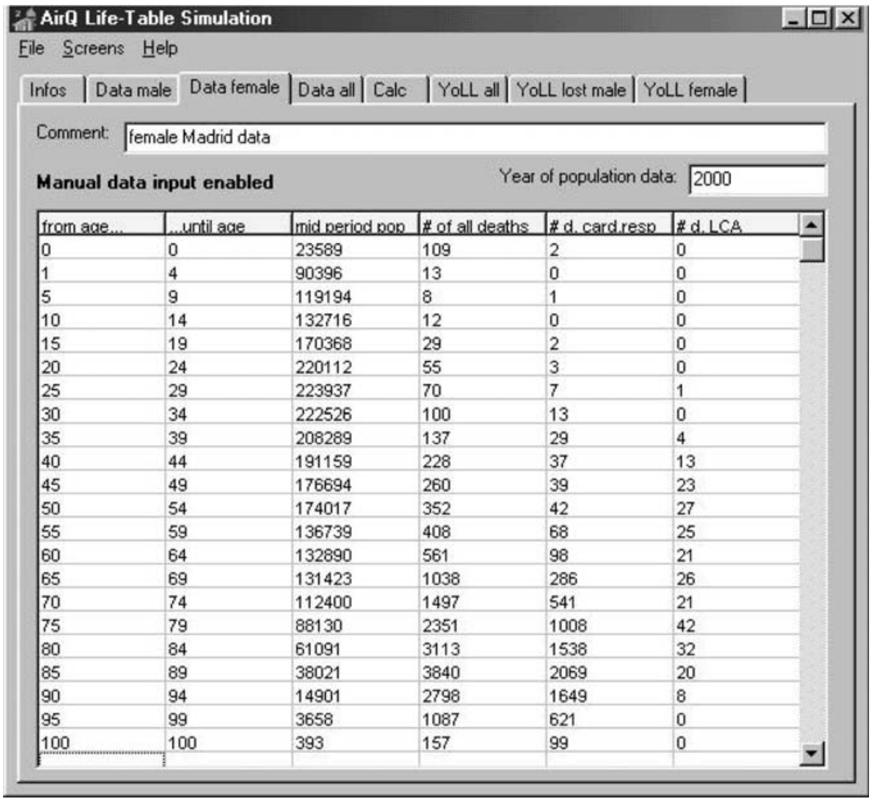
Make sure that all the data is stored in the same number format (comma or point).

3. Data population sheets

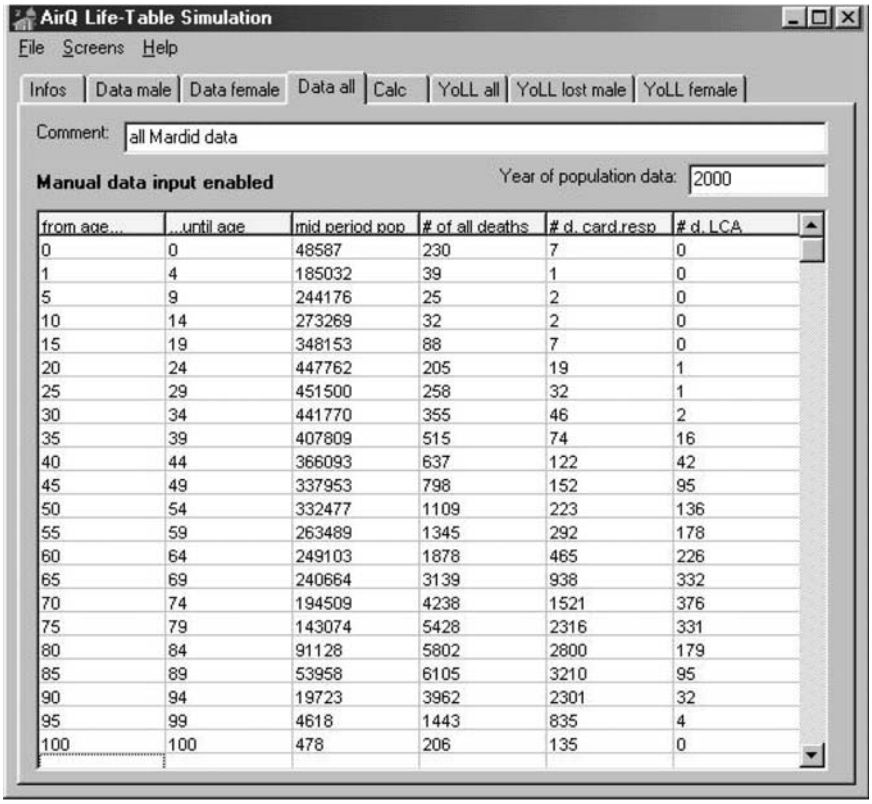
Three data entry sheets are available for male, female, and all empirical population data and mortality data (total mortality, cardiopulmonary, LCA), respectively. Items are arranged in a table. Each row consist of an age range (from beginning of age 1…until end of age 2). The first interval (from age…until age) should be, if possible, 0-0 for all younger than one year in the screen “data male”, “data female” and “data all”.



from age...	...until age	mid period pop	# of all deaths	# d. card.resp	# d. LCA
0	0	24998	121	5	0
1	4	94636	26	0	0
5	9	124982	17	2	0
10	14	140553	20	2	0
15	19	177785	59	5	0
20	24	227650	150	16	1
25	29	227563	188	25	0
30	34	219244	255	33	2
35	39	199520	378	45	12
40	44	174934	409	85	29
45	49	161259	538	113	72
50	54	158460	757	181	109
55	59	126750	937	224	153
60	64	116213	1317	367	205
65	69	109241	2101	652	306
70	74	82109	2741	980	355
75	79	54944	3077	1308	289
80	84	30037	2689	1262	147
85	89	15937	2265	1141	75
90	94	4822	1164	652	24
95	99	960	356	214	4
100	100	85	49	36	0



from age...	...until age	mid period pop	# of all deaths	# d. card.resp	# d. LCA
0	0	23589	109	2	0
1	4	90396	13	0	0
5	9	119194	8	1	0
10	14	132716	12	0	0
15	19	170368	29	2	0
20	24	220112	55	3	0
25	29	223937	70	7	1
30	34	222526	100	13	0
35	39	208289	137	29	4
40	44	191159	228	37	13
45	49	176694	260	39	23
50	54	174017	352	42	27
55	59	136739	408	68	25
60	64	132890	561	98	21
65	69	131423	1038	286	26
70	74	112400	1497	541	21
75	79	88130	2351	1008	42
80	84	61091	3113	1538	32
85	89	38021	3840	2069	20
90	94	14901	2798	1649	8
95	99	3658	1087	621	0
100	100	393	157	99	0



from age...	...until age	mid period pop	# of all deaths	# d. card.resp	# d. LCA
0	0	48587	230	7	0
1	4	185032	39	1	0
5	9	244176	25	2	0
10	14	273269	32	2	0
15	19	348153	88	7	0
20	24	447762	205	19	1
25	29	451500	258	32	1
30	34	441770	355	46	2
35	39	407809	515	74	16
40	44	366093	637	122	42
45	49	337953	798	152	95
50	54	332477	1109	223	136
55	59	263489	1345	292	178
60	64	249103	1878	465	226
65	69	240664	3139	938	332
70	74	194509	4238	1521	376
75	79	143074	5428	2316	331
80	84	91128	5802	2800	179
85	89	53958	6105	3210	95
90	94	19723	3962	2301	32
95	99	4618	1443	835	4
100	100	478	206	135	0

The length of consecutive age groups may vary, but an age group must start with the age that follows the previous “until end of age” value. Data tables for males, females and all need to match in size as well as in format : there must be the same number of age groups (same number of lines) and the age groups must be identical. In addition, age groups have to be consecutive.

The user has to enter the *year of population data* and the population data in the *manual data input enabled table*: the age range, the mid period population, the total mortality, the cardiopulmonary mortality and lung cancer mortality for age-specific groups. The total number of deaths must be entered, the two others are optional. If no values are supplied for number of cardio-pulmonary deaths or number or LCA deaths, these numbers are set to zero.

If calculation are to be performed for cardiopulmonary or LCA both have to be supplied as the software algorithm is calculating the impact taking into account simultaneously both outcomes.

Note: even if death numbers for cardiovascular and LCA causes of death are entered, AirQ calculates the associated Years of Life Lost only if the appropriate selection is made on the calculation screen.

The sign # means "number". For each indicated age group the table row contains the absolute number of people in the middle of the calendar year, number of deaths due to all causes, number of deaths due to cardiovascular diseases and number of LCA deaths in calendar year. Those values are always absolute numbers, rates are not to be entered.

If mid-year population it isn’t available, the mean of the two consecutive 1st January populations can be used.

Data can be introduced by two modes:

- Manual data entry

If data is manually entered, AirQ checks for logical consistency of data only. One may enter data for male, female, or exclusively all data (the latter one being comprised of all= male + female numbers).

- If data entry starts for either *male or female* data, the program assumes that data for *all* has to be computed and prohibits (disables) manual entry of data into the *all* sheet (a button appears in data *all* screen for adding data automatically after both male and female data have been entered).

- If data entry starts on the <u>all</u> sheet, AirQ assumes that neither male nor female data is available and therefore inhibits (disables) data entries on those sheets. If data are available for total population only, then the user goes directly to the *data all screen*.

Note: all cells in the row have to be filled in! If no data available enter zero "0" (compulsory)

- <u>Data entry from a file</u>

Data can be imported into AirQ tables as TAB delimited <*.txt> files by using the
FILE MENUE -> OPEN INPUT/RESUTS DATA option.

The best approach to enter/ store the original data set in a Excel spreadsheet and to use the SAVE AS function in Excel to convert it to a TXT (TAB delimited) file

If you create directly a TXT file make sure no tabs left at the end of the row as free spaces

If you created it from a Excel file check the TXT file so that no free tabs are left at the end of the row (all rows – text and numbers)

The files must have the following format:

Please pay attention to the first 3 lines and last line of the table (see model)
- No free lines allowed
- No extra lines allowed
- No extra/free tabs after the last character in the row allowed

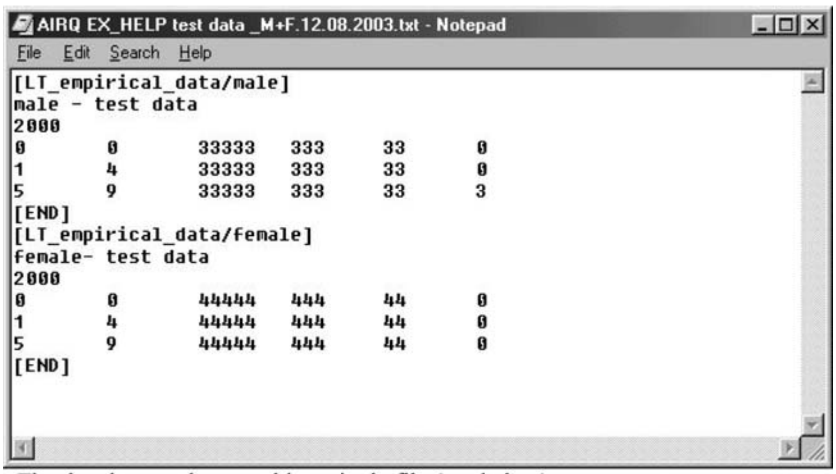
- Example - just for males test data:

[LT_empirical_data/male] **– this is the starting line –compulsory**
"male - test data" (comments line – can be left empty)
2000 (year line – can be left empty)
0 0 33333
333 33
0
1 4 33333
333 33
0
5 9 33333 333 33 3
[END] – ***this is the ending line – compulsory***

NO OTHER LINES CAN BE ADDED, PLEASE make sure that the data in the *.TXT file correspond with the column headings in AirQ.

Data import for males and females if separately available

The data have to be stored in a single file (see below)




```
[LT_empirical_data/male]
male - test data
2000
0	0	33333	333	33	0
1	4	33333	333	33	0
5	9	33333	333	33	3
[END]
[LT_empirical_data/female]
female- test data
2000
0	0	44444	444	44	0
1	4	44444	444	44	0
5	9	44444	444	44	0
[END]
```

In this case in the <**Data all**> screen the data can be added up to a total.
Please note that in this case in order to activate the <**male + female**> button in the <**Data all**> screen you have to overwrite one of the values in the males or females AirQ screens, as the software is not activating this button when importing data.

Data import for males & females & all if separately available

```
AIRQ EX_HELP test data _M+F+all.12.08.2003.txt - Notepad
File  Edit  Search  Help
[LT_empirical_data/male]
male - test data
2000
0       0       33333   333     33      0
1       4       33333   333     33      0
5       9       33333   333     33      3
[END]
[LT_empirical_data/female]
female- test data
2000
0       0       44444   444     44      0
1       4       44444   444     44      0
5       9       44444   444     44      0
[END]
[LT_empiricla_data/male+female]

2000
0       0       77777   777     77      0
1       4       77777   777     77      0
5       9       77777   777     77      3
[END]
```

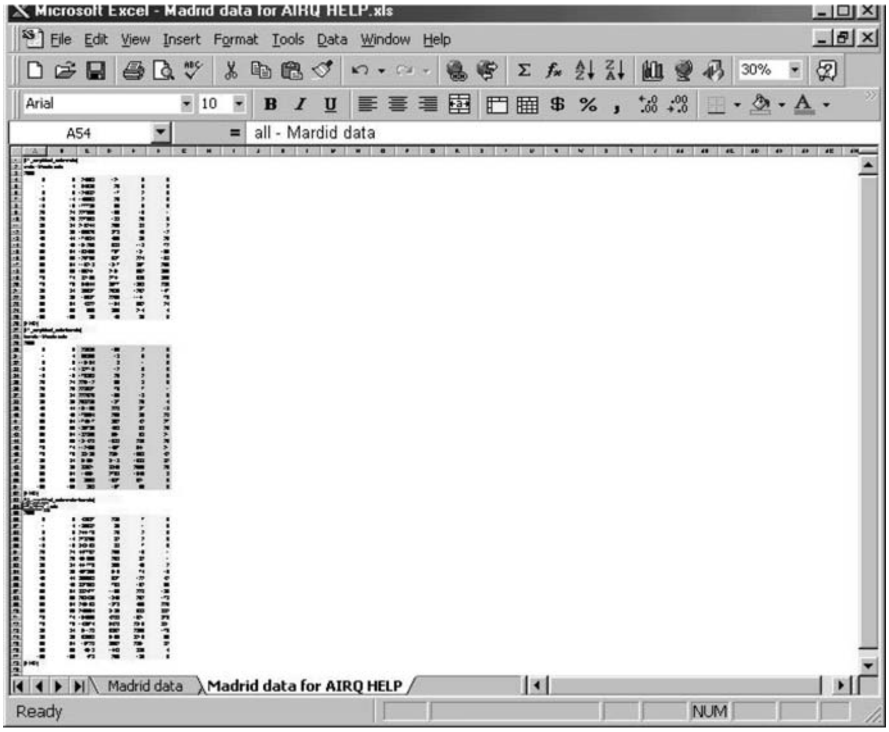
Please note leave the spelling mistake as such in the male+female data entry
Excel file model For data entry [LT_empiricla_data/male+female]

Data import for <Data all> screen –only <all> data available

```
NewalgorithmAll204.- import test.3_12.08.2003.txt - Notepad
File  Edit  Search  Help
[LT_empiricla_data/male+female]
Data from Annex 2, deaths/cardio and LCA artificial
1995
0       4       3387900 4727    0       0
5       9       3401300 472     27      15
10      14      3212300 557     34      12
15      19      3026100 1323    93      45
20      24      3494600 2075    156     50
25      29      4094200 2646    188     66
30      34      4234400 3344    222     71
35      39      3654500 3938    250     83
40      44      3348000 5662    344     120
45      49      3658600 9574    571     241
50      54      2953000 12964   781     205
55      59      2660700 19345   1196    358
60      64      2458000 30575   1904    603
65      69      2353100 50359   3049    1203
70      74      2201400 77674   4453    1062
75      79      1555700 85235   4500    1795
80      84      1178500 104269  4731    2978
85      89      650900  88455   3148    1025
90      94      240630  49754   1278    423
95      99      46420   14858   253     103
100     100     4550    2327    26      12
[END]
```

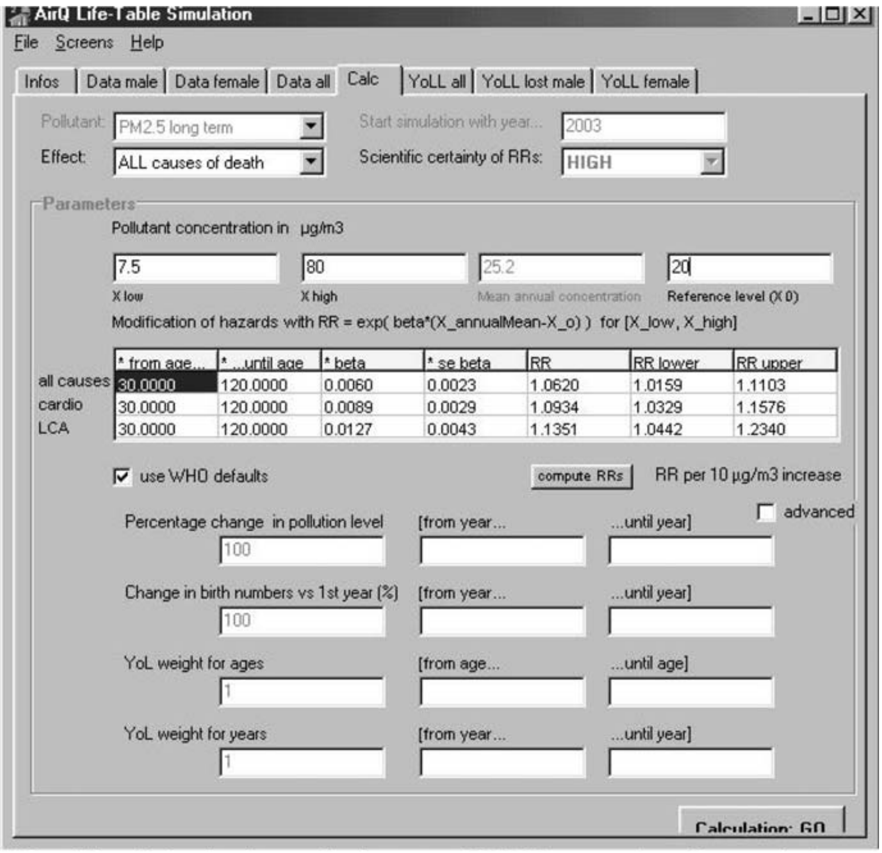
Please note leave the spelling mistake as such in the male+female data entry
[LT_empiricla_data/male+female]

This can be converted to tab delimited text file by using the <save as> function in the Excel file menu. (FILE attached – Madrid data)



4. Calc sheet

This sheet displays all parameters used for performing the calculations. Some calculation parameters have to be filled by the user on the Calc Sheet.



YLLo will be calculated in this case for the impact of $PM_{2.5}$ long term (annual mean values) on total mortality (all causes), due to exposures above the threshold of 20 ug/m^3 $PM_{2.5}$

Pollutant: it's possible to select a type of pollutant. The pollutant is $PM_{2.5}$ long term (annual mean values) for APHEIS 3.

Start simulation with year: this is the starting year of the calculation. AirQ takes the data from the infos screen.

Effect: the user has to choose the cause of death [total mortality (all causes of death), cardiopulmonary mortality, lung cancer (LCA) mortality].

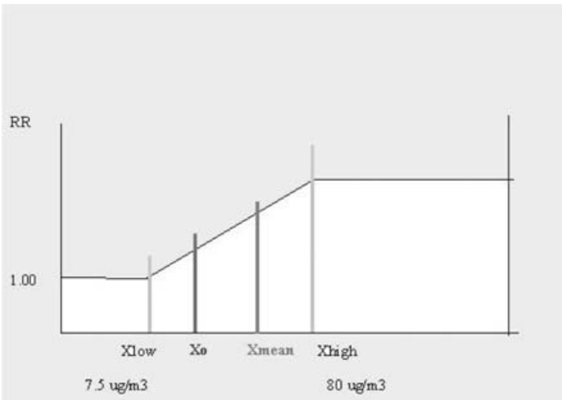
For the predefined health outcomes, included in AirQ program, the user can use WHO default values for Relative Risk. These are automatically displayed by pressing the use WHO defaults button and the values appear automatically in all the cells (from age…, until age…, beta, se beta, RR, RR lower, RR upper) as well as the *Scientific certainty of RRs*.

Scientific certainty of RRs: The setting does not affect calculations, it is automatically set by AirQ for documentation purposes. The level of their scientific certainty is given according to the epidemiological evidence available. WHO default values are with high scientific certainty.
Parameters fields: parameters describing air pollution concentration in the specific agglomeration (X low, X high, mean annual concentration and reference level) and are all expressed in µg/m^3.
1. USE WHO DEFAULT VALUES

- [*X low* –*X high*] is the range for which the RR's are scientifically valid
WHO default values are 7.5 µg/m^3 for *X low* and 80 µg/m^3 for *X high*.

- The *mean annual concentration* [*X mean*] is the mean annual city value, and will automatically retrieved from the infos screen.

X mean has to be greater than the reference level. If *X mean* is smaller than *X low* or above *X high*, it will be automatically set to *X low* or *X high* respectively, once the <*calculation GO*> button is pressed. AirQ is assuming that below *X low* there are no effects and above *X high* the effect are levelling off.



- [Xo] is the reference level above which the impact is calculated and it has to be chosen by the user. It refers to different reductions in annual mean air pollution levels as detailed in specific scenarios. For APHEIS 3, the following scenarios has been chosen:

  - For PM_{10}:

    - Reduction to 40 µg/m^3
    - Reduction to 20 µg/m^3
    - Reduction by 5 µg/m^3

  - For $PM_{2.5}$:

    - Reduction to 20 µg/m^3
    - Reduction to 15 µg/m^3
    - Reduction by 3.5 µg/m^3

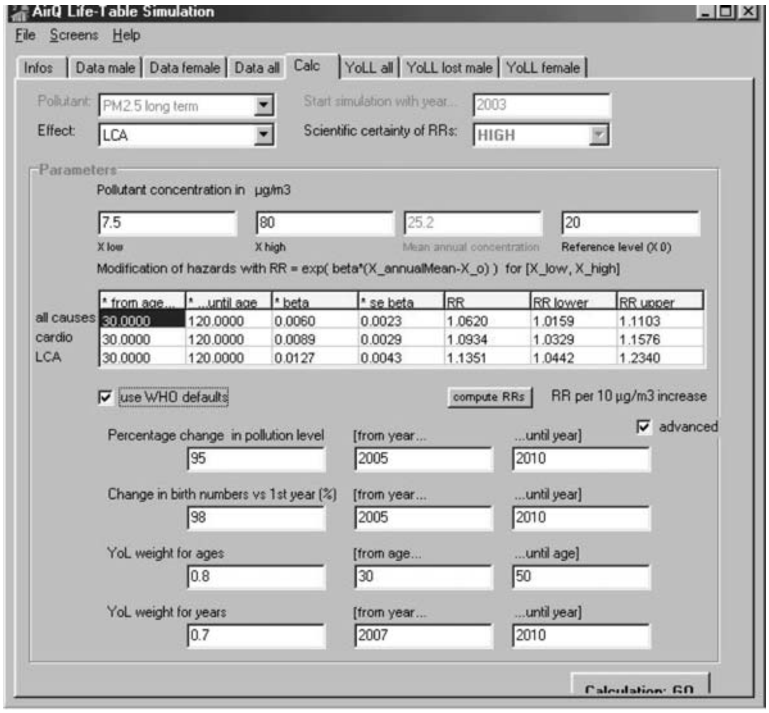
[*Xo*] should be between *Xlow* and *Xhigh* (*X low* < *Xo* < *X high*) and *Xo*] should be smaller than *Xmean* (*Xo*<*Xmean*). If *Xo*] is greater than *X mean* a error message appears, and calculations can not be performed.

2. IF USER DO NOT USE WHO DEFAULT VALUES

If $PM_{2.5}$ annual mean value is lower than 10 µg/m^3, for the scenario reducing annual mean value by 3.5 µg/m^3 the user is allowed to modify X low *by annual mean-3.5 µg/m^3*. In this case, the user doesn't select WHO default values and has to enter all the parameters *(X low, X high, mean annual concentration, reference level, from age, until age, beta, se beta, RR, RR lower, RR upper).*

Advanced options for calculations

For advanced scenarios the user can check the advanced box. In this case additional calculations are performed taking into account changes in time of air pollution or birth rates.



A. Percentage change in pollution level from year 20xx to year 20zz:

The basic calculations assume that air pollution stays stable over time. This dose not hold true in real life. In order to assess the impact if air pollution is changing over time the user can apply a reduction or increase in air pollution levels, expressed in percentage of the reference year. (e.g. assuming that starting with 2005 air pollution will be decreasing with 5% of the current levels till 2010, the user will fill in the value 95 in the corresponding cell).

B. Percentage change in birth numbers from year 20xx to year 20zz:

The basic calculations assume that birth numbers stay stable over time. This dose not hold true in real life. In order to assess the impact if this is changing over time the user can apply a reduction or increase in birth numbers, expressed in percentage of the reference year. (e.g. assuming that starting with 2005 this number will be decreasing with 2% of the current levels till 2010, the user will fill in the value 98 in the corresponding cell).

C. Weight for years of life (yol) for ages:

The basic calculations assume that all age groups of the birth cohort have the same weight (importance) for the YoL. The user can attribute different weights for a specified age category of the birth cohort for which the weight is considered to differ from the rest of it (e.g 0.8 for 30-50 yr. – just a made up example) Values to be filled in the corresponding cells.

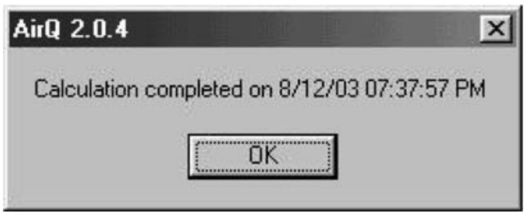
D. Weight for yol for years

The basic calculations assume that the YoL in the next 100 years have the same importance as today (starting year of simulations). The user can attribute different weights for a specified time periods in the future, reflecting the importance given to YoL as a weight of the starting year. (e.g 0.7 for 5 years from staring year of simulations (2003); 2007-2010 – just a made up example) Values to be filled in the corresponding cells.

Note: when changing the weights for ages or years only the expected life remaining is changing!

5. Calculation

Finally, the user has to click on Calculation: Go, wait some minutes and the results are in YoLL screens.



6. YoLL sheets

Definition of YoLL: YoLL = Years of Life (null hypothesis) - Years of Life (presence of pollution). YoL values are computed using the mid year population values (see description of formulas). Values are computed relative to the first year of simulation.

Expected Life Remaining (ELR):

ELR(starting with AGE) = Sum (from AGE until end) YoL / number of people at AGE.

ELR lost = ELR (null hypothesis) - ELR(presence of pollution). Note: The ELRs will change if YoL weights are different from 1.0 (see calculation sheet). The list may be displayed in one, five, or ten years steps.

Years of Life Lost:

”Years of Life Lost for starting year of simulation” and ”Years of Life Lost for first ten years” compare the absolute numbers of YoL based on the initial distribution. Formulas:

YoL (first year) = Sum (age range) YoL and

YoL (first ten years) = Sum (first ten years) [Sum(age range) YoL]).

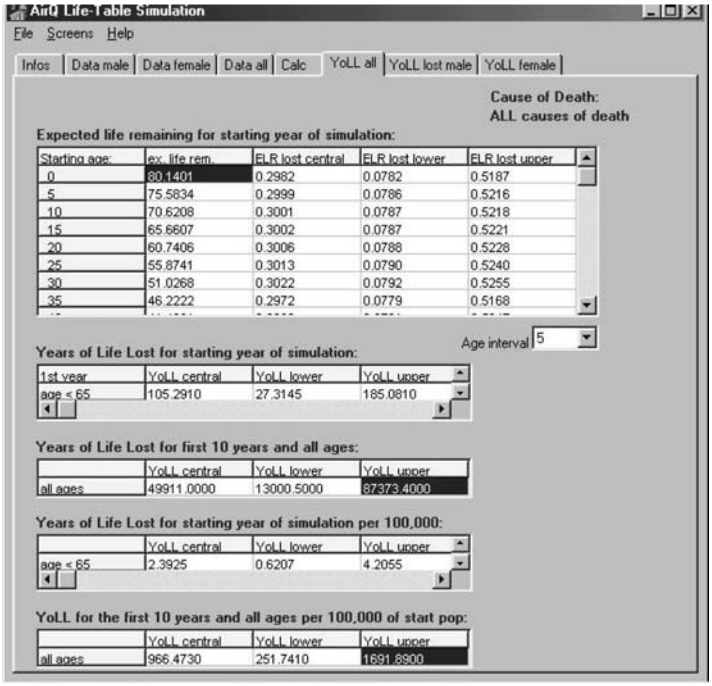
Normalized values (per 100 000 population):

YoL_norm(first year) = 100 000 * Sum (age range) YoL / Sum (age range) Entries (first year) and

YoL_norm (first ten years) = 100 000 * Sum (first ten years) [Sum(age range) YoL]) / Sum (first ten years) [Sum (age range) Entries (first year)]).

The user has to interpret the findings in the YoLL screens. All results are total numbers.

The list may be displayed in one, five, or ten years steps.


AirQ Life-Table Simulation

File Screens Help

Infos | Data male | Data female | Data all | Calc | YoLL all | YoLL lost male | YoLL female

Cause of Death:
ALL causes of death

Expected life remaining for starting year of simulation:

Starting age:	ex. life rem.	ELR lost central	ELR lost lower	ELR lost upper
0	80.1401	0.2982	0.0782	0.5187
5	75.5834	0.2999	0.0786	0.5216
10	70.6208	0.3001	0.0787	0.5218
15	65.6607	0.3002	0.0787	0.5221
20	60.7406	0.3006	0.0788	0.5228
25	55.8741	0.3013	0.0790	0.5240
30	51.0268	0.3022	0.0792	0.5255
35	46.2222	0.2972	0.0779	0.5168

Age interval 5

Years of Life Lost for starting year of simulation:

1st year	YoLL central	YoLL lower	YoLL upper
age < 65	105.2910	27.3145	185.0810

Years of Life Lost for first 10 years and all ages:

	YoLL central	YoLL lower	YoLL upper
all ages	49911.0000	13000.5000	87373.4000

Years of Life Lost for starting year of simulation per 100,000:

	YoLL central	YoLL lower	YoLL upper
age < 65	2.3925	0.6207	4.2055

YoLL for the first 10 years and all ages per 100,000 of start pop:

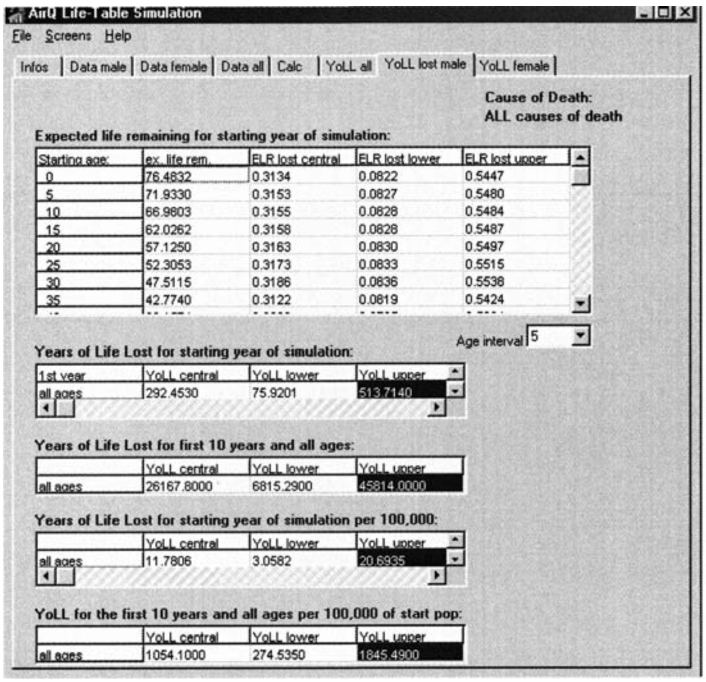
	YoLL central	YoLL lower	YoLL upper
all ages	966.4730	251.7410	1691.8900

All other things being equal, reducing annual mean value from 25.2 µg/m^3 to 20 µg/m^3, as specified in Calc screen, would avoid losing an average total life expectancy of 0.3022 years for all causes of death and for each person older than 30 years of the total population exposed in Madrid (Spain), with the life expectancy at birth being 80.1401 years.

For population older than 30 years and less than 65 years and for starting year of simulation (in this example, year 2003) as detailed in *infos* sheet, the years of life lost are 105.291. Per 100 000 inhabitants and for starting year of simulation, the years of life lost are 2.3925 years.

For population older than 30 years, for first 10 years (from 2003 to 2013), the years of life lost are 49911. Per 100.000 inhabitants and for first 10 years, the years of life lost are 966.473 years.

In the following tables are displayed the findings for male and female and for different causes of death (LCA).


AirQ Life-Table Simulation

File Screens Help

Infos | Data male | Data female | Data all | Calc | YoLL all | YoLL lost male | YoLL female

Cause of Death:
ALL causes of death

Expected life remaining for starting year of simulation:

Starting age:	ex. life rem.	ELR lost central	ELR lost lower	ELR lost upper
0	76.4832	0.3134	0.0822	0.5447
5	71.9330	0.3153	0.0827	0.5480
10	66.9803	0.3155	0.0828	0.5484
15	62.0262	0.3158	0.0828	0.5487
20	57.1250	0.3163	0.0830	0.5497
25	52.3053	0.3173	0.0833	0.5515
30	47.5115	0.3186	0.0836	0.5538
35	42.7740	0.3122	0.0819	0.5424

Age interval 5

Years of Life Lost for starting year of simulation:

1st year	YoLL central	YoLL lower	YoLL upper
all ages	292.4530	75.9201	513.7140

Years of Life Lost for first 10 years and all ages:

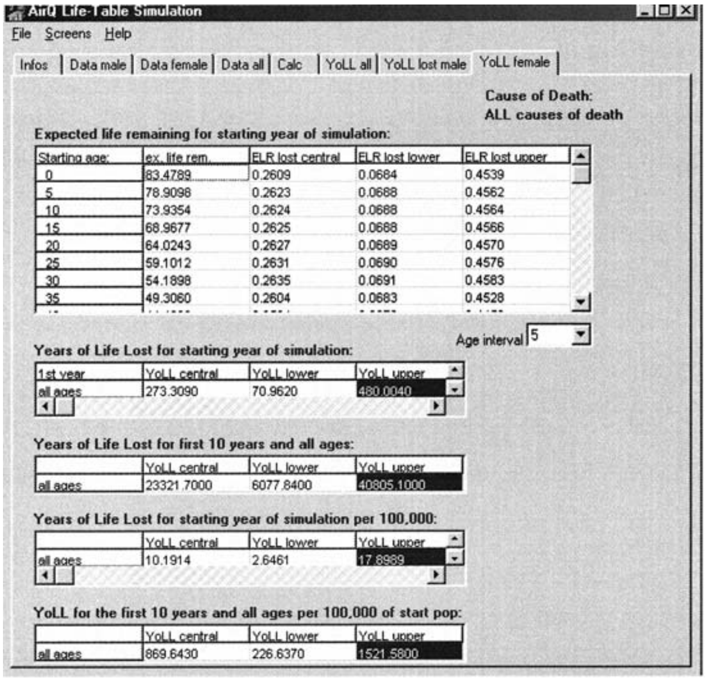
	YoLL central	YoLL lower	YoLL upper
all ages	26167.8000	6815.2900	45814.0000

Years of Life Lost for starting year of simulation per 100,000:

	YoLL central	YoLL lower	YoLL upper
all ages	11.7806	3.0582	20.6935

YoLL for the first 10 years and all ages per 100,000 of start pop:

	YoLL central	YoLL lower	YoLL upper
all ages	1054.1000	274.5350	1845.4900



AirQ Life-Table Simulation
File Screens Help
Infos | Data male | Data female | Data all | Calc | YoLL all | YoLL lost male | YoLL female
Cause of Death:
ALL causes of death
Expected life remaining for starting year of simulation:

Starting age:	ex. life rem.	ELR lost central	ELR lost lower	ELR lost upper
0	83.4789	0.2609	0.0684	0.4539
5	78.9098	0.2623	0.0688	0.4562
10	73.9354	0.2624	0.0688	0.4564
15	68.9677	0.2625	0.0688	0.4566
20	64.0243	0.2627	0.0689	0.4570
25	59.1012	0.2631	0.0690	0.4576
30	54.1898	0.2635	0.0691	0.4583
35	49.3060	0.2604	0.0683	0.4528

Age interval 5
Years of Life Lost for starting year of simulation:

1st year	YoLL central	YoLL lower	YoLL upper
all ages	273.3090	70.9620	480.0040

Years of Life Lost for first 10 years and all ages:

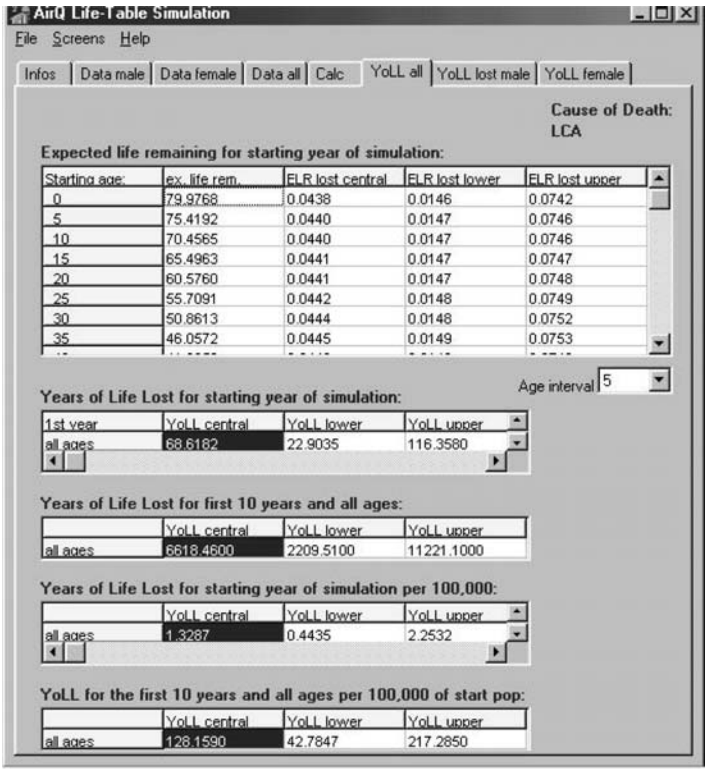
	YoLL central	YoLL lower	YoLL upper
all ages	23321.7000	6077.8400	40805.1000

Years of Life Lost for starting year of simulation per 100,000:

	YoLL central	YoLL lower	YoLL upper
all ages	10.1914	2.6461	17.8989

YoLL for the first 10 years and all ages per 100,000 of start pop:

	YoLL central	YoLL lower	YoLL upper
all ages	869.6430	226.6370	1521.5800



AirQ Life-Table Simulation
File Screens Help
Infos | Data male | Data female | Data all | Calc | YoLL all | YoLL lost male | YoLL female
Cause of Death:
LCA
Expected life remaining for starting year of simulation:

Starting age:	ex. life rem.	ELR lost central	ELR lost lower	ELR lost upper
0	79.9768	0.0438	0.0146	0.0742
5	75.4192	0.0440	0.0147	0.0746
10	70.4565	0.0440	0.0147	0.0746
15	65.4963	0.0441	0.0147	0.0747
20	60.5760	0.0441	0.0147	0.0748
25	55.7091	0.0442	0.0148	0.0749
30	50.8613	0.0444	0.0148	0.0752
35	46.0572	0.0445	0.0149	0.0753

Age interval 5
Years of Life Lost for starting year of simulation:

1st year	YoLL central	YoLL lower	YoLL upper
all ages	68.6182	22.9035	116.3580

Years of Life Lost for first 10 years and all ages:

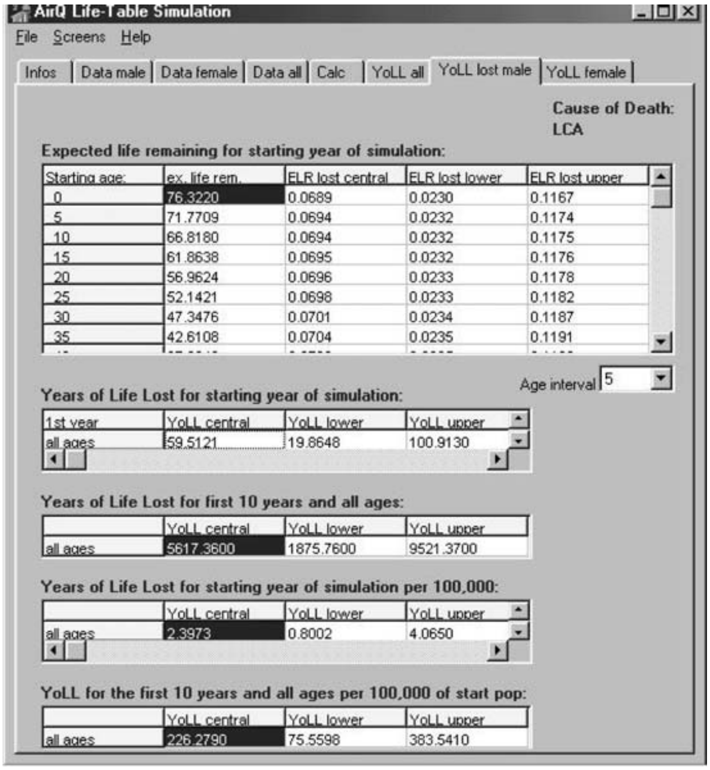
	YoLL central	YoLL lower	YoLL upper
all ages	6618.4600	2209.5100	11221.1000

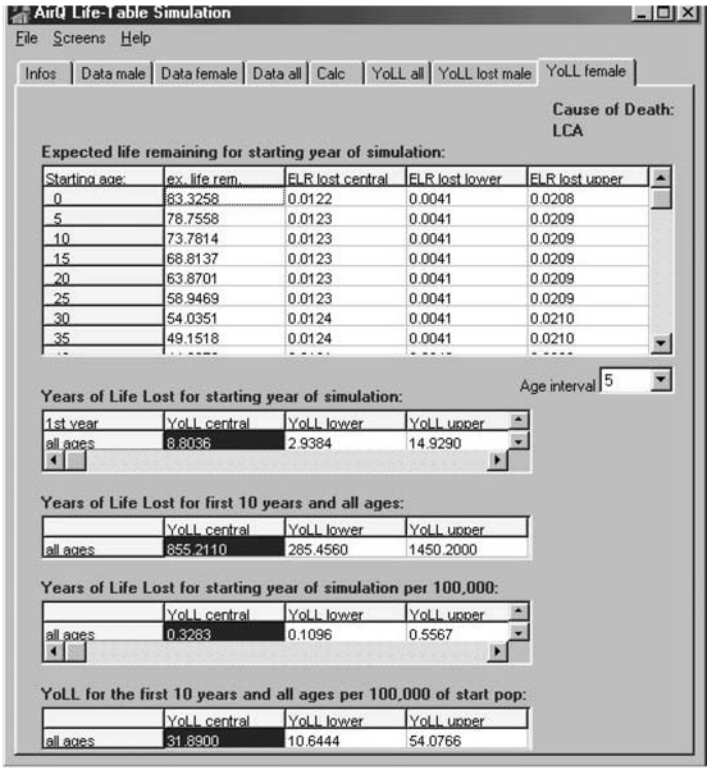
Years of Life Lost for starting year of simulation per 100,000:

	YoLL central	YoLL lower	YoLL upper
all ages	1.3287	0.4435	2.2532

YoLL for the first 10 years and all ages per 100,000 of start pop:

	YoLL central	YoLL lower	YoLL upper
all ages	128.1590	42.7847	217.2850


AirQ Life-Table Simulation
File Screens Help
Infos | Data male | Data female | Data all | Calc | YoLL all | YoLL lost male | YoLL female
Cause of Death: LCA
Expected life remaining for starting year of simulation:
Starting age: | ex. life rem. | ELR lost central | ELR lost lower | ELR lost upper
0 | 76.3220 | 0.0689 | 0.0230 | 0.1167
5 | 71.7709 | 0.0694 | 0.0232 | 0.1174
10 | 66.8180 | 0.0694 | 0.0232 | 0.1175
15 | 61.8638 | 0.0695 | 0.0232 | 0.1176
20 | 56.9624 | 0.0696 | 0.0233 | 0.1178
25 | 52.1421 | 0.0698 | 0.0233 | 0.1182
30 | 47.3476 | 0.0701 | 0.0234 | 0.1187
35 | 42.6108 | 0.0704 | 0.0235 | 0.1191
Age interval 5
Years of Life Lost for starting year of simulation:
1st year | YoLL central | YoLL lower | YoLL upper
all ages | 59.5121 | 19.8648 | 100.9130
Years of Life Lost for first 10 years and all ages:
| YoLL central | YoLL lower | YoLL upper
all ages | 5617.3600 | 1875.7600 | 9521.3700
Years of Life Lost for starting year of simulation per 100,000:
| YoLL central | YoLL lower | YoLL upper
all ages | 2.3973 | 0.8002 | 4.0650
YoLL for the first 10 years and all ages per 100,000 of start pop:
| YoLL central | YoLL lower | YoLL upper
all ages | 226.2790 | 75.5598 | 383.5410

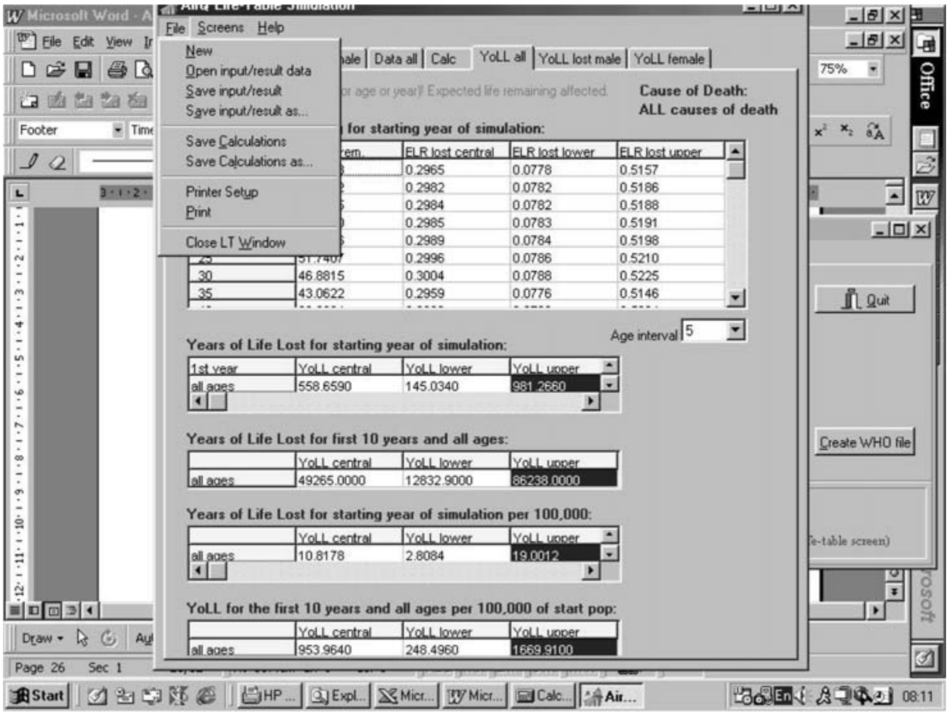

AirQ Life-Table Simulation
File Screens Help
Infos | Data male | Data female | Data all | Calc | YoLL all | YoLL lost male | YoLL female
Cause of Death: LCA
Expected life remaining for starting year of simulation:
Starting age: | ex. life rem. | ELR lost central | ELR lost lower | ELR lost upper
0 | 83.3258 | 0.0122 | 0.0041 | 0.0208
5 | 78.7558 | 0.0123 | 0.0041 | 0.0209
10 | 73.7814 | 0.0123 | 0.0041 | 0.0209
15 | 68.8137 | 0.0123 | 0.0041 | 0.0209
20 | 63.8701 | 0.0123 | 0.0041 | 0.0209
25 | 58.9469 | 0.0123 | 0.0041 | 0.0209
30 | 54.0351 | 0.0124 | 0.0041 | 0.0210
35 | 49.1518 | 0.0124 | 0.0041 | 0.0210
Age interval 5
Years of Life Lost for starting year of simulation:
1st year | YoLL central | YoLL lower | YoLL upper
all ages | 8.8036 | 2.9384 | 14.9290
Years of Life Lost for first 10 years and all ages:
| YoLL central | YoLL lower | YoLL upper
all ages | 855.2110 | 285.4560 | 1450.2000
Years of Life Lost for starting year of simulation per 100,000:
| YoLL central | YoLL lower | YoLL upper
all ages | 0.3283 | 0.1096 | 0.5567
YoLL for the first 10 years and all ages per 100,000 of start pop:
| YoLL central | YoLL lower | YoLL upper
all ages | 31.8900 | 10.6444 | 54.0766

7. Saving data and calculations

Attention! Remember to <u>save data and calculations</u> table in the file menu.

The user can :

- save input/results temporarily while working
- save input/results as – this option will save in a txt file the data available in the AirQ screens and can be retrieved later by using < open input/results data> option from the File Menu
- In order to save the calculation matrices, use the < Save calculations as> option . This will save them in a TXT file



Finally, the user closes AirQ.

Appendix 9

Summary Apheis-2 findings

Descriptive statistics

The following charts show the demographic characteristics of the Apheis cities; the levels of particulate air pollution observed; and the health measures 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 Number	Population over 65 years 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.

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) 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).

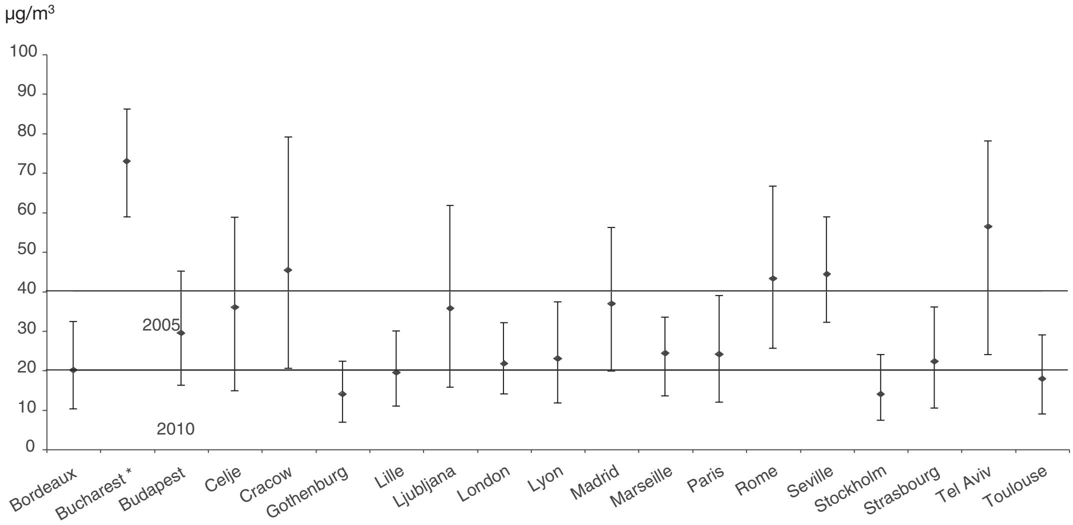
When reading these tables, we should remember that it is difficult to compare air-pollution levels between different cities in Europe due to the use of different years and possible different sources of variability in the measurements.

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

City	Year	PM10				BS			
		Mean	SD	P10	P90	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	1996	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

In Figure 1, horizontal lines indicate the EC annual mean cut-offs of 40 µg/m^3 and 20 µg/m^3 to be reached respectively in 2005 and 2010.

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



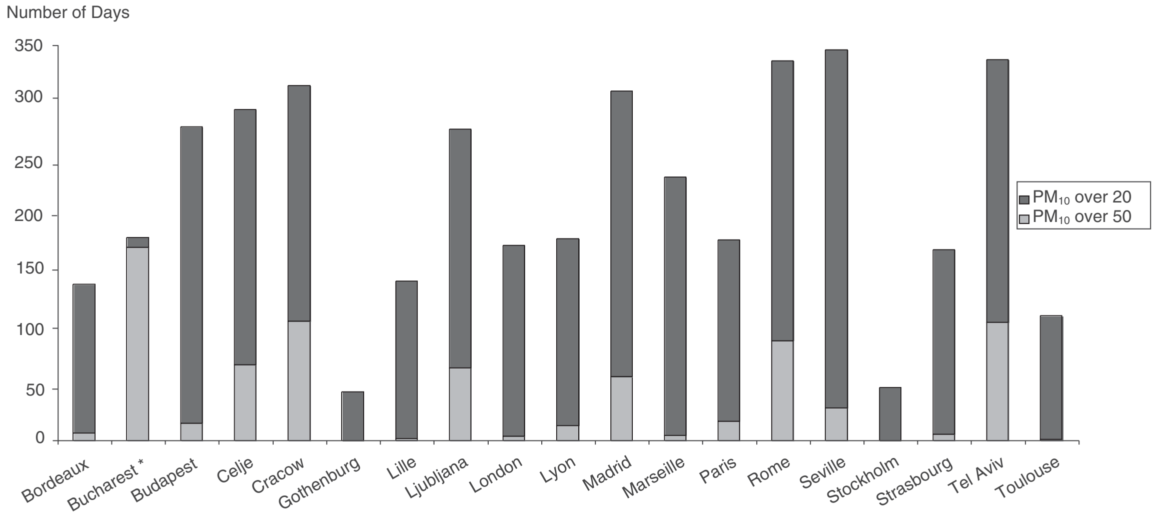
* Bucharest shows the highest PM_{10} levels, but in this city measurements were only available for four weekdays (Monday to Thursday); this may explain the high levels observed.

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/m^3.

Mean values of most of the cities are in the range between 40 and 20 µg/m^3. Gothenburg, Lille, Stockholm and Toulouse show levels below 20 µg/m^3.

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/m³.

Figure 2. Number of days per year when PM_{10} exceeded 24-hour values of 20 and 50 µg/m³



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

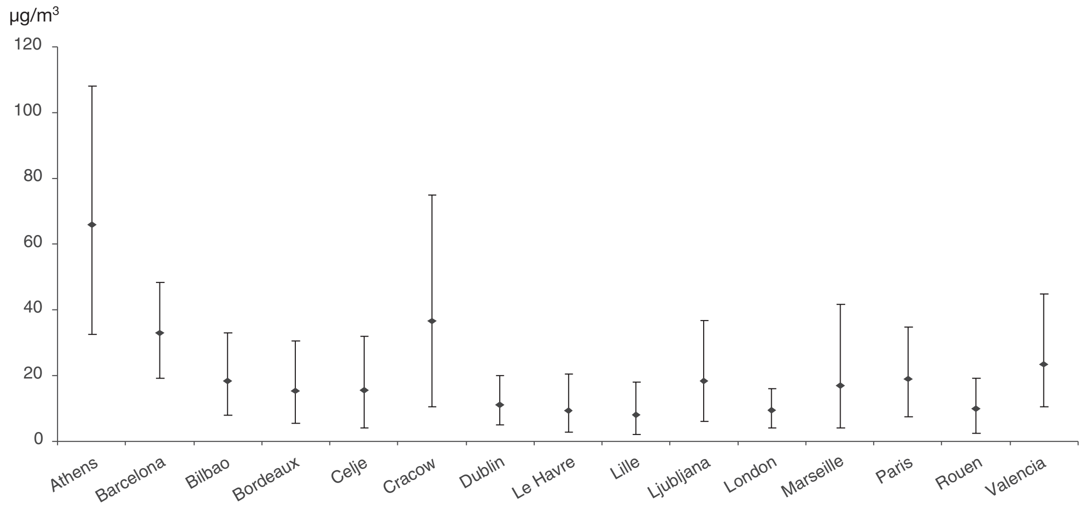
The PM_{10} 24-hour value of 20 µg/m³ is exceeded frequently.

During a 1-year period, PM_{10} 24-hours value exceeded 20 µg/m³ 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/m³ 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/m³ 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/m³ at the monitoring sites 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.

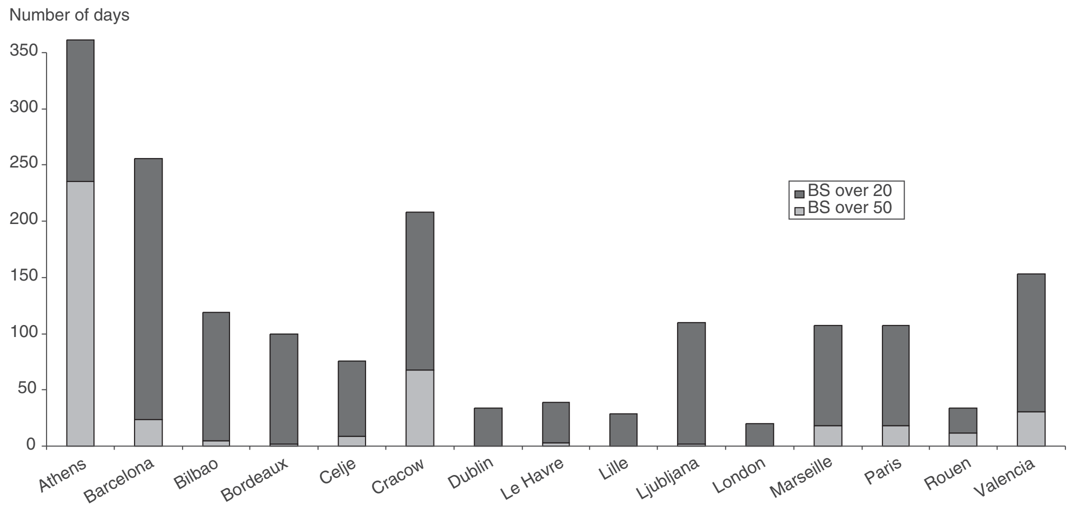
Figure 3. Annual mean levels and 10th and 90th percentiles of the distribution of black smoke



Regarding BS, 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.

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

Health indicators

Mortality

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).

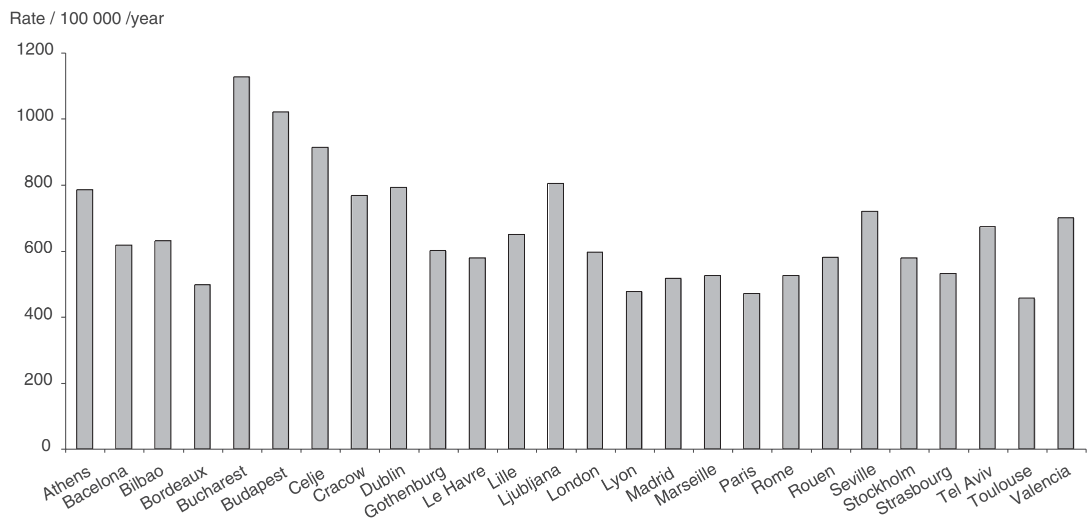
Table 5. Daily mean (standard deviation) number of deaths and age-standardised mortality rates in the 26 cities

City	Year	Total mortality*	Age standardised**
		Daily mean (standard deviation)	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 (0.35)	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)	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	1996	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, 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

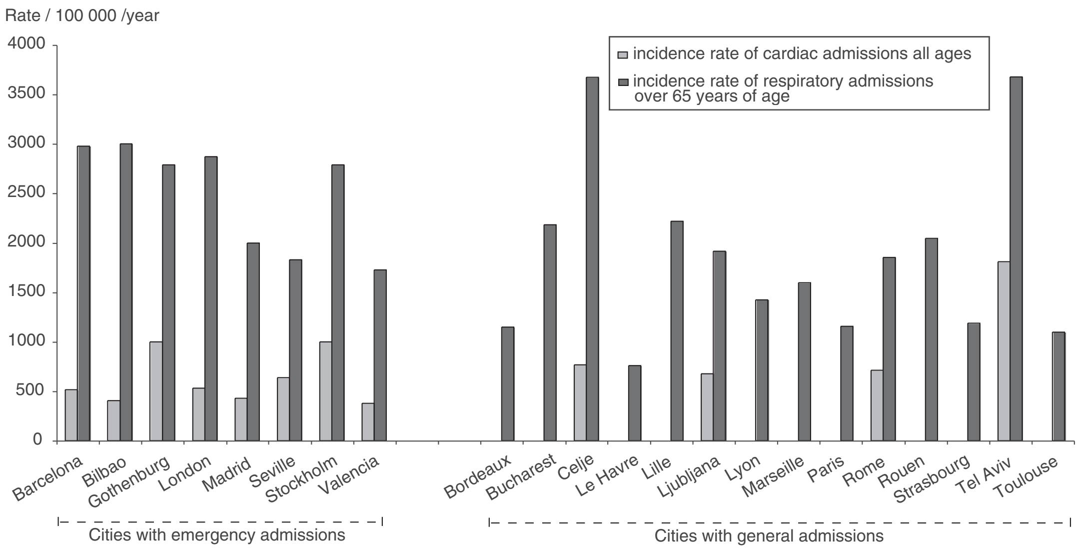
Twenty-two cities had data on hospital admissions. Although most of the cities have data from registers with a quality-control programme, there are limitations in the comparability of the data between cities.

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 in the second-year 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 of second-year report).

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) 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 weekdays measurements were available).
According to the PEACE project[1], 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.

Replacing all the days with 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.

References

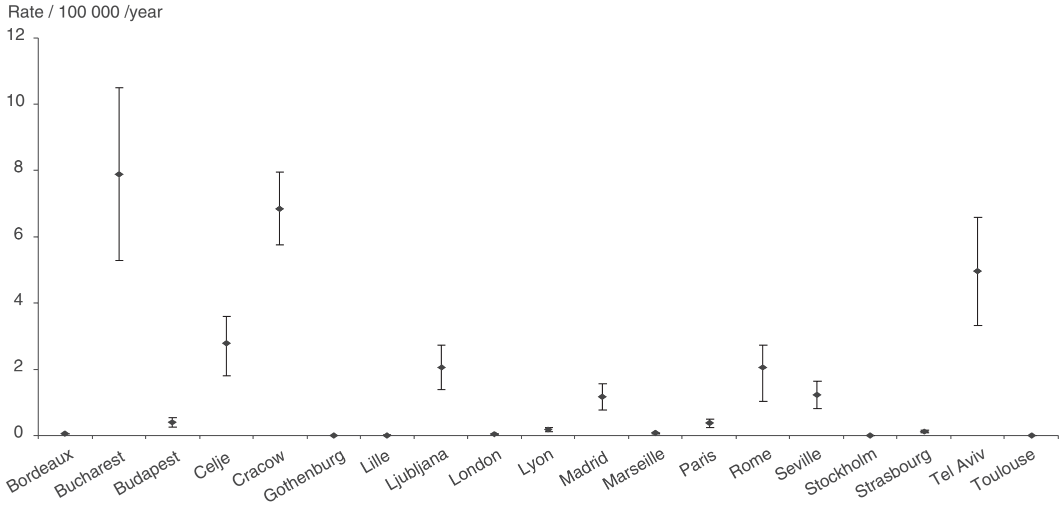
1. Hoek G, Forsberg B, Borowska M, Hlawiczka S, Vasksövi H, Welinder H, Branis M, Benes I, Kotesovec F, Hagen LO, Cyrus J, Jantunen M, Roemer W, Brunekreef B. Wintertime PM_{10} and Black smoke concentrations across Europe: results from the PEACE study *Atmospheric Environment* 1997;31:3609-3622.

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.

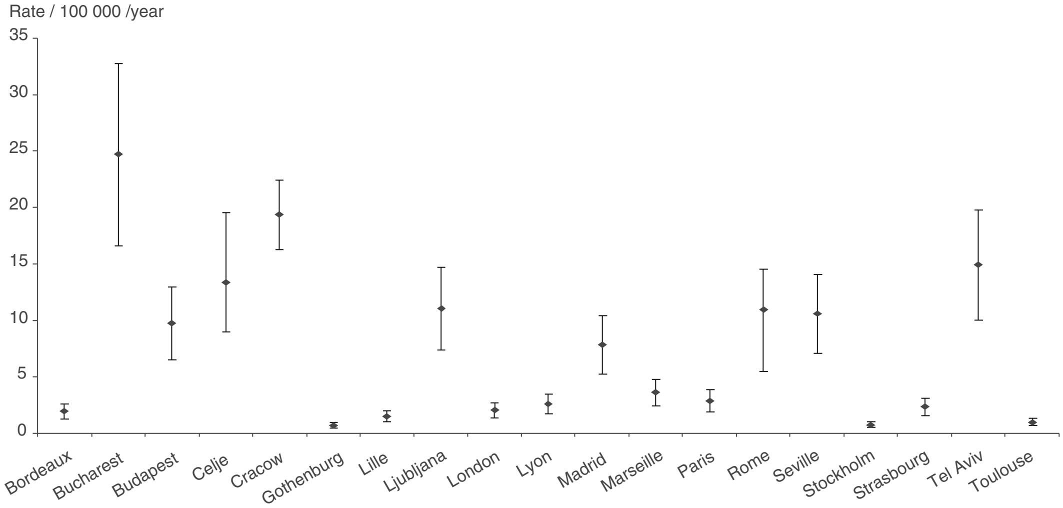
Figure 7. Potential benefits of reducing PM_{10} levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}



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.

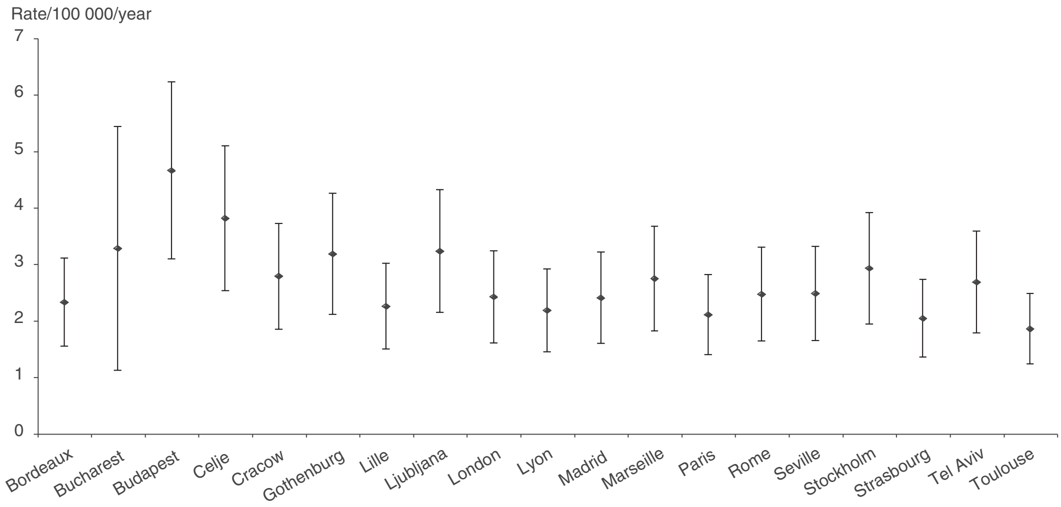
Figure 8. Potential benefits of reducing PM_{10} levels to a 24-hour value of 20 μg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}



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, 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 Lubljana, 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}



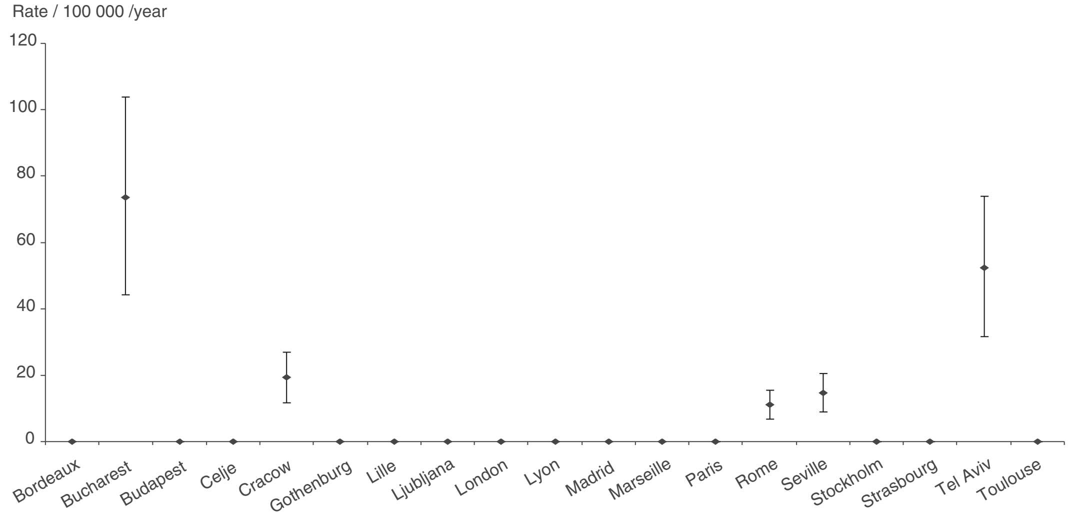
If daily PM_{10} levels were reduced by 5 µg/m^3 in all the cities, the consequent reduction in the number of deaths per 100 000 inhabitants would range between 2 in Toulouse and 5 in Budapest (depending on the number of deaths observed in each city) and would average 3 (2 to 4) deaths per 100 000 inhabitants 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 522 to 1053) that could be prevented if short-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m^3.

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.

Chronic effects

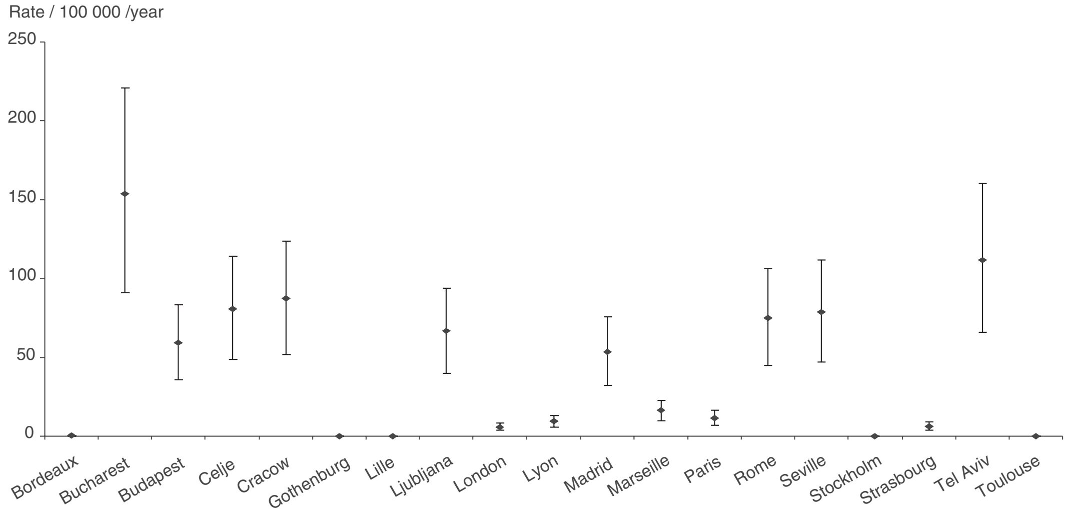
Figure 10. Potential benefits of reducing annual mean values of PM_{10} to a level of 40 µg/m^3 (2005 limit values for PM_{10}) - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}



Among the cities where PM_{10} is measured, the reduction of the annual mean value to 40 µg/m^3 (2005 limit values for PM_{10}) would reduce the number of deaths per 100 000 inhabitants by 73.6 in Bucharest (including 11 related to short-term exposure to PM_{10}), 19.3 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.

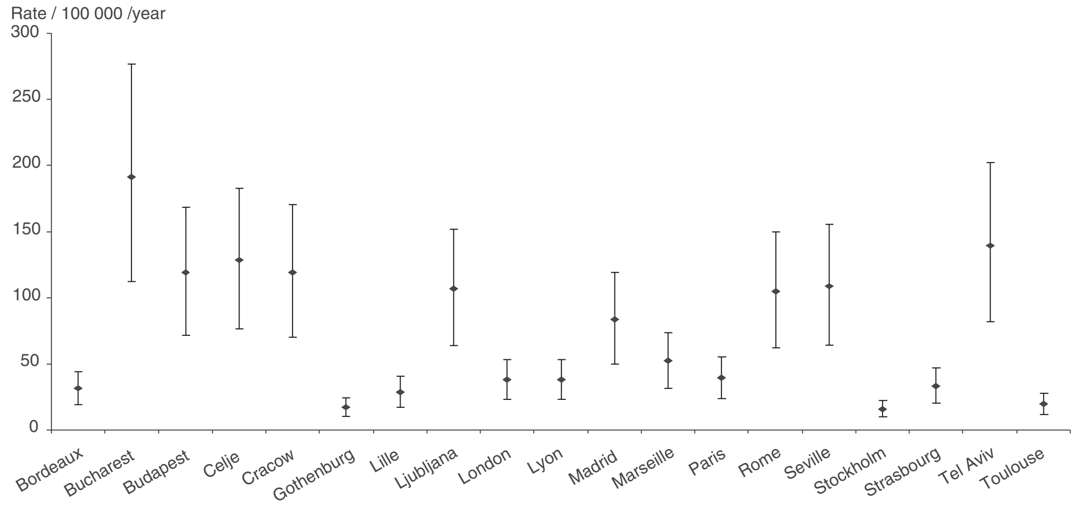
Figure 11. Potential benefits of reducing annual mean values of PM_{10} to a level of 20 µg/m^3 (2010 limit values for PM_{10}) - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}



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

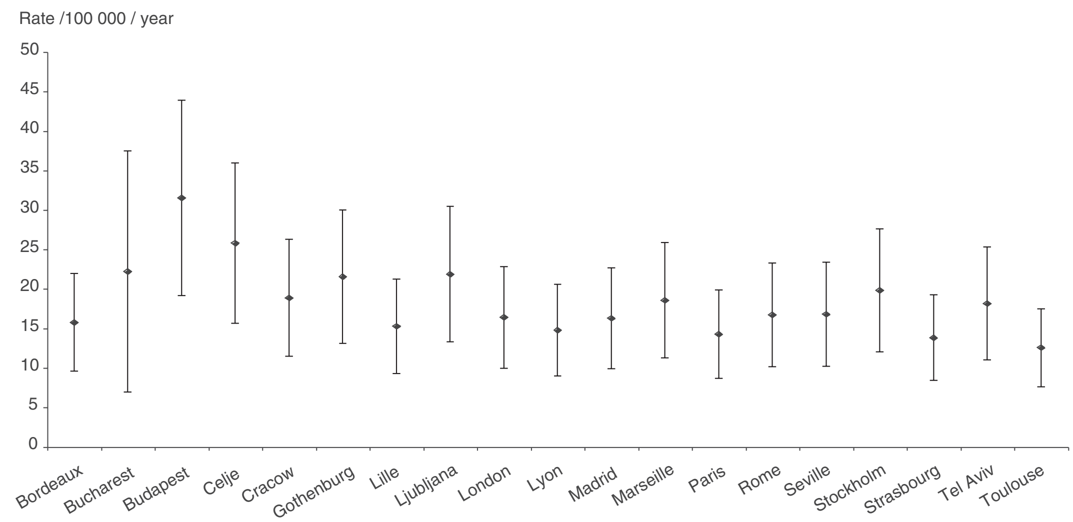


This scenario considers a reduction in annual mean values to 10 µg/m³. Even if this scenario is idealistic for many cities, it would allow cities with very low levels of air pollution, like those in Sweden, London and a few in France, to benefit from the improvement in air quality, since even their low 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}).

Fiigure 13. Potential benefits of reducing annual mean values of PM_{10} by 5 µg/m³- 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/m³ in all the cities, 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 3 235 to 7 439) could be prevented annually if long-term exposure to outdoor concentrations of PM_{10} were reduced by 5 µg/m³ in each city.

Black smoke scenarios

Acute effects 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.

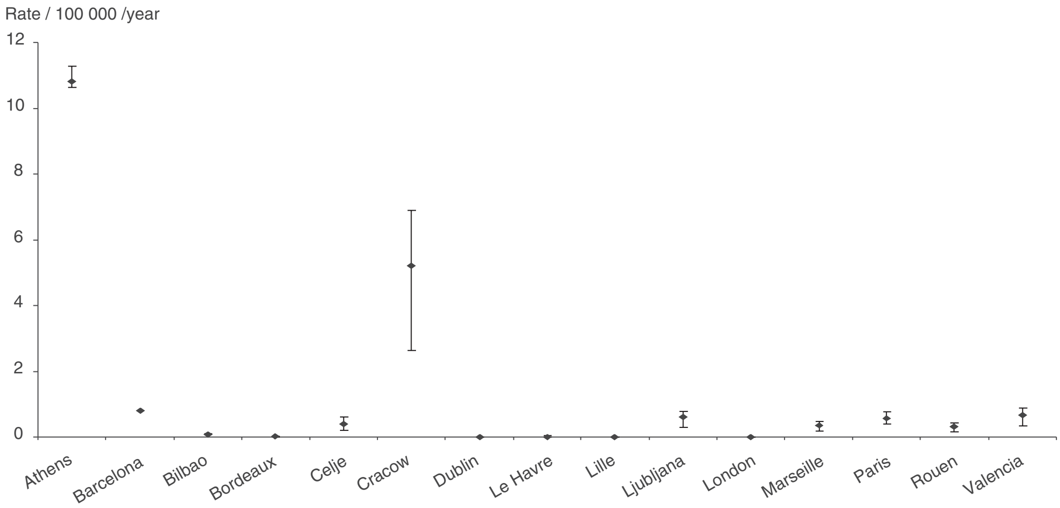
We considered only the short-term exposure or acute-effects scenarios, since no exposure-response functions are currently available for the long-term effects of black smoke.

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

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

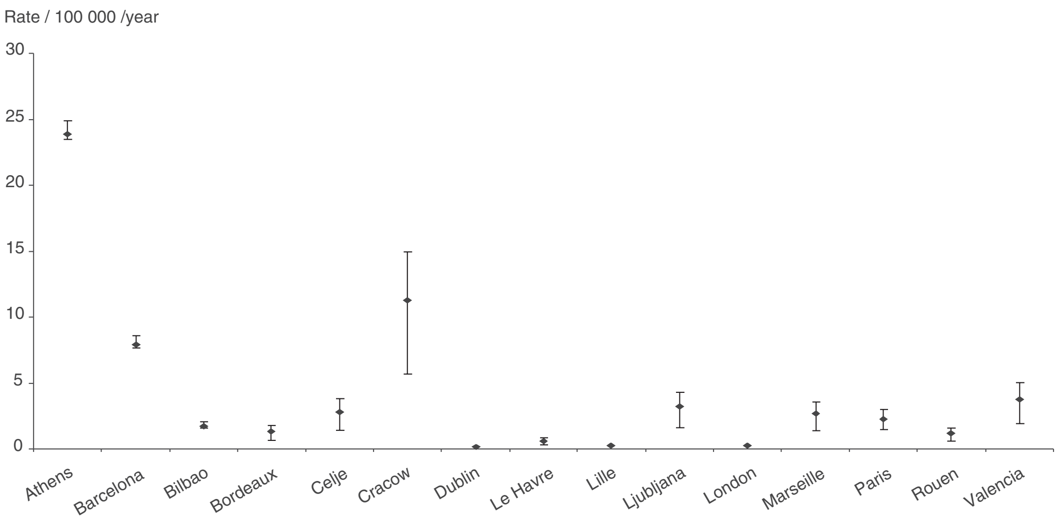


Among the 15 cities measuring BS, Athens would show by far the highest decrease in the number of deaths per 100 000 inhabitants (11) if BS levels for all days exceeding a 24-hour value of 50 µg/m^3 were reduced to 50 µg/m^3, remembering that Athens shows the highest BS levels, probably because of the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

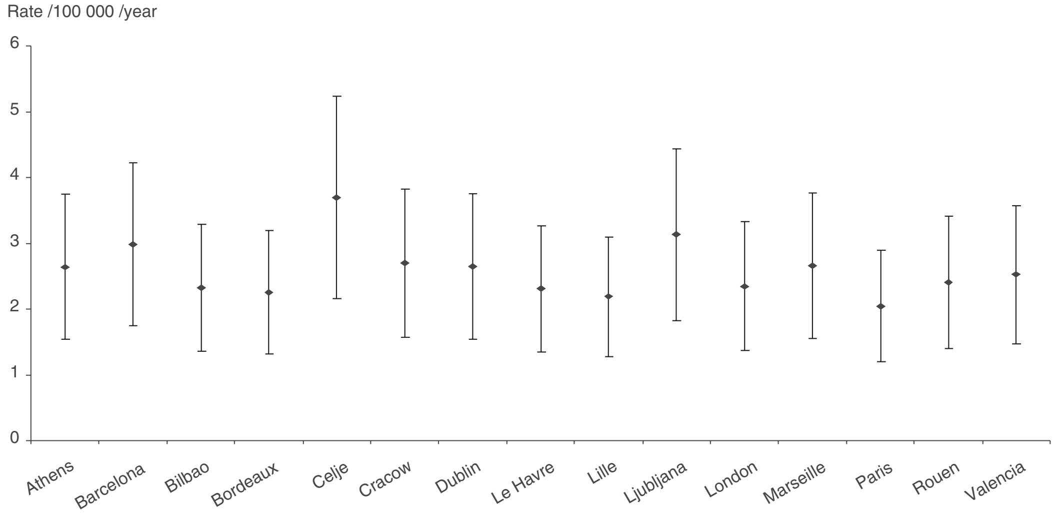
Figure 15. Potential benefits of reducing black smoke levels to a 24-hour value of 20 µg/m^3 on all days exceeding this value - Number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of black smoke



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.

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/m^3- 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/m^3 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.

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/m^3.

Appendix 10

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

Article 5 : ***Particulate matter***

1. Member States shall take the measures necessary to ensure that concentrations of PM_{10} in ambient air, as assessed in accordance with Article 7, do not exceed the limit values laid down in Section I of Annex III as from the dates specified therein.
The margins of tolerance laid down in Section I of Annex III shall apply in accordance with Article 8 of Directive 96/62/EC.

2. Member States shall ensure that measuring stations to supply data on concentrations of $PM_{2.5}$ are installed and operated. Each Member State shall choose the number and the siting of the stations at which $PM_{2.5}$ is to be measured as representative of concentrations of $PM_{2.5}$ within that Member State. Where possible sampling points for $PM_{2.5}$ shall be co-located with sampling points for PM_{10}.
Within nine months of the end of each year Member States shall send the Commission the arithmetic mean, the median, the ninety-eighth percentile and the maximum concentration calculated from measurements of $PM_{2.5}$ over any twenty-four hours within that year. The ninety-eighth percentile shall be calculated in accordance with the procedure laid down in Section 4 of Annex I to Council Decision 97/101/EC of 27 January 1997 establishing a reciprocal exchange of information and data from networks and individual stations measuring ambient air pollution within the Member States(6).

3. Action plans for PM_{10} prepared in accordance with Article 8 of Directive 96/62/EC and general strategies for decreasing concentrations of PM_{10} shall also aim to reduce concentrations of $PM_{2.5}$.

4. Where the limit values for PM_{10} laid down in Section I of Annex III are exceeded owing to concentrations of PM_{10} in ambient air due to natural events which result in concentrations significantly in excess of normal background levels from natural sources, Member States shall inform the Commission in accordance with Article 11(1) of Directive 96/62/EC, providing the necessary justification to demonstrate that such exceedances are due to natural events. In such cases, Member States shall be obliged to implement action plans in accordance with Article 8(3) of Directive 96/62/EC only where the limit values laid down in Section I of Annex III are exceeded owing to causes other than natural events.

5. Member States may designate zones or agglomerations within which limit values for PM_{10} as laid down in Section I of Annex III are exceeded owing to concentrations of PM_{10} in ambient air due to the resuspension of particulates following the winter sanding of roads. Member States shall send the Commission lists of any such zones or agglomerations together with information on concentrations and sources of PM_{10} therein. When informing the Commission in accordance with Article 11(1) of Directive 96/62/EC, Member States shall provide the necessary justification to demonstrate that any exceedances are due to such resuspended particulates, and that reasonable measures have been taken to lower the concentrations.
Within such zones or agglomerations Member States shall be obliged to implement action plans in accordance with Article 8(3) of Directive 96/62/EC only where the limit values laid down in Section I of Annex III are exceeded owing to PM_{10} levels other than those caused by winter road sanding.

Annex III

Limit values for particles (PM_{10})

	Mean period	Limit value	Margin of tolerance	Date on which the limit value must be respected
PHASE I				
1. 24 hours limit value for the human health protection	24 hours	50 µg/m³ PM_{10} to be not exceeded more than 35 times per year	50% at the date of entering into force of the present directive, with reduction by 1st january 2001, and every 12 months following, by a constant percentage, until reaching 0% at 1st january 2005	1st january 2005
2. Annual limit value for the human health protection	1 year	40 µg/m³ PM_{10}	20% at the date of entering into force of the present directive, with reduction by 1st january 2001, and every 12 months following, by a constant percentage, until reaching 0% at 1st january 2005	1st january 2005
PHASE II				
1. 24 hours limit value for the human health protection	24 hours	50 µg/m³ PM_{10} to be not exceeded more than 7 times per year	According to the data; should be equivalent to the limit value of Phase I	1st january 2010
2. Annual limit value for the human health protection	1 year	20 µg/m³ PM_{10}	50% at the date of 1st january 2005, with reduction every 12 months following, by a constant annual percentage, to reach 0% at 1st january 2010	1st january 2010

Appendix 11

EC Directives-WHO/EC assessment on $PM_{2.5}$ (update Hans Guido Müecke, Michal Krzyzanowski)

Current status on $PM_{2.5}$ within the EC legislation process (end of July 2003)

Rationale

Recent studies showing that there is strong evidence that fine particles ($PM_{2.5}$) are more hazardous than larger ones (coarse particles) in terms of mortality and cardiovascular and respiratory effects in panel studies. But this does not imply that the coarse fraction of PM_{10} in innocuous.

Health aspects

In 2001, WHO agreed with the European Commission to provide the Clean Air for Europe (CAFE) programme of EC DG Environment **http://europa.eu.int/comm/environment/air/cafe/index.htm**) with a systematic, periodic, scientifically independent review of health aspects of air quality in Europe. A report on the health aspects of air pollution with particulate matter, ozone and nitrogen dioxide was recently published by WHO (**http://www.euro.who.int/document/e79097.pdf**). In particular, the report states that fine particles (commonly measured as $PM_{2.5}$) are strongly associated with mortality and hospitalisation of cardio-pulmonary disease e.g. WHO recommends that Air Quality Guidelines for $PM_{2.5}$ be further developed. Revision of the PM_{10} WHO Air Quality Guidelines and continuation of PM_{10} measurement is indicated for public health protection.

In addition, it is noted that the recommendation to use $PM_{2.5}$ as indicator for PM-related effects does not imply that $PM_{2.5}$ is the only relevant parameter to characterize PM pollution. Therefore, the WHO report recommends to set up a more comprehensive monitoring programme in different European cities (possibly including PM_{10}, $PM_{2.5}$, PM_{10}, BS, PM components, gases), which, in combination with properly designed health studies, could lead to an additional gain in knowledge on the health effects of ambient air pollution in the coming years.

Measurement aspects

a) Problems in $PM_{2.5}$ mass concentration measurements

Several problems, partially known from previous experiences with PM_{10} measurements, have to be taken into consideration when determining $PM_{2.5}$ mass concentration. Preliminary inter-comparison studies carried out in a number of Member States have shown significant differences between the results of manual $PM_{2.5}$ samplers, ranging up to +/- 30%. It has to be noted that the chemical composition of $PM_{2.5}$ is significantly different from that of PM_{10} especially the semi-volatile particulate matter (e.g. ammonium nitrate, organic compounds) is enriched in the fine $PM_{2.5}$ size fraction. Hence the problems with losses of semi-volatile matter already observed when sampling PM_{10} may be even more pronounced for $PM_{2.5}$ measurements. It can be anticipated that any heating of the sampling system will show significantly lower $PM_{2.5}$ mass concentrations than a system kept under ambient conditions.

b) Standardisation work

A reference method for sampling and measurement of $PM_{2.5}$ is currently being standardised by the European Committee for Standardisation (CEN). In absence of the reference method, guidance on a provisional reference method for sampling and measurement of $PM_{2.5}$ was provided by the European Commission (Decision of 16 January 2003 concerning guidance on a provisional reference method for the sampling and measurement of $PM_{2.5}$ under directive 1999/30/EC (2003/37/EC)). DG Environment has given a mandate to CEN to develop a standard European reference method for the measurement of $PM_{2.5}$ mass fraction collected on a filter under ambient conditions. This method is based on the gravimetric determination of the $PM_{2.5}$ fraction of particles in air, sampled at ambient conditions. CEN TC 264/WG 15 started its work in 2000. The first four field validation campaigns (Madrid/E, Duisburg/D, Vredepeel/NL and Vienna/A) have been completed; four further campaigns in Sweden, England, Greece and Italy are currently on-going. The final CEN standard method will therefore not available before end of 2004. Within these campaigns CEN is testing various candidate devices based on the gravimetric determination method and equipped with different inlet types from European manufacturers as well as the United States Reference sampler. In addition, CEN is also testing a number of automated measurement devices, based on the beta ray attenuation method and the tapered element oscillating microbalance (TEOM), for equivalence with the reference gravimetric method. Methods such as those based on optical methods (particle counting or nephelometry) are not considered for possible use under the directive.

Finally, the EC $PM_{2.5}$ guidance recommends on $PM_{2.5}$ data reporting, that it is essential to document fully the measurement methodology which was used to generate the data.

Next step within the CAFE process will be the dissemination of the updated and revised version of the so-called first daughter directive on ambient air quality (council directive 1999/30/EC, including particulate matter) by the European Commissions' DG Environment to the EU Member States within August 2003.

Appendix 12

Geographical representation of the Apheis findings: Euroheis collaboration (Bertil Forsberg)

The EUROHEIS project aims to improve the understanding of the links between environmental exposures, health outcomes and risk through the development of an integrated information system for the rapid assessment of relationships at a geo-spatial level.

The system is termed the RIF; Rapid Inquiry Facility. It is built on the use of geographically referenced datasets; population health (cases), environmental exposures and, when possible, socio-economic data. The RIF is designed to answer questions like: Is the risk in a specific study area (and period) different than elsewhere or expected? The study involves definition of study area (around a source), subgroup (age), period (years), disease (ICD) and comparison area. This approach has a potential also for health impact assessment at a more detailed geographical level than now used in Apheis.

The major problem is however that the air pollution literature covers exposure-response relations of which very few build on high resolution exposure data. The health effects included in APHEIS are all estimated from urban background levels. A GIS approach need to be based on a new kind of exposure estimates, especially geographically modelled exposure or concentrations.

In order to judge the potential for new HIA methods using GIS, we investigated which centres can use:

(1) geocoded population data, i.e. in a gridnet of 50*50 meters (residents - if possible by age groups),

(2) city maps with traffic flow (N of vehicles of different types per day) and

(3) a dispersion model that can match traffic flow (+ emission factors) and population data to estimate number of inhabitants exposed to different levels of modelled mean annual (and if possibly daily) exhaust levels (NOx, NO2, PM).

Twelve cities from 26 answered to the above three questions:
- The answer for Stockholm and Gothenburg is:

  (1) Yes, at any level based on the geocoded addresses. Also daytime (working) population.

  (2) Yes, but traffic flow in very small streets is not measured.

  (3) Annual means based on "an average year meteorology" is easy to model. Daily values would be very time consuming to model.

- Besides the Swedish cities, only Budapest answered positively to the three questions
- Bilbao, Lyon, Krakow, Madrid, Marseille, Paris, Rome, Toulouse and Valencia could provide partial answers with some but not enough detailed information available. Some cities would have to pay for data/dispersion modelling.

In conclusion, based on the answers provided by some Apheis centres, for the time being a geo-spatial representation of Apheis findings cannot use Euroheis GIS.

NOTES

Expertise

La troisième phase du programme Apheis (Air Pollution and Health: A European Information System) (www.apheis.net) conduit dans 26 villes de 12 pays européens avait pour objectifs de développer une stratégie de communication et d'actualiser l'évaluation d'impact sanitaire à partir de son système de surveillance. Les nouveaux résultats d'EIS confirment ceux de la deuxième phase. A savoir que la pollution atmosphérique demeure une préoccupation de santé publique en Europe.

Apheis-3 a également développé une stratégie pour communiquer les effets de la pollution atmosphérique sur la santé auprès des décideurs et de leurs conseillers. Par des entretiens individuels avec les différents acteurs de la chaîne de décision au niveau local et européen, nous avons recueilli des informations sur leur appréciation des rapports Apheis, nous avons analysé toutes les étapes du processus décisionnel et nous avons recueilli des informations pour comprendre comment mieux répondre à leurs besoins en matière de pollution atmosphérique et santé.

Cette double approche produisant les résultats d'EIS et développant une stratégie pour les communiquer a pour but de répondre aux objectifs d'Apheis de fournir aux décideurs, aux professionnels de la santé et de l'environnement et au grand public des informations à jour, simples et d'accès facile pour les aider à mieux répondre aux questions qu'ils se posent concernant la pollution atmosphérique et son impact sur la santé publique.

The new evidence provided by the third phase of the Apheis (Air Pollution and Health: A European Information System) (www.apheis.net) programme conducted in 26 cities in 12 European countries confirmed the finding of Apheis-2 that air pollution continues to pose a significant threat to public health in urban environments in Europe.

Another key part of Apheis-3 investigated how to reach individuals who make and influence policy on air pollution and health in Europe; and how to deliver Apheis' findings to them effectively and efficiently. This work produced a model that shows who the key players are in the policy-making process; how information flows between them; what types of information scientific and policy users active in the process each require; and what are the best forms in which to deliver this content to them to ensure maximum understanding and usage of the information Apheis produces.

This twin focus on both providing the latest scientific findings and developing a strategy for communicating them aims to fulfill Apheis' mission of meeting the information needs of individuals and organizations concerned with the impact of air pollution on health in Europe, and in particular the needs of individuals who influence and set policy in this area on the European, national, regional and local levels.

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