MADRID CITY REPORT

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Summary of the main findings

Air pollutants levels in the city of Madrid are within that established by current regulations. Most of them have reached minimum historical annual mean in 2002[1]. The downward trend of these levels in the previous years seems to be stabilized.

Nevertheless, PM levels established by the E.C. Council Directive 1999/30 for the year 2010 have not yet been reached. Transport constitutes the main source of air pollution, followed by that generated by heating boilers and, in a lower level, industry.

The City Council has launched an emissions reductions plan known as "Bases para un plan estratégico municipal 2003, para la reducción de las emisiones contaminantes a la atmósfera en el municipio de Madrid"[1].

The first health impact assessment (HIA) of air pollution in the city of Madrid was developed for the year 1998[2].

In this report, we have brought up to date the HIA of air pollution in the city referred to the year 2000 including new indicators. The mean annual level for PM_{10} was 37 µg/m^3 (SD: 17) in 2000. The analysis estimates that reduction in the long-term of $PM_{2.5}$ levels to 15 µg/m^3, all other things being equal, would reduce mortality in Madrid by 562 deaths in one year, which would save 268.43 years of expected life for starting year of simulation. If the daily means of PM_{10} would be kept under 20 µg/m^3, in the short term 260 deaths and 538 hospital admissions could have been avoided in the year 2000.

Background

The city of Madrid is located on a plateau 600 meters above sea level between the Central Mountain System and the Toledo Mountains, in the centre of the Madrid Region. Although its area is only 7.5% of the total area of the region, 57% of the population lives in the city. The Community of Madrid occupies the second place in gross internal product, with productivity mainly centred in the services sector. A 74.7% of the population works on services, 14.9% in the industry, 9.4% in construction and 0.8% in agriculture.

In 2000, the population has increased since 1998 in around 150 000, and it's of 2938723 people. The population continues ageing. The proportion of the population older than 65 years has increased since 1998 from 17.8% to 21.4% in the year 2000.

The annual daily mean for maximum temperatures is 19.1 ºC, ranging from 9.6 ºC in the coldest month to 30.7 ºC in July. The annual daily mean for minimum temperatures is 9.5 ºC,

[1] Libro Blanco de la Calidad del Aire en el Municipio de Madrid. Ayuntamiento de Madrid, 2003 .
[2] Health Impact Assesment of Air Pollution in 26 European Cities. Second year report 2000-2001.

ranging from 2.7 ºC in January to 18.0 ºC in July. The annual mean relative humidity is 56%. Rainfall varies from 9 to 64 mm/month.

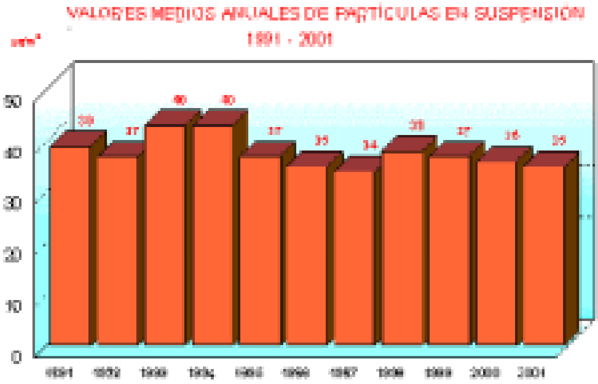
In 2000 minimum and maximum temperatures were –2 ºC and 36.4 ºC respectively.

Air pollutants levels in Madrid city are within that established by current regulations. Most of them have reached minimum historical annual mean in 2002[1]. The downward trend of these levels in the previous years seems to be stabilized.

Nevertheless, PM levels established by the E.C. Council Directive 1999/30 for the year 2010 have not yet been reached.

The City Council has launched an emissions reductions plan known as “Bases para un plan estratégico municipal 2003, para la reducción de las emisiones contaminantes a la atmósfera en el municipio de Madrid”[3].

Figure 1: Mean annual values for PM_{10}, 1991-2001



The contemplated measures in this plan are focused mainly in air pollutants which can create problems to achieve the air quality standards. Some of these measures have already started in 2003. In general, the measures proposed in this plan are directed to next sectors:

- Buildings from the domestic and service sectors: the implementation of building measures, thermals, replacement of combustible…
- Industrial combustion and industrial processes
- Transport and combustibles distribution.
- Activities related to the use organic solvents
- Activities related to road transports
- Activities related to other vehicles and mobile machinery of municipal use
- Activities related to other ways of road transports : the rail network and the air traffic
- Activities related to agriculture, nature and green spaces

The first health impact assessment (HIA) of air pollution on health in the city of Madrid was developed in the year 2002. This assessment was part of the Apheis project in which a

[3] Libro Blanco de la Calidad del Aire en el Municipio de Madrid. Ayuntamiento de Madrid, 2003 .

health impact information system for air pollution was implemented in 26 European cities following a standardized procedure.

In the first HIA, done for the year 1998, the improvements in the air pollution indicators levels for the city of Madrid in the last decade were highlighted. Nevertheless, according to HIA results, if the levels of PM_{10} were reduced and all days with levels above 50 µg/m^3 reduced to 50 µg/m^3, all other risks being equal, 34 deaths and 39 hospital admissions for respiratory and cardiac diseases would be avoided in the short term. The expected benefits on reduced mortality in the long-term if, according to the European directives for 2010, annual mean levels of PM_{10} are reduced to 20 µg/m^3 are still greater. More than one thousand five hundred attributable mortality cases could be avoided, which represent 53.7 cases per 100 000 inhabitants.

In the 3rd Apheis Madrid report, on the one hand, we have brought up to date the HIA of air pollution in the city, referred in this report to the year 2000. At the same time the number of health indicators to establish the impact have been extended, and include also years of life lost. On the other hand, a qualitative study was developed with the aim of assessing the interest and usefulness of the Apheis 2 report for decision makers. The results will be published shortly.

Air pollution sources

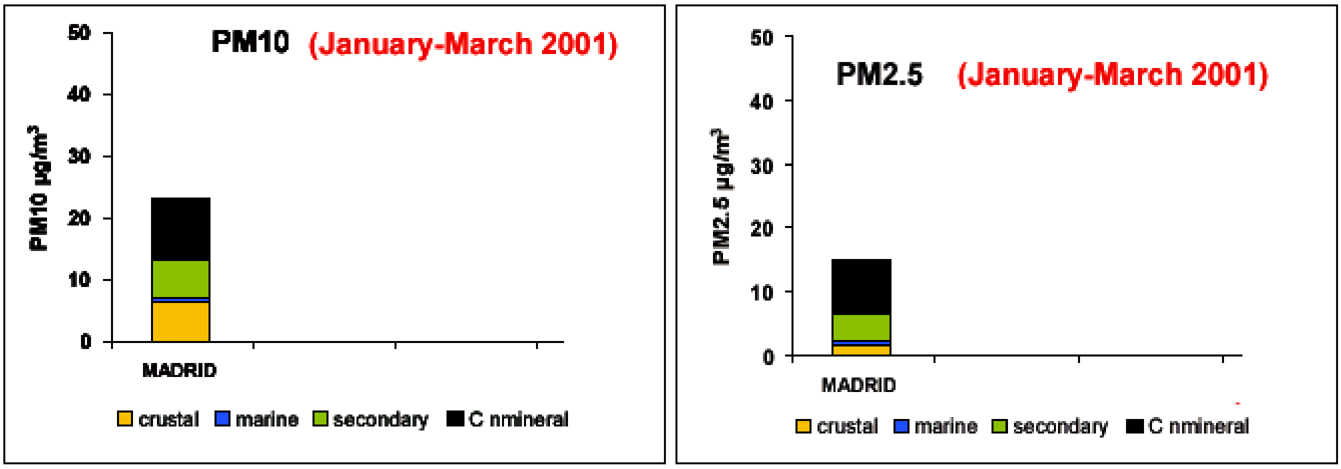
There is no heavy industrial activity affecting air quality. There is an important level of emission of air pollutants primarily due to the activity of the population. The transport constitutes the main source of air pollution, followed by that generated by heating boilers and, in a lower level, industry.

According to the results of the last mobility survey, developed by the Regional Transport Consortium (Consorcio Regional de Transportes) in 1996, there are 6.6 million mechanized travels in a standard day, 52.8% of them are done in public transport, and 47.2% through private vehicles. The total number of travels has increased by 20% from 1988 to 1996, while the population has increased only by 5% in the same period.

For the Madrid population, traffic is one of the environmental factors considered more dangerous for health [4].

[4] « Informe sobre el Estado de Salud de la Población de la Comunidad de Madrid, 2003 » Instituto de Salud Pública de la Comunidad de Madrid.

Figure 2. Sources Contribution to PM_{10} composition in Madrid[5]



Exposure data

The air quality network for the city of Madrid is managed by the Madrid City Council through the "Sistema Integral de Vigilancia, Predicción e Información de la Contaminación Atmosférica". The network includes 25 monitoring stations which measure sulphur dioxide, PM_{10}, nitrogen dioxide, carbon monoxide, ozone, benzene, toluene, and also meteorological variables and noise levels.

In this report (Apheis 3), year 2000, 23 stations were selected for PM_{10}. We have included the data of 9 additional stations in respect to those used in Apheis 2, as they accomplished the criteria established for data completeness. All but one of them are traffic stations.

The stations use ∃-attenuation method for measuring PM_{10}[6]. The correction factor, determined through a comparison study[7] between the automatic measurement method and the reference method, is 1.

For $PM_{2.5}$ the local conversion factor $PM_{2.5} = 0.51\ PM_{10}$ has been applied, as we haven't got direct measures for $PM_{2,5}$. The local conversion factor was estimated using simultaneous measures of PM_{10} and $PM_{2,5}$ during the period from the first of January 2002 to July 7(th) 2003. The data were collected by the Madrid City Council. The data were analysed following the "Guidance To Member States On PM_{10} Monitoring And Intercomparisons: UIT Reference Method" proposed by the EC Working Group On Particulate Matter.

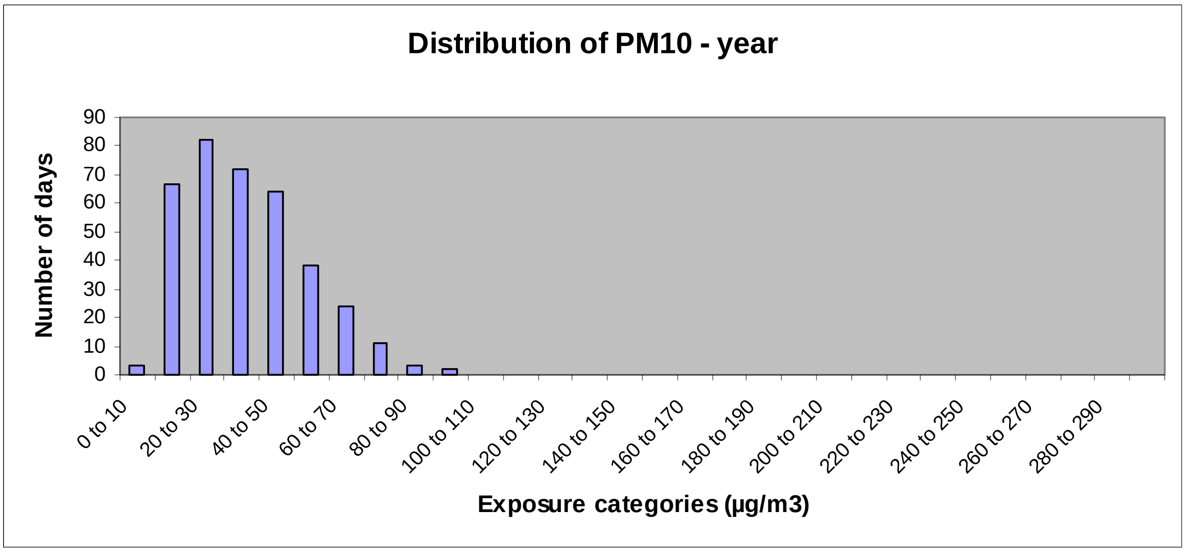
[5] « Interpretación de series temporales (1996-2000) de niveles de partículas en suspensión en España » CSIC, CIEMAT, CEAM, ISCIII, Ministerio de Medio Ambiente.

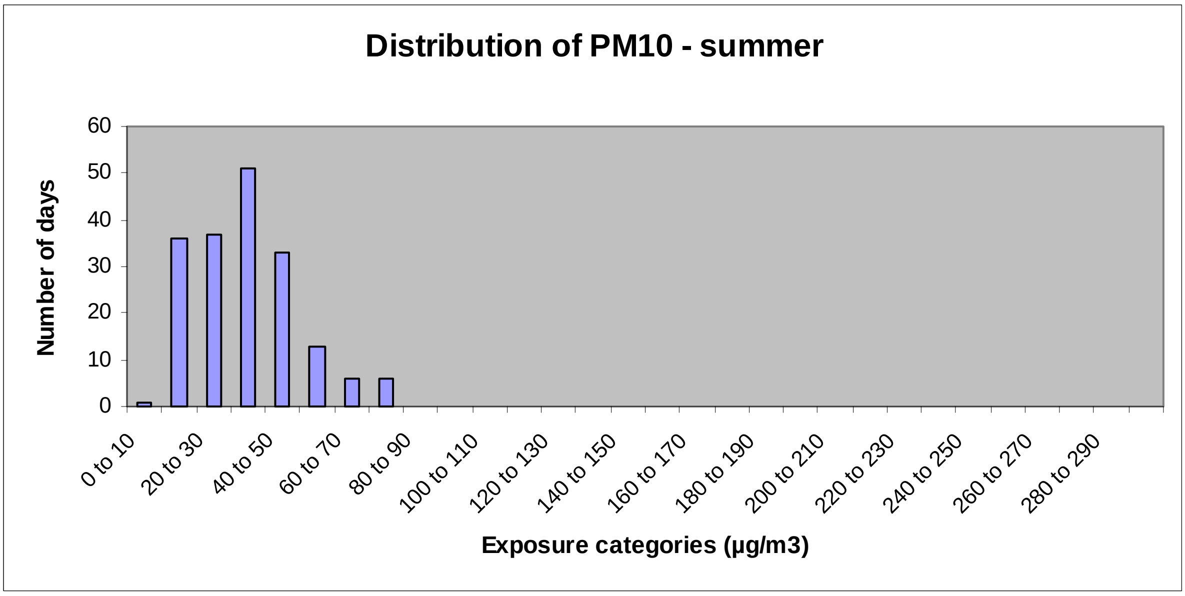
[6] There was an error in the Apheis 2 report regarding the measurement method for PM_{10}

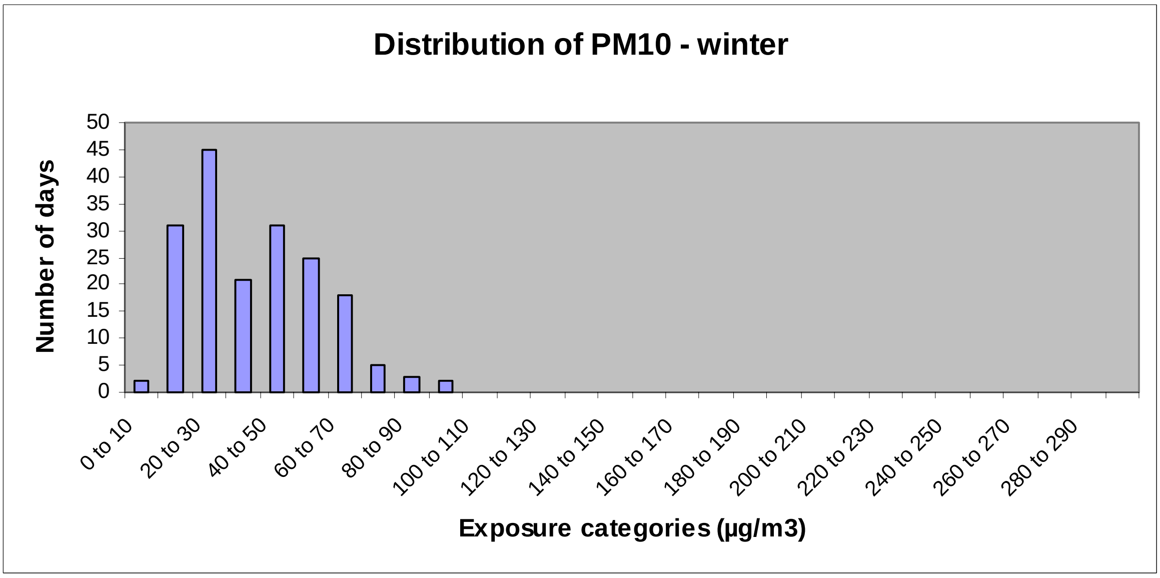
[7] Estudio y evaluación de la contaminación atmosférica por material particulado en España. Intercomparación de equipos automáticos de medida de PM_{10} con el método de referencia en España. Instituto de Ciencias de la Tierra, CSIC, CIEMAT, CEAM, Instituto de Salud Carlos III. Julio, 2002.

- Exposure data for Apheis 3:
  - The data belong to the year 2000.
  - Daily mean levels (SD) of PM_{10} were 37 (17) µg/m^3.
  - The levels of PM_{10} reached during the 19 days with the lowest (5th percentile) and the highest (95th percentile) levels were respectively 15 µg/m^3 and 69 µg/m^3.
  - Daily mean levels (SD) of $PM_{2.5}$ converted from PM_{10} were 19 (9) µg/m^3.
  - The levels of $PM_{2.5}$ reached during the 19 days with the lowest (5th percentile) and the highest (95th percentile) levels were respectively 8 µg/m^3 and 35 µg/m^3.
  - For PM_{10}, in 2000, the levels exceeded 20 µg/m^3 in 296 days and 50 µg/m^3 in 78 days.

Figure 3. Distribution of PM_{10} in the city of Madrid, 2000.







Since 1999, a descending trend is observed in PM_{10} values due to the various measures developed with the aim of reducing air pollution emissions, i.e. economic incentives to promote the replacing of coal heating boilers and old cars, and public transport buses are being gradually changed for buses which use natural gas and the subway and suburban trains have been greatly expanded.

Figure 4 compares annual mean levels and percentiles of the distribution of PM_{10} by station in Apheis 2 and 3.

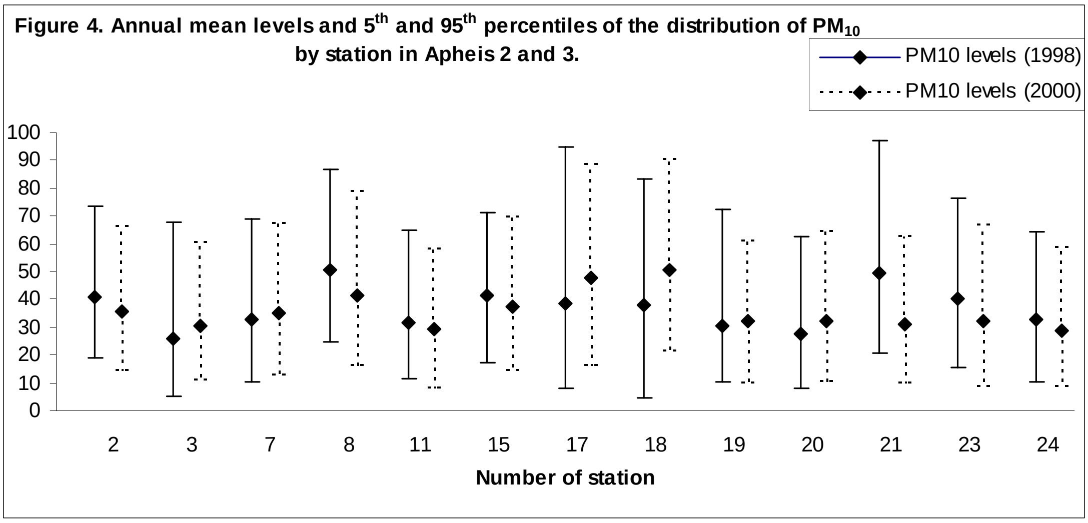


Figure 4. Annual mean levels and 5th and 95th percentiles of the distribution of PM_{10} by station in Apheis 2 and 3.

No changes are observed between the two compared years. The increments/decrements recorded within the stations in the 2 years do not follow a pattern.

Health data

We used the annual revision of the city census for 2000 for the exposed population.

The Mortality Register of the « Instituto de Estadística de la Comunidad de Madrid » provides the mortality data, coded using the International Causes of Diseases, ICD 10. The codification is automatic for 60% causes of death. Death registration is complete. The completeness of the data for the basic cause of death is 100%.

In 2000, the daily mean number of deaths was 71.4. The standardised mortality rate of Madrid using the European population (both sexes combined) for year 2000[8] is 690.25 per 100 000 inhabitants.

Hospital admissions data used for current HIA have been obtained from a register, while in Apheis 2 the data were taken from a survey. The register, «Conjunto Mínimo Básico de Datos al Alta Hospitalaria » (Hospital Discharge Minimum Standardized Data Set) for the year 2001 includes all hospital admissions in the region. The data base is developed annually by the Consejería de Sanidad and it has to be completed compulsory by all public and private hospitals in the region. The discharge causes are coded using the ICD9. Completeness is higher than 95%. The register follows a quality assessment programme. For HIA only emergency admissions have been selected.

The daily rate of cardiac admissions (ICD9: 390-429) is 1.54 per 100 000, which represents a daily mean number of admissions of 43.9 cases. The rate for respiratory hospital admissions (ICD9: 460-519) is 1.82 per 100 000, with a daily mean of 52 cases.

Table 3. Daily mean number, and daily rate per 100 000 of deaths (year 2000) and hospital admissions (year 2001)

Health outcome	ICD9	ICD10	Daily mean number (SD)	Daily rate per 100 000
Short term HIA				
All causes mortality (excluding external causes)*	< 800	A00-R99	68.7 (11.3)	2.33
Cardiovascular mortality	390-459	I00-I99	22.3 (5.3)	0.75
Respiratory mortality	460-519	J00-J99	8.8 (4.1)	0.29
Cardiac hospital admissions	390-429	I00-I52	43.9 (11.7)	1.54
Respiratory hospital admissions	460-519	J00-J99	52 (16.4)	1.82
Long term HIA				
All causes mortality	0-999	A00-Y98	71.4 (11.4)	2.42
Cardiopulmonary mortality	401-440 460-519	I10-I70 J00-J99	29.6 (7.5)	1
Lung cancer mortality	162	C33-C34	3.9 (1.9)	0.13

* For short and long term scenarios

[8] UNITED NATIONS. Population Division Department of Economic and Social Affairs. World Population Prospects: The 2000 Revision.

Health impact assessment

Different scenarios were used to evaluate the effect of short and long-term exposure to particulate pollution. In the city of Madrid, these scenarios were built for two indicators PM_{10} and $PM_{2.5}$. The estimated health impact of these indicators may overlap, and caution is recommended in the interpretation of findings: under no circumstances should we add findings of these indicators because they represent the same type of pollution.

Different tools and different estimates were used to evaluate the short and long-term impact of this particulate pollution on health (Table 4).

Also different approaches were used to describe the impacts:

For PM_{10}, short and long-term findings are expressed in terms of number of attributed deaths per year.

For $PM_{2.5}$, long-term findings are expressed in terms of:

- number of attributed deaths per year.
- number of expected years of life lost for starting year of simulation.

Table 4. Summary short and long term health impact assessment					
	Health indicator	**ICD**	**Tool**	**RR (95%CI) for 10 μg/m^3 increase**	**Scenarios**
Short Term HIA					
Attributable Cases					
PM_{10}	All ages, All causes mortality (excluding external causes)	ICD10: A00-R99	French PSAS-9 spreadsheet	WHO, 2003: 1.006 (1.004-1.008)	Reduction to 50 μg/m^3 Reduction to 20 μg/m^3 Reduction by 5 μg/m^3
	All ages, Cardiovascular mortality	ICD10: I00-I99		WHO, 2003: 1.009 (1.005-1.013)	
	All ages, Respiratory mortality	ICD10: J00-J99		WHO, 2003: 1.013 (1.005-1.021)	
	All ages, Respiratory admissions	ICD9: 460-519		Le Tetre et al., 2002: 1.0114 (1.0062-1.0167)	
	All ages, Cardiac admissions	ICD9: 390-429		Apheis3: 1.006 (1.003-1.009)	
PM_{10} distributed lag (40 days)	All ages, All causes mortality (excluding external causes)	ICD10: A00-R99	French PSAS-9 spreadsheet	A. Zanobetti et al., 2002: 1.01227 (1.0081-1.0164)	
	All ages, Cardiovascular mortality	ICD10: I00-I99		A. Zanobetti et al., 2003: 1.01969 (1.0139-1.0255)	
	All ages, Respiratory mortality	ICD10: J00-J99		A. Zanobetti et al., 2003: 1.04206 (1.0109-1.0742)	
Complementary Short Term HIA					
PM_{10} with shrunken estimates	All ages, All causes mortality (excluding external causes)	ICD10: A00-R99	French PSAS-9 spreadsheet	Apheis 3: RR and 95% CI of the shrunken estimate	Reduction to 50 μg/m^3 Reduction to 20 μg/m^3 Reduction by 5 μg/m^3
			Madrid	1.006 (1.002-1.010)	
Long Term HIA					
Attributable Cases					
PM_{10}	All ages, All causes mortality (excluding external causes)	ICD10: A00-R99	French PSAS-9 spreadsheet	Kunzli et al, 2000: 1.043 (1.026-1.061)	Reduction to 40 μg/m^3 Reduction to 20 μg/m^3 Reduction by 5 μg/m^3
$PM_{2.5}$	All causes mortality	ICD 10: A00-Y98	French PSAS-9 spreadsheet	CA III Pope, 2002: 1.06 (1.02-1.11)	Reduction to 20 μg/m^3 Reduction to 15 μg/m^3 Reduction by 3.5 μg/m^3
	Cardiopulmonary mortality	ICD 10: I10-I70 and J00-J99		CA III Pope, 2002: 1.09 (1.03-1.16)	
	Lung cancer mortality	ICD 10: C33-C34		CA III Pope, 2002: 1.14 (1.04-1.23)	
YoLL					
$PM_{2.5}$	All causes mortality	ICD 10: A00-Y98	WHO AirQ software	CA III Pope, 2002: 1.06 (1.02-1.11)	Reduction to 20 μg/m^3 Reduction to 15 μg/m^3 Reduction by 3.5 μg/m^3
	Cardiopulmonary mortality	ICD 10: I10-I70 and J00-J99		CA III Pope, 2002: 1.09 (1.03-1.16)	
	Lung cancer mortality	ICD 10: C33-C34		CA III Pope, 2002: 1.14 (1.04-1.23)	

HIA SCENARIOS

a) Short-term scenarios

We used the following scenarios to estimate the acute effects of short-term exposure to PM_{10} on mortality and hospital admissions over one year:

Short term HIA scenarios for PM_{10}

- **Short-term HIA of PM_{10} on 0-1 days and cumulative HIA of PM_{10} up to 40 days**

We used three scenarios to estimate the acute health effects of PM_{10} on 0-1 days and cumulative health effects of PM_{10} up to 40 days on all causes (excluding external causes), cardiovascular and respiratory mortality over one year:

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

- **Combined local and meta-analytic estimates for short-term HIA of PM_{10}**

We used the same scenarios than above with combined local and meta-analytic estimates to calculate the acute health effects of PM_{10} on all causes of death (excluding external causes) over one year. This sensitivity analysis was done to study the interest of including the weight of a local estimates in the combined (meta-analytic) one.

b) Long-term scenarios

Long-term HIA scenarios for PM_{10}

We used three scenarios to estimate the chronic effects of long-term exposure to PM_{10} on all causes mortality (excluding external causes) over one year:

- 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 in the annual mean value of PM_{10} (to allow for cities with low levels of PM_{10})

Long term HIA for $PM_{2.5}$

We estimated chronic effects of $PM_{2.5}$ in the Madrid population over 30 years old as impacts on mortality due to all causes, cardiopulmonary and lung cancer deaths.

The following three pollution scenarios were considered:

- reduction of the annual mean value of $PM_{2.5}$ to a level of 20 µg/m^{3} [2]
- reduction of the annual mean value of $PM_{2.5}$ to a level of 15 µg/m^{3} [2]
- reduction by 3.5 µg/m^{3} in the annual mean value of $PM_{2.5}$ (to allow for cities with low levels of $PM_{2.5}$)

RESULTS

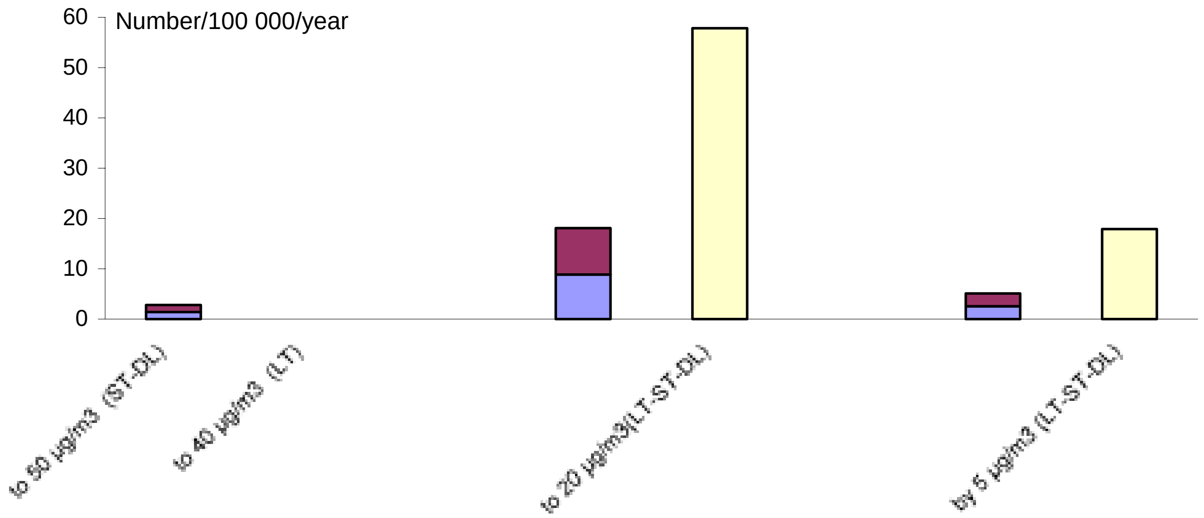
1. PM_{10} FINDINGS

1.1. Short-term HIA of PM_{10} on 0-1 days and cumulative HIA of PM_{10} up to 40 days, and long term HIA of PM_{10}

1.1.1. Mortality findings

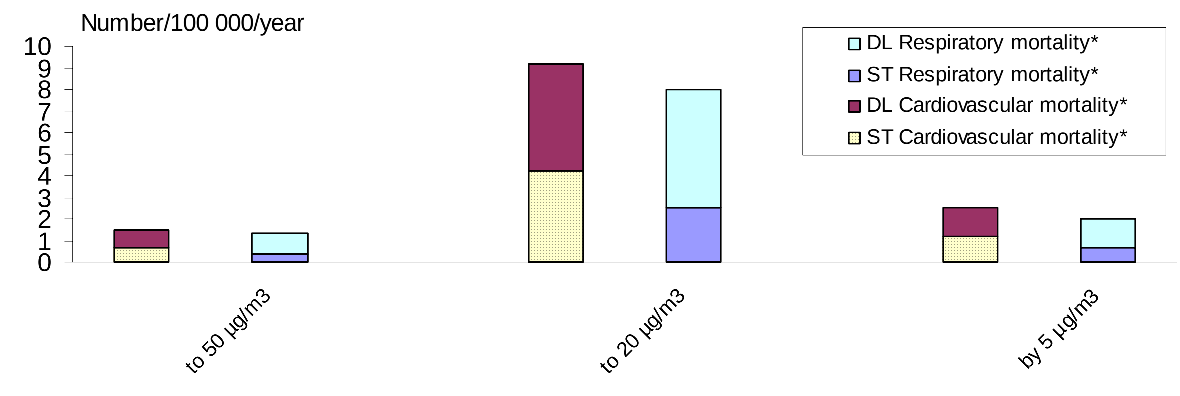
The following graphs show the health impact of PM_{10} on mortality for different lags: short-term-ST (0-1 day lag), cumulative effect –DL- distributed lag (up to 40 days lag) and long-term LT (years) on all causes mortality, figure 5, and specific mortality (cardiovascular and respiratory), figure 6.

Figure 5. PM10: reductions to 50/40-20-by 5 µg/m^{3}. Short term (ST), cumulative (DL), long term (LT) health impact on all causes mortality (ICD 9 <800)



* PM_{10} data for 2000, mortality data for 2000

Figure 6. PM_{10}: reductions to 50-20-by 5 µg/m^3. Short term (ST), cumulative (DL) health impact on specific mortality



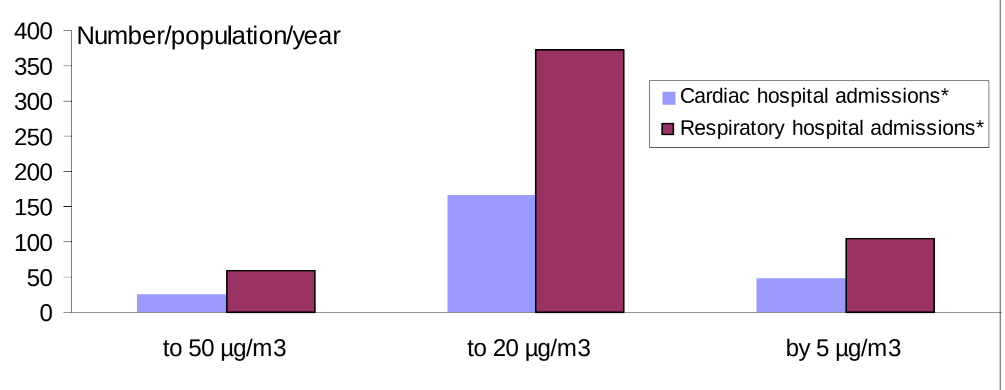
*Cardiovascular mortality (ICD9 390-459), respiratory mortality (ICD9 460-519).
** PM_{10} data for 2000, mortality data for 2000

If the actual levels of PM_{10} were reduced and all days with levels above 20 µg/m^3 reduced to 20 µg/m^3, all other risks being equal, and only the short term effects (0-1 days) are taken into account 260.4 deaths for all causes (124 cardiovascular and 73.3 respiratory deaths) would be avoided. When the cumulative health effects up 40 days (DL) are taken into account, extending the short term effect estimates, the benefits arise, and the avoided impact is of 531 deaths, 271 for cardiovascular deaths and 234 of them for respiratory causes. The city of Madrid gets no benefit from reducing PM_{10} to 40 µg/m^3 because this scenario has already been achieved.

1.1.2. Hospital admissions findings

We estimated the acute effects of short-term exposure to PM_{10} on cardiac and respiratory hospital admissions over one year. Results are presented on figure 7.

Figure 7. PM_{10} : reductions to 50-20-by 5 µg/m^3. Short-term health impact on hospital admissions



* Cardiac (ICD9 390-429) and respiratory hospital admissions (ICD9 460-519)
** PM_{10} data for 2000, hospital admissions data for 2001

If the actual levels of PM_{10} were reduced and all days with levels above 20 µg/m^3 reduced to 20 µg/m^3, all other risks being equal, and only the short term effects (0-1 days) are taken into account, 538 hospital admissions for respiratory and cardiac diseases would be avoided.

1.2. Combined local and meta-analytic estimates for the health effects of PM_{10}

We combined local and meta-analytic findings to establish the shrunken relative risk estimate-SE) and applied it to calculate the acute health effects of PM_{10} on all causes of death (excluding external causes) over one year.

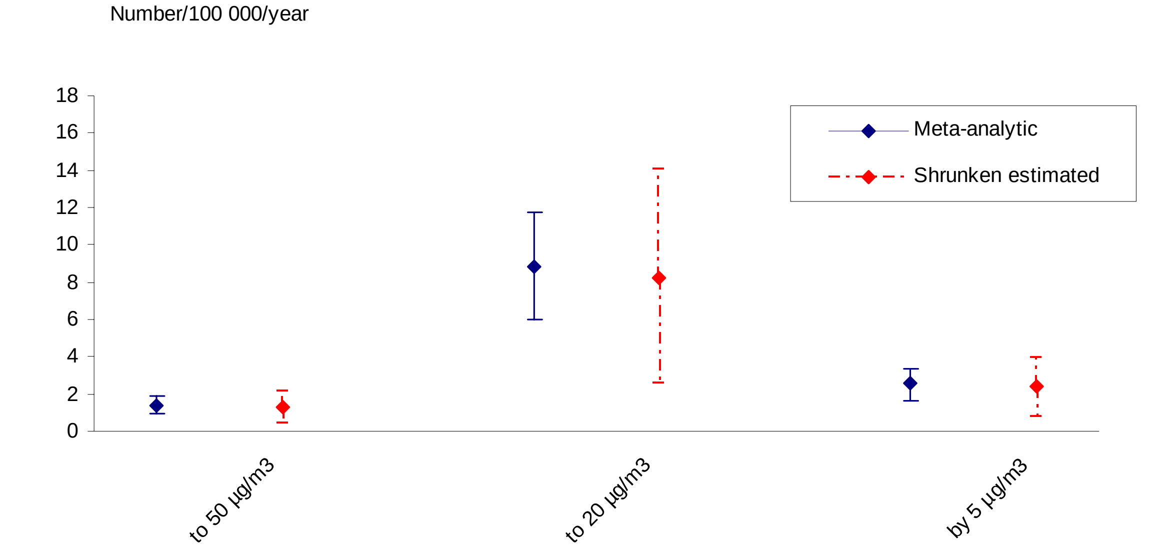


Figure 8. PM_{10}: reductions to 50-20-by 5 µg/m^3. Meta-analytic vs shrunken estimated health impact on all causes mortality*.

* All causes mortality excluding external causes (ICD9 < 800)
** PM_{10} data for 2000, mortality data for 2000

As it can be seen in figure 8, which compares the HIA of PM10 on 0-1 days and that of the combined estimate (SE), the difference between both estimates is negligible in the case of Madrid.

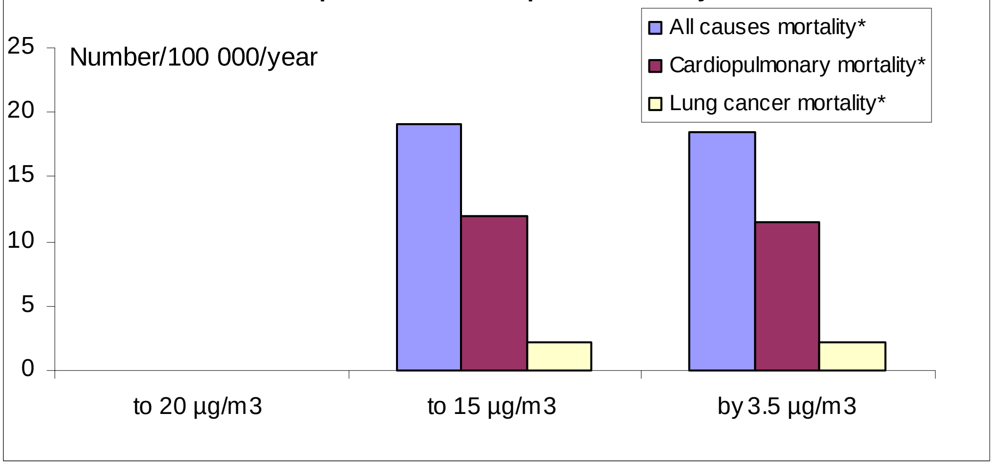
2. $PM_{2.5}$ FINDINGS

2.1. Long-term attributable cases for $PM_{2.5}$

We also used three scenarios to estimate the chronic effects of long-term exposure to $PM_{2.5}$ on mortality over one year.

The following graph presents the attributable number of all causes, cardiopulmonary and lung cancer deaths expressed as rates per 100 000 inhabitants.

Figure 9. $PM_{2.5}$: reductions to 20-15-by 3.5 µg/m^3. Long-term health impact on total and specific mortality



* All causes mortality (ICD9 0-999), cardiopulmonary mortality (ICD9 401-440 and 460-519), lung cancer mortality (ICD9 162).
** $PM_{2.5}$ data for 2000, mortality data for 2000

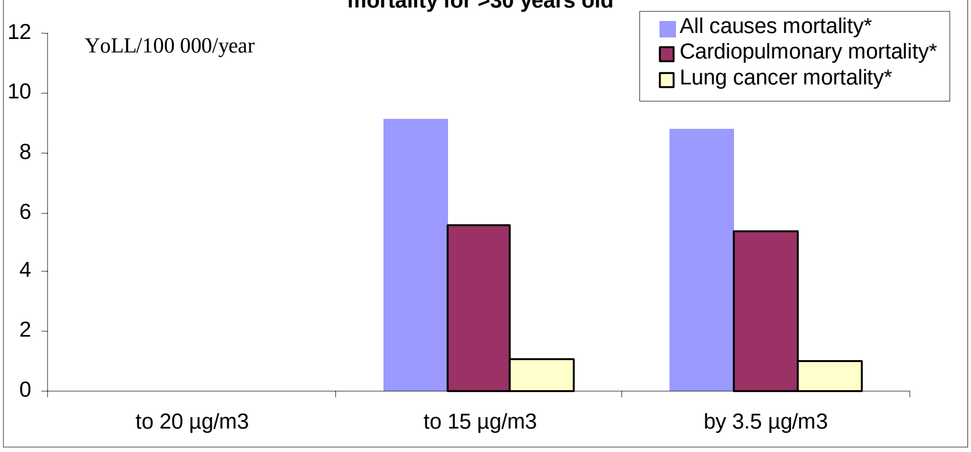
A reduction of $PM_{2.5}$ 15 µg/m^3 in 2000 would save around 562 all causes deaths in Madrid, all other things being equal. The benefits of reducing to 15 µg/m^3 and by 3.5 µg/m^3 are approximately the same in the case of Madrid. The reduction of $PM_{2.5}$ to 20 represents no benefit in Madrid as this level has currently been achieved.

2.2. Years of life lost for $PM_{2.5}$

We estimated the years of life lost attributable to the chronic effects of $PM_{2.5}$ using the data for 2000.

Figure 10 presents the years of life lost for starting year of simulation for all causes, cardiopulmonary and lung cancer deaths for 30 years of age or older in the population of Madrid.

Figure 10. $PM_{2.5}$: reductions to 20-15-by 3.5 µg/m^3. Expected years of life lost for the first year of simulation (2000) for total and specific mortality for >30 years old



* All causes mortality (ICD9 0-999), cardiopulmonary mortality (ICD9 401-440 and 460-519), lung cancer mortality (ICD9 162).
** $PM_{2.5}$ data for 2000, mortality data for 2000

For all causes of deaths, all other things being equal, reduction of $PM_{2.5}$ by 3.5 μg/m^3 in 2000 would save almost 258 years of expected life for starting year of simulation in people older than 30 years in the city of Madrid. For cardiopulmonary mortality, this number would be around 159 and for lung cancer mortality, 30.

The following table presents the findings in terms of life expectancy.

Table 5. Life expectancy and its possible increase by reduction of air pollution to 15 μg/m^3 in Madrid

		Expected gain in life expectancy in years		
Age	**Life expectancy**	**Mean**	**Low estimate**	**High estimate**
At birth	80.43	0.22	0.06	0.38
30	51.36	0.22	0.06	0.39
65	19.85	0.17	0.04	0.30

In terms of life expectancy, all other things being equal, if annual mean $PM_{2.5}$ levels (18.639 μg/m^3) would be reduced to 15 μg/m^3, the 51.36 years of life expectancy in a person of 30 years old would be increased by 0.22 years, due to reduced risk of death from all causes in the city of Madrid.

Interpretation of findings

According to HIA results, if the actual levels of PM_{10} were reduced and all days with levels above 20 μg/m^3 reduced to 20 μg/m^3, other risks being equal, and only the short term effects (0-1 days) are taken into account 260.4 deaths for all causes (124 cardiovascular and 73.3 respiratory deaths) would be avoided.

The previous HIA for Madrid (1998) limited the short term estimates to the effect for lag 0-1, as most studies of air pollution and daily deaths related pollution levels to deaths in the day or two immediately following the exposure.

Recent studies (Zanobetti et al., 2002 and 2003) have shown that the effect of air-bone particles, when the cumulative effects up to 40 days of follow up are examined, doubles for total mortality and cardiovascular diseases and increases more than 3 fold for respiratory deaths. Acute attributable cases when only one or two days (short term) following exposure are taken into account, or when the effects up to 40 days (distributed lag) are applied have been estimated giving a more complete picture of the effects.

When the cumulative health effects up 40 days are taken into account, extending the short term effect estimates, the benefits arise, and the avoided impact is of 531 deaths, 271 for cardiovascular deaths and 234 of them for respiratory causes.

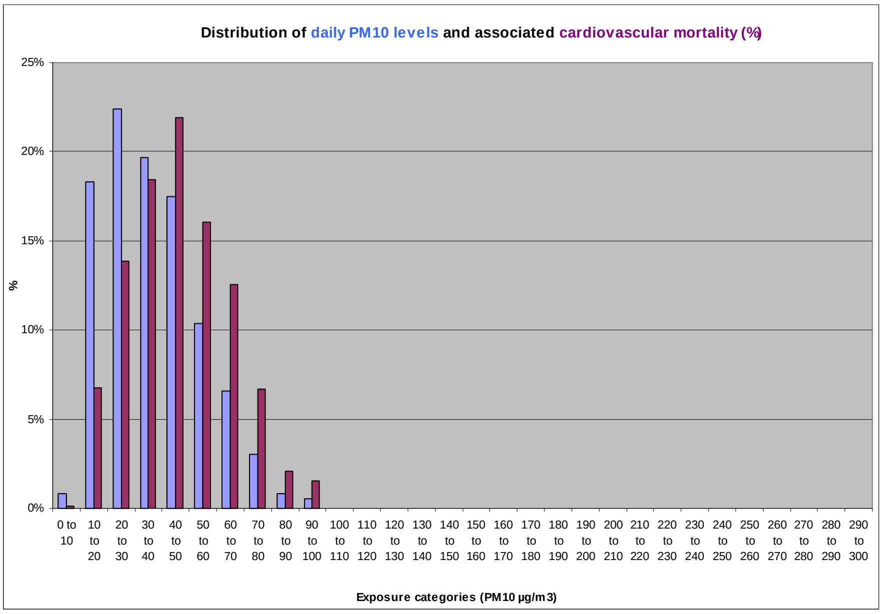
At the same time 538 hospital admissions for respiratory and cardiac diseases would be avoided.

The expected benefits on reduced mortality in the long term, applying the approach based in the levels of $PM_{2,5}$ (converted from PM_{10}), 563 lives would be avoided, 351 due to cardiovascular diseases and 66 lung cancer deaths. This would represent 9.09 per 100000 years of life lost (YoLL), mainly due to cardiopulmonary diseases.

As it has been previously expressed, indicators on short and long term effects should not be added. The exposure data used for HIA may overestimate the exposure due to the use mainly of traffic monitoring stations. This means that the effects may be slightly overestimated.

The next figure represent the distribution of daily PM_{10} levels an the associated total mortality (fig. 11). Only 6% of the attributable mortality corresponds to the days with PM_{10} levels higher than 80 µg/m^3, while the main burden can be attributed to days below this level.

Figure 11. Short term distribution of PM_{10} levels and associated percentage of cases



General comments and conclusions

The implementation of the Apheis project has enhanced the collaboration between institutions responsible of health and environment in the Community of Madrid.

The reached experience allows us to develop HIA in other areas of environmental risk factors in the future.

The findings provided by the project are now well known in the professional and scientific sectors.

In these first years of the development of the project, HIA has only been applied to the city of Madrid. It is necessary to expand the study area to the whole Madrid metropolitan area with which intense relations are maintained in the working, leisure and transport fields and that in many senses can be considered a unit.

Appendix

1. **Questionnaire on the exposure measurement methods**

Harmonised compilation of information indicating the exposure relevant area of the city, number of PM10, PM2.5 or BS monitoring sites, and the type, sampling and measurement characteristics of stations selected for the HIA of APHEIS

1.	City:	Madrid
2.	Total area of agglomeration (km²):	606
3.	Area (km²) covered by the air monitoring network in the city:	606
4.	Number of population in this (exposure relevant) area:	2 938 723
5.	Total number of PM10 monitoring stations in this area:	25
6.	Total number of BS monitoring stations in this area:	0
7.	**Total number of PM2.5 monitoring stations in this area:**	**0**_______________
8.	Number of selected PM10 monitoring stations for HIA:	23
9.	Number of selected BS monitoring stations for HIA:	0
10.	**Number of selected PM2.5 monitoring stations for HIA:**	**0**_______________

11. Measurement interval (please cross)

continuous **x** hourly 24 hours weekly 2 weekly

12. Quality assurance and control (please cross)

yes **x** no do not know

13. Data quality (please cross)

validated data **x** [9] invalidated data

[9] The city council has got validation procedures, but we are not sure that the procedures required by the Apheis protocol are reached . We don't have any written document.

14. Name, classification and sampling characteristics of the monitoring site (traffic, kerbside, building line, commercial, urban residential, sub-urban, rural, industrial, others)

Name	PM10/BS/PM2.5	Classification
1. PASEO DE RCOLETOS	PM10	TRAFFIC
2. GLORIETA CARLOS V	PM10	TRAFFIC
3. PLAZA DEL CARMEN	PM10	TRAFFIC
4. PLAZA DE ESPAÑA	PM10	TRAFFIC
5. BARRIO DEL PILAR	PM10	TRAFFIC
6. PLAZA DOCTOR MARAÑÓN	PM10	TRAFFIC
7. MARQUÉS DE SALAMANCA	PM10	TRAFFIC
8. ESCUELAS AGUIRRE	PM10	TRAFFIC
9. PLAZA LUCA DE TENA	PM10	TRAFFIC
10. CUATRO CAMINOS	PM10	TRAFFIC
11. RAMÓN Y CAJAL	PM10	TRAFFIC
12. PLAZA MANUEL BECERRA	PM10	TRAFFIC
13. VALLECAS	PM10	TRAFFIC
14 PLAZA FERNÁNDEZ LADREDA	PM10	TRAFFIC
15. PLAZA DE CASTILLA	PM10	TRAFFIC
17. VILLAVERDE	PM10	NOT CLASSIFIED
18. GTA. MARQUÉS DE VADILLO	PM10	TRAFFIC
19. ALTO EXTREMADURA	PM10	TRAFFIC
20. MORATALAZ	PM10	TRAFFIC
21. ISAAC PERAL	PM10	TRAFFIC
22. PASEO DE PONTONES	PM10	TRAFFIC
23. ALCALA	PM10	TRAFFIC
24. CASA DE CAMPO	PM10	SUBURBAN-BACKGROUND

All the stations except CASA DE CAMPO are in urban areas, with residential and commercial activities.

15. Measurement meted / Type of instrument

BS: ____________________

PM10 manual:____________________
Automated: β- attenuation
optical:____________________

PM2.5 manual:____________________
automated:____________________
probe temperature (in °C):____________________
optical:____________________

16. Using PM10 data for your city HIA calculation, did you used a conversion factor in order to compensate losses of volatile particulate matter?

no

yes X **if yes, a) which factor: __1.0____________________**

b) is it a default factor? **yes** **no X**

or c) derived from own parallel measurements (reference method vs. TEOM or beta attenuation) yes X no

The national Environment Department has estimated a factor of 1.0 for the central area of Spain including Madrid. The study was carried out by the "Instituto Jaime Almera" de Barcelona (CSIC = National Research Centre)

17. If your PM2.5 data have been calculated from your PM10 data, what conversion factor did you use? factor: ratio of PM2,5/PM10=0,51

- The local convertion factor was estimated using simultaneous measures of PM_{10} and $PM_{2,5}$ during the period from the first of January, 2002 to July, 7, 2003. The data were collected by the Madrid City council.The data were analyzed following the "Guidance To Member States On PM_{10} Monitoring And Intercomparisons: UIT Reference Method" proposed by the EC Working Group On Particulate Matter.

2. Tables for PM_{10} findings

2.1. Health effects of PM_{10} on 0-1 days

Tables 1 presents the attributable number of all causes, cardiovascular and respiratory deaths expressed as absolute numbers and as rates per 100 000 inhabitants. Table 2 presents the results for cardiac and respiratory hospital admissions.

Table 1. Potential benefits of reducing daily PM_{10} levels (year 2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

			Attributable cases per year					
	Scenarios	Number of days per year exceeding 20 and 50 µg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
Deaths all causes (ICD10: A00-R99)	20 µg/m^3	296	260.42	173.22	348.01	8.86	5.89	11.84
	50 µg/m^3	78	40.16	26.74	53.60	1.37	0.91	1.82
	By 5 µg/m^3	NA*	74.23	49.51	98.93	2.53	1.68	3.37
Cardiovascular deaths (ICD10 I00-I99)	20 µg/m^3	296	124.36	68.78	180.44	4.2	2.3	6.1
	50 µg/m^3	78	19.31	10.71	27.96	0.7	0.4	1.0
	By 5 µg/m^3	NA*	35.15	19.54	50.72	1.2	0.7	1.7
Respiratory Deaths (ICD10 J00-J99)	20 µg/m^3	296	73.34	27.95	119.55	2.5	1.0	4.1
	50 µg/m^3	78	11.50	4.40	18.66	0.4	0.1	0.6
	By 5 µg/m^3	NA*	20.49	7.90	33.03	0.7	0.3	1.1

Table 2. Cardiac (ICD9 390-429) and respiratory (ICD9 460-519) hospital admissions (year 2001). Potential benefits of reducing daily PM_{10} levels (year 2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number (95% CI) attributable to the acute effects of PM_{10}

		Attributable cases per year		
Scenarios	Number of days per year exceeding 20 and 50 µg/m^3	N° of admissions central	N° of admissions lower	N° of admissions upper
Hospital admissions for cardiac diseases (all ages)				
20 µg/m^3	296	166.06	82.75	249.94
50 µg/m^3	78	25.61	12.78	38.48
By 5 µg/m^3	NA*	47.34	23.69	70.95
Hospital admissions for respiratory diseases (all ages)				
20 µg/m^3	296	371.87	201.06	548.04
50 µg/m^3	78	58.09	31.5	85.35
By 5 µg/m^3	NA*	104.37	56.84	152.7

**NA: not applicable*

2.2. Cumulative health effects of PM_{10} up to 40 days

Table 3 present the attributable number of all causes, cardiovascular and respiratory deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 3. Cumulative health effects of PM_{10} up to 40 days (year 2000). Potential benefits of reducing daily PM_{10} levels (year 2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

			Attributable cases per year					
	Scenarios	Number of days per year exceeded	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
All causes of deaths (ICD10: A00-R99)	20 µg/m^3	296	530.87	348.8	712.89	18.1	11.87	24.26
	50 µg/m^3	78	83.10	54.73	111.33	2.83	1.86	3.79
	By 5 µg/m^3	NA*	148.63	98.22	198.46	5.1	3.34	6.75
Cardiovascular deaths (ICD10: I00-I99)	20 µg/m^3	296	270.63	189.8	352.81	9.21	6.46	12.01
	50 µg/m^3	78	43.12	30.34	56.02	1.47	1.03	1.91
	By 5 µg/m^3	NA*	74.18	52.44	95.93	2.52	1.78	3.26
Respiratory deaths (ICD10: J00-J99)	20 µg/m^3	296	234.07	58.54	428.59	8.0	2.0	14.6
	50 µg/m^3	78	39.28	10.00	70.57	1.3	0.3	2.4
	By 5 µg/m^3	NA*	60.20	15.72	105.39	2.0	0.5	3.6

2.3. Combined local and meta-analytic estimates for the health effects of PM_{10}

Table 4 presents the attributable number of all causes of deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 4. Combined local and meta-analytic estimates for the health effects of PM_{10} and all causes of deaths (ICD10: A00-R99). (year 2000). Potential benefits of reducing daily PM_{10} levels (year 2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

	Attributable cases per year						
Scenarios	Number of days per year exceeding 20 and 50 µg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m^3	296	243.11	69.15	418.65	8.27	2.35	14.25
50 µg/m^3	78	37.45	10.68	64.35	1.27	0.36	2.19
By 5 µg/m^3	NA*	69.38	19.84	118.82	2.36	0.67	4.04

**NA: not applicable*

2.4. Long term HIA for PM_{10}

Table 5 presents the attributable number of all causes of deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 5. Deaths all causes (ICD10: A00-R99) (year 2000). Potential benefits of reducing annual mean values of PM_{10} (year 2000) to levels of 20 and 40 µg/m^3, and by 5 µg/m^3. Absolute number of deaths and number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}

	Attributable cases per year					
	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m^3	1699.46	1021.99	2424.71	57.83	34.78	82.5
40 µg/m^3	0	0	0	0	0	0
By 5 µg/m^3	526.06	319.4	743.04	17.9	10.87	25.28

3. Tables for $PM_{2.5}$ findings

3.1. LT $PM_{2.5}$: Attributable Cases

Table 6 present the attributable number of all causes, cardiopulmonary and lung cancer deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 6. Potential benefits of reducing annual mean values of $PM_{2,5}$ (year 2000) to levels of 15 and 20 µg/m^3, and by 3.5 µg/m^3. Absolute number of deaths and number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of $PM_{2,5}$

		Attributable cases per year					
	Scenarios	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
Deaths all causes (ICD10: A00-Y98)	15 µg/m^3	562.67	146.37	986.69	19.15	4.98	33.58
	20 µg/m^3	0.00	0.00	0.00	0.00	0.00	0.00
	By 3.5 µg/m^3	541.39	140.87	949.07	18.42	4.79	32.30
Cardiopulmonary deaths (ICD10 I10-I70; J00-J99)	15 µg/m^3	351.05	125.95	581.42	11.95	4.29	19.78
	20 µg/m^3	0.00	0.00	0.00	0.00	0.00	0.00
	By 3.5 µg/m^3	337.84	121.26	559.32	11.50	4.13	19.03
Lung cancer deaths (ICD10: C33-C34)	15 µg/m^3	65.98	22.18	111.17	2.25	0.75	3.78
	20 µg/m^3	0.00	0.00	0.00	0.00	0.00	0.00
	By 3.5 µg/m^3	63.51	21.36	106.95	2.16	0.73	3.64

3.2. LT $PM_{2.5}$: Years of Life Lost

Tables 7 present the years of life lost of all causes, cardiopulmonary and lung cancer deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 7. Potential benefits of reducing annual mean values of $PM_{2,5}$ (year 2000) to levels of 15 and 20 µg/m^3, and by 3.5 µg/m^3. Years of life lost (YoLL) and YoLL per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of $PM_{2.5}$

		Years of life lost					
	Scenarios	YoLL central	YoLL lower	YoLL upper	YoLL per 100 000 central	YoLL per 100 000 lower	YoLL per 100 000 Upper
Deaths all causes >30 years, male and female, for one year (ICD10: A00-Y98)	15 µg/m^3	268.43	70.98	462.92	9.09	2.4	15.68
	20 µg/m^3	0	0	0	0	0	0
	By 3.5 µg/m^3	258.28	68.28	445.54	8.75	2.31	15.09
Cardiopulmonary deaths >30 years, male and female, for one year deaths (ICD10 I10-I70;J00-J99)	15 µg/m^3	164.92	60.33	267.47	5.59	2.04	9.06
	20 µg/m^3	0	0	0	0	0	0
	By 3.5 µg/m^3	158.72	58.03	257.50	5.38	1.97	8.72
Lung cancer deaths >30 years, male and female, for one year (ICD10: C33-C34)	15 µg/m^3	31.68	10.97	51.76	1.07	0.37	1.75
	20 µg/m^3	0	0	0	0	0	0
	By 3.5 µg/m^3	30.49	10.55	49.86	1.03	0.36	1.69

Madrid partners

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