HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

ENHIS-1 PROJECT: WP5 HEALTH IMPACT ASSESSMENT

LOCAL CITY REPORT

Lisbon

Summary of main findings for Lisbon

In 2002 the PM_{10} annual mean (SD) was 32 (16) µg/m^3, above the 1999/30/EC Directive limit value for 2010 (20 µg/m^3), and below that established for 2005 (40 µg/m^3). For the summer period of the same year, the mean (SD), P5 (5th percentile) and P95 of the maximum daily 8-hour moving average concentration of ozone (O_3) were 79 (22), 44 and 114 µg/m^3.

Regarding children, infant mortality in Europe is quite low and consequently, the expected attributable number of deaths related to air pollution is also very low. All other things being equal, the reduction of the annual average levels of PM_{10} to 20 µg/m^3 would prevent 2,3 total postneonatal deaths. Reducing PM_{10} daily mean values to 20 µg/m^3 would prevent 41,2 hospital respiratory admissions.

As far as short-term effects of O_3 in summer are concerned, all other things being equal, each reduction by 10 µg/m^3 of the daily maximum 8-hour moving average concentrations would delay 26,8 deaths per year in the general population in the study area, 17,4 from cardiovascular diseases, and 7,8 from respiratory causes. In terms of hospital admissions, this would represent 2,5 respiratory admissions in the adult population and 21 in the population over 64 years.

Summary of HIA of outdoor air pollution in Lisbon in ENHIS-1

Health outcome	**Population**	**Pollutant**	**Period**	**Mean type**	**RR (for 10 µg.m^3 increase)**	*References*	**Number of attributable cases by scenario**[1]	
Mortality							**Ozone: Reduction by 10 µg.m^3**	**PM10: Reduction by 5 µg/m^3**
Total mortality excluding external causes (ICD9 < 800 - ICD10 A00-R99)	All ages	O_3 8h max	Summer[2]	Daily	1.0031 (1.0017-1.0052)	Gryparis et al 2004	24,20	
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.0046 (1.0022-0.0073)		15,47	
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.0113 (1.0074-1.0151)		5,93	
Total postneonatal mortality	1 month- 1 year	Corrected PM_{10}[3]	Year	Annual	1.048 (1.022-1.075)	Lacasaña et al 2005		0,97
Postneonatal respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.216 (1.102-1.342)			0,19
Postneonatal Sudden Infant Death Syndrome Mortality (ICD9 798.0 - ICD10 R95)					1.12 (1.07-1.17)	Woodruff 1997		0,17
Morbidity								
Emergency room visits for asthma (ICD-9 codes 493, ICD-10 codes J45, J46)	< 18 years	O_3 1h max	Year	Daily	1.0115 (1.0067-1.0163)	CARB 2004	not available	
Cough	< 18 years	Measured PM_{10}			1.0407 (1.0202-1.0511)	Ward and Ayres 2004	not available	not available
Lower respiratory symptoms LRS	< 18 years	Measured PM_{10}			1.0407 (1.0202 -1.617)	Ward and Ayres 2004		not available
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	< 15 years	Measured PM_{10}			1.010 (0.998-1.021)	Anderson et al 2004		18,92
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	15 - 64 years	**O_3 8h max**	Summer		1.001 (0.991-1.012)		2,14	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	> 64 years				1.005 (0.998-1.012)		16,45	

[1] For ozone: absolute reduction by 10 µg/m^3. For PM_{10} absolute reduction by 5 µg/m^3.

[2] Definition of summer period : 01 April – 30 September

[3] PM_{10} reference papers for HIA on postneonatal mortality use gravimetric methods to measure PM_{10}. If the local air quality network uses automatic methods (TEOM or other) a correction factor is required to compensate for loss of volatile compounds: if available, a local correction factor recommended by the air quality network or, by default, the European factor 1.3.

Introduction

Lisbon is a new Apheis centre. The study area of Lisbon is composed of 8 municipalities that are part of the district of Lisbon, including Lisbon city, corresponding to an area of 1055 km^2 and totalizing 1.892.903 inhabitants. This area is approximately identical to one of the portuguese agglomerations, defined according to the criteria of the EU Directive 1999/30/CE.

Table 1 gives the number of inhabitants per municipality in the study area, according to the Census in 1981, 1991 and 2001, developed by the National Institute of Statistics (INE).

Table 1. Inhabitants in 1981, 1991 and 2001

Municipality	Inhabitants in 1981	Inhabitants in 1991	Inhabitants in 2001
Amadora	163.874	181.774	175.872
Cascais	141.498	153.294	170.683
Lisboa	807.937	666.394	564.657
Loures	276.467	192.143	199.059
Odivelas	---	130.015	133.847
Oeiras	149.328	151.342	162.128
Sintra	226428	260.951	363.749
Vila Franca de Xira	88.193	103.571	122.908
Portugal	9.833.014	9.867.147	10.356.117

The municipality of Lisbon had around 560.000 inhabitants in 2001, corresponding to nearly 30% of the population included in study area (29,83%). Recently there has been a redistribution of population within the metropolitan area of Lisbon. The internal movements had main incidence in the reduction of the population of the city of Lisbon and an expansion of the urban spot through the occupation of the bordering municipalities, mainly in the North edge.

If we analyse the population density and the main infrastructures of transport we will detect higher population densities near the main roads and railways, that function as preferential vectors for urban expansion (CCDR-LVT & FCT/UNL, 2005).

In the study area, 15,8% of the people are over 64 years old and 14,7% are under 15 years. From these, 1,1% are children between 1 month and one year.

In 2001 the municipality of Lisbon was the one with major differences concerning the age of population with a clear tendency to double aging of population, with a bigger percentage of elder people and a lesser percentage of young people.

Concerning the productive structure, in 2001, about 70% of the active population of the metropolitan area of Lisbon worked in the tertiary sector (CCDR-LVT & FCT/UNL, 2005).

Lisbon is located at 39ºN and 09ºW, approximately, in the transition zone between subtropical anticyclones and the sub-polar depressions. Lisbon lies close to the estuary of river Tagus and in the proximity of the Atlantic Ocean, which confers specificness to the climate of the city and the surrounding regions.

In 2002, the annual daily mean for maximum temperatures in Lisbon was 21ºC, ranging from 15ºC in January to 27ºC in August. The number of days with maximum temperature above 25ºC is very significant. The annual daily mean for minimum temperatures was 13,5ºC, ranging from 9,5ºC in January to 17,5ºC in August. The annual mean relative humidity was 67%. In 2002 minimum and maximum temperatures were 4,1ºC and 37,5ºC, respectively.

The maximum absolute temperatures are above 40ºC and the occurrence of very hot periods is frequent. Despite this, the Heat Waves have a lesser frequency, because the maritime breeze prevents the periods of higher temperatures from exceeding more than 2-3 days.

Winter is rainy and relatively wet, in special in the region of Sintra, and summer is dry. These climatic characteristics, with rainy and pleasant winters and dry and hot summers, attribute to the metropolitan area of Lisbon a Mediterranean Climate of Atlantic influence.

The dominant route of the wind in Lisbon is North. The months that more contribute for the dominant wind are the months of spring and summer seasons (from May until September) and the ones that less contribute are those of autumn – winter seasons, in special the months from December until February. The annual average of wind speed is 13 km/h. In summer the average wind speed is higher.

According to CCDR-LVT & FCT/UNL (2005), between 2001 and 2004, there were several exceedences of the daily mean values of PM_{10} not only to the limit value but also taking into account the margin of tolerance. Punctually, there were some exceedences to the annual limit value of PM_{10} and NO_x in traffic stations. When this situation occurs, the concentrations may have an impact on public health and for this reason, Member States have to develop plans and programmes for the zones or agglomerations where the exceedences occur. The main goal of these plans and programmes is the reduction of concentrations of air pollutants within the limit values.

For the population living in urban areas such as the Lisbon city, traffic is one of the environmental factors considered to be more dangerous for health. For working and educational reasons, Lisbon city is also the main destination of most part of the population within the Lisbon agglomeration. In 1991, the capital population increased 35% daily due to pendular movements and in 2001 this percentage slightly increased.

In order to reduce air pollution, several policies and measures on the sector of transports are being evaluated, in the context of the development of plans and programmes (CCDR-LVT & FCT/UNL, 2005).

Generally, the main causes for mortality in Portugal (and also in Lisbon) are cardiovascular diseases, followed by tumors. In children, external causes followed by tumors are the most responsible for mortality.

In case of adult morbidity, the main causes are the circulatory system diseases at first place, at second the digestive diseases, at third cancer and at fourth the respiratory diseases.

Concerning children, respiratory diseases, malformations and congenital anomalies are the main causes for morbidity. In older children, digestive diseases are at first place.

This report seeks to analyze the impact of air pollution on public health in Lisbon and is part of the Apheis programme. This work has been carried out within the framework of work package WP5 on health impact assessment of ENHIS-1 project (www.enhis.net). For the first time a health impact assessment is being carried out in this study area, referring to the year 2002.

This report also shows the main results obtained from the HIA in children and in the general population, in adults and in people over 64 years, for PM_{10} and ozone. Concerning children, the impact of exposure to PM_{10} in the long term, if all other things were equal and outdoor concentrations of PM_{10} were reduced to 20 $\mu g/m^3$ in Lisbon study area, about 2,32 total postneonatal deaths could have been prevented and the number of annual hospital admissions due to respiratory reasons for children under 15 years could have been reduced by 41,2.

Regarding short term effects of ozone, a reduction by 10 $\mu g/m^3$ of daily maximum 8-hour moving average concentrations would delay 26,8 deaths in the study area. For cause specific mortality, 17,5 deaths from cardiovascular diseases and 7,8 from respiratory causes could have been prevented in the year 2002. Hospital respiratory admissions could have been reduced, mainly in what the elder concerns (> 64 years), by a number of 21.

Sources of air pollution

According to CCDR-LVT & FCT/UNL (2005), the main source of air pollution in Lisbon is traffic, mostly in urban areas. The road transport sector contributes with both vehicle exhaust particles and resuspension of road dust (mineral dust of street surface and abrasion of tyres, brakes and the road surface).

Portugal also suffers from the influence of other particles coming from natural sources, like sea salt, dust from the desert and forest fires.

Lisbon city is the main destination for most of the population of the whole agglomeration due to work or education. In 1991, the total number of people in a normal day increased by 35% and this percentage has also increased in 2001 (CCDR-LVT & FCT/UNL, 2005).

In the last decade, the percentage of people who used public transport decreased from 50% in 1991 to 37% in 2001. On the opposite, the number of people who prefer using private transport has increased (26% in 1991 and 45% in 2001).

In Portugal, during Summer, the pollution episodes are commonly due to tropospheric ozone. The health effects associated to this pollutant are sufficiently well known and it is a major pollutant particularly during heat waves which are expected to be more and more frequent. When the values of ozone are above specific thresholds in the atmosphere (180 $\mu g/m^3$ and 240 $\mu g/m^3$, according to the 2002/3/EC Directive), it can be harmful for human health and ecosystems. Being a secondary pollutant, i.e., resulting from primary pollutants (and depending on certain meteorological factors such as solar radiation), a system has been developed that allows to predict the ozone levels in the atmosphere and to inform the population in case of situations exceeding the limits.

Exposure data

The air pollution surveillance system has been gradually implemented in Portugal and there is an extensive network of air pollution monitoring sites throughout Lisbon. The location of each station, in relation to its immediate surroundings is classified as background, traffic or industrial.

The air pollution levels are monitored by the regional environmental services (*Commission for Coordination and Regional Development of Lisbon and Tagus Valley*) and are gathered in a database that is accessible to the public through the website of the portuguese Institute of the Environment. The air pollution network that was included in the study consists of 3 stations for PM_{10} and 5 stations for ozone.

As recommended in the Update on Guidelines on Exposure Assessment (May 2005), only data from background stations were considered. Regarding completeness criteria for PM_{10}, in case of 1h values there was a minimum data capture of 75% and for 24 hour average there were at least 13 1-hour values available, not more than six successive 1-hour values missing (criteria of the Guidance Report on the Annexes of Decision 97/101/EC, on Exchange of information as revised by Decision 2001/752/EC). For ozone (1-hour values) there was a minimum data capture of 75%. In the maximum 1h daily values, 75% of the hourly values from 6-7 pm have to be available. In case of maximum 8h daily values (calculated as 8 hour moving average), 75% of the hourly values from 9 am to 5 pm need to be available.

The missing data were completed following the recommendations of the APHEA Guidelines on Exposure Assessment.

PM_{10} is measured using automated β-attenuation method. For background stations the correction factor is 1,11. For the long term health impact assessment, which uses relative risks based on gravimetric methods, this correction factor was applied to the original data. For short term health impact assessment the original data were used, without any correction factor.

How indicators have been calculated:

- PM_{10}: Daily exposure indicator has been calculated as the arithmetic mean of the daily concentrations of the stations.
- Ozone: The daily maximum 1-hour indicator has been calculated as the arithmetic mean of the 1-hour maximum of the stations. The daily maximum 8-hour moving average of each day have been calculated as the arithmetic mean of the maximum 8-hour moving averages of the stations for the summer period (1st April to 30th September).

The annual mean level (SD) of PM_{10} in Lisbon was 32 (16) µg/m^3, and P5 and P95 of the daily mean values were, respectively, 12 µg/m^3 and 64 µg/m^3. The mean (SD), P5 and P95 of the daily maximum 8-hour moving average concentrations of O_3 were, respectively, 79 (22), 44 and 114 µg/ m^3, and those of the daily maximum 1-hour concentrations 76 (23), 44 and 118 µg/m3 (Table 1 and figures 1-3).

According to the European Council Directive 1999/30/EC, 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 all 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.

In case of PM_{10}, the annual mean level of 32 µg/m^3 in 2002 was below the limit value established for 2005 in the 1999/30/EC Directive (40 µg/m^3) and for 2002 (55 µg/m^3), but above the limit value for 2010 (20 µg/m^3).

If we consider the daily limit value established for 2002 in the 1999/30/EC Directive (65 µg/m^3), there were 16 values above the limit value in 2002 which means these exceedences were within the 35 permitted.

Nevertheless, if we consider the daily limit value established for 2005 in the 1999/30/EC Directive (50 µg/m^3), in the year 2002 there were 54 values above 50 µg/m^3, which means there were more exceedences than the 35 permitted. Finally, if we consider the daily limit value established for 2010 (20 µg/m^3), there were 278 values above this limit value in 2002.

Concerning ozone concentration in 2002, there were 7 values above the target value for the protection of human health established for 2010 in the 2002/3/EC Directive (120 µg/m^3, not to be exceeded more than 25 days per calendar year averaged over three years), and the maximum daily 8h-mean was 163 µg/m^3. Nevertheless, there was only one 1-hour average value above 180 µg/m^3, defined as information threshold according to the 2002/3/EC Directive, meaning a level beyond which there is a risk to human health from brief exposure for particularly sensitive sections of the population and for whom up-to-date information is necessary.

Table 2 gives a broad picture of the observed levels of PM_{10} and ozone in Lisbon (2002).

Table 2. Descriptive statistics for ozone and PM_{10} levels in Lisbon (2002)

	O3 8h - summer	**O3 1h max - year**	**PM10 - year**
Number	183	365	365
Minimum	33	21	8
Percentile 5	44	44	12
Percentile 25	65	62	20
Median	78	73	29
Percentile 75	90	88	42
Percentile 95	114	118	64
Percentile 98	130	133	70
Maximum	163	196	87
Daily mean	79	76	32
standard error	22	23	16
% missing values	0,00%	0,00%	0,00%

Figures 1, 2 and 3 represent the distribution of ozone and PM_{10} levels for the year 2002 in Lisbon, and also for summer in case of ozone.

Fig. 1 shows that in Lisbon area, in 2002, the major part of the days have values of O_3 8-hour maximum between 70 and 90 µg/m^3. There was only one O_3 value above 160 µg/m^3.

Fig 1. Distribution of daily O3 8h max in Lisbon area. Summer 2002

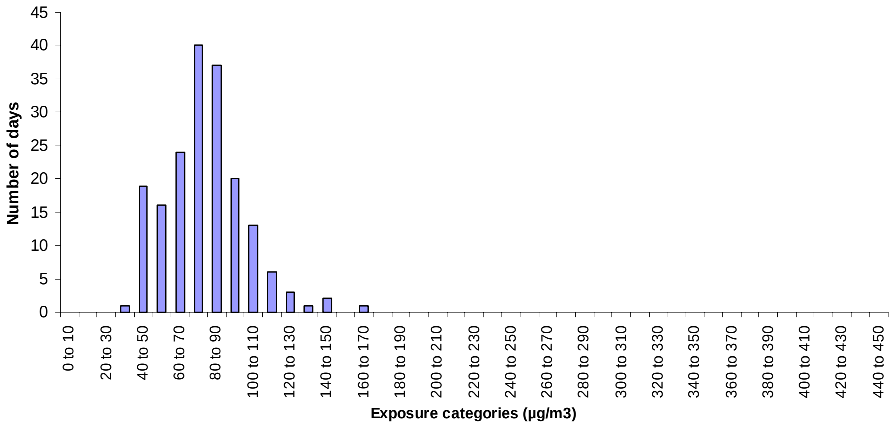


Fig. 2 shows that in Lisbon area, in 2002, the major part of the days had values of O_3 1-hour maximum in the exposure category of 70 to 80 µg/m^3. There was one O_3 value above 180 µg/m^3, classified as information threshold in the 2002/3/EC Directive.

Fig 2. Distribution of daily O3 1-hour max in Lisbon area - 2002

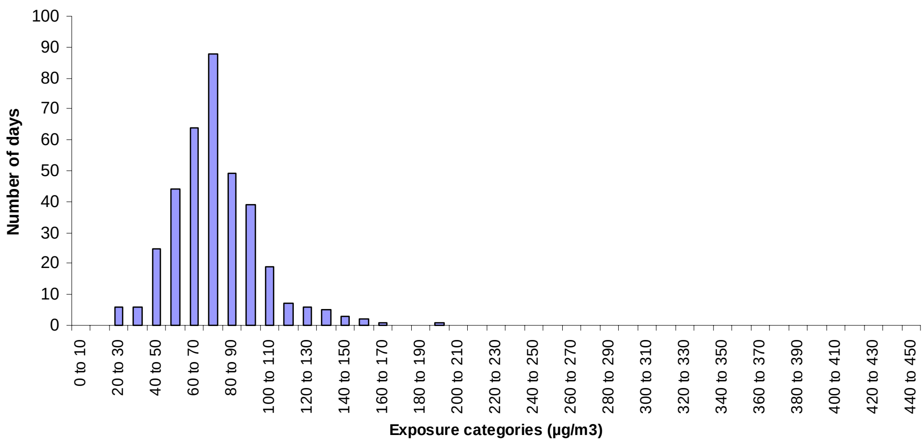
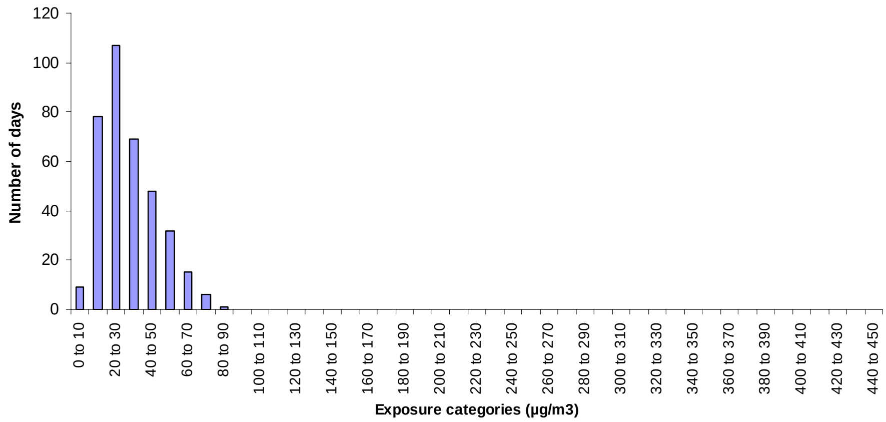


Fig. 3 shows that in Lisbon area, in 2002, the major part of the days had values of PM_{10} in the exposure category of 20 to 30 µg/m^3. There were 54 values above 50 µg/m^3, which means there were more exceedences than the 35 permitted. These values were mostly in the exposure category of 50 to 60 µg/m^3 (32) or in the exposure category 60 to 70 µg/m^3 (15). There was only one PM_{10} value above 80 µg/m^3.

Fig 3. Distribuion of daily PM 10 in Lisbon area - 2002



Health data

Data on mortality of the year 2002 was provided by the National Institute of Statistics of Portugal which provides by the end of every year a database to the General Directorate of Health. This registry is coded by the General Directorate of Health, according to the International Classification of Diseases ICD-9 and ICD-10 and is quality controlled. The percentage of missing data is 0%.

The age standardized mortality rate (per 100 000 inhabitants) using European population for the year 2000 was 932,83.

Data on hospital admissions were retrieved from a database, held by the Ministry of Health (Related Diagnosis Groups Register) which uses ICD-9 coding (clinical modification) and is not quality controlled. The existing data is based on total hospital admissions, excluding emergencies, and it refers to discharges from hospitals of the National Health Service in the mainland (public sector, only). Concerning discharges, the data are validated and percentage of missing data is 0%.

Apart from being based on discharges, the data on hospital admissions are taken into account annually. Therefore, the data referring to “summer hospital admissions” should be analysed with extra careful.

The system registry does not allow so far a straightforward classification of the emergency room visits by diagnosis and only the total number is available. Therefore, the emergency room visits for asthma and the lower respiratory symptoms and cough weren’t included in the HIA.

Table 3 shows the descriptive statistics for health outcomes in Lisbon (2002). It includes the daily number and annual total and cause-specific rates of the mortality and morbidity groups included in this report.

Concerning general population, the daily rate (per 100 000) is higher in the case of cardiovascular mortality. Children and older people (> 64 years) registered higher annual incidence rate (per 100 000) for hospital admissions due to respiratory reasons. Regarding children, infant mortality is quite low, especially when taking into account cause-specific mortality.

Table 3. Descriptive statistics for health outcomes in Lisbon (2002)

Health outcome	ICD9	ICD10	Annual deaths	Annual rate (per 100 000)	Daily mean (SD)	Daily rate (per 100 000)	Annual incidence rate (per 100 000)
POSTNEONATAL MORTALITY							
Total			42	206,5			
Respiratory *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99	2	9,8			
Sudden infant death syndrome *ICD9 798.0 – ICD10 R95*	798.0	R95	3	14,7			
GENERAL POPULATION MORTALITY							
Total mortality all causes *ICD9 <800 ICD10 A00-R99*	<800	A00-R99			48,32 (10,76)	2,6	
Cardiovascular mortality *ICD9 390-459 ICD10 I00-I99*	390-459	I00-I99			21,3 (6,25)	1,7	
Respiratory mortality *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99			4,05 (2,39)	0,3	
MORBIDITY							
Cough					not available		
Lower respiratory symptoms LRS					not available		
Emergency room visits for asthma - Age < 18 years *ICD9 493, ICD10 J45 J46*	493	J45-J46			not available	not available	
Hospital respiratory admissions - Age < 15 years *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99					1404
Hospital respiratory admissions - Age 15 -64 years	460-519	J00-J99					381
Hospital respiratory admissions - Age > 64 years	460-519	J00-J99					2896

Health Impact Assessment

Methodology

Health impact of air pollution (AP) has been calculated as the annual number of health events attributable to AP in the target population. A causal relationship between AP and the effects is assumed, and therefore HIA can only be performed for those outcomes with sufficient evidence of causality. Once the effects with sufficient evidence of causal relationship with AP have been determined, the next step is to find the best exposure-response functions (ERFs) for each of the selected outcomes. Table 4 shows the result of a systematic review on these issues carried out by the Bilbao Apheis team[1] for WP5 of ENHIS-1. This table summarizes the health outcomes and ERFs deemed suitable for HIA according to the criteria established by WP5 with the advice of the air pollution experts of WP5[2].

[1] Cambra K, Alonso E, Cirarda FB, Martínez-Rueda T. Bilbao APHEIS group. Selection of outcomes and exposure response functions for health impact assessment of particles and ozone. Review of the evidence. ENHIS project. WORK PACKAGE 5. Bilbao, February 2005. Http:

[2] Ferran Ballester: Valencian School of Health Studies, Valencia, Spain; Sylvie Cassadou: National Institute of Public Health Surveillance, InVS, Toulouse, France; Fintan Hurley: Institute of Occupational Medicine, Edinburgh, Scotland, UK; Nino Künzli: University of Southern California, Division of Occupational and Environmental Health, Los Angeles, CA, USA; Odile Meckel: Institute of Public Health NRW (LOEGD), Bielfeld, Germany; Hans-Guido Mücke: WHO Collaborating Center (Air)-Federal

Table 4. Health outcomes and Exposure-response functions (ERFs) selected for health impact assessment

	OUTCOME	POLLUTANT	ERFs	ORIGINAL SOURCE
CHILDREN - PARTICLES				
	Total postneonatal mortality (1 month-1 year)	PM_{10} Annual Mean	RR=1.048 (1.022-1.075) ↑10µg/m^3	Lacasaña et al 2005
	Postneonatal respiratory mortality ICD9 460-519 ICD10 J00-J99	PM_{10} Annual Mean	RR=1.216 (1.102-1.342) ↑10µg/m^3	Lacasaña et al 2005
	Postneonatal Sudden Infant Death Syndrome (SIDS) mortality (normal birth weight ≥2500g) ICD9 798.0 –ICD10 R95	PM_{10} Annual Mean	Adjusted Odds Ratio AOR=1.12 (1.07-1.17) ↑10µg/m^3	Woodruff et al. 1997
	Cough	PM_{10} Daily Mean	OR=1.041 (1.020-1.062) ↑10µg/m^3	Ward & Ayres 2004
	Lower respiratory symptoms LRS	PM_{10} Daily Mean	OR=1.041 (1.020-1.051) ↑10µg/m^3	Ward & Ayres 2004
CHILDREN – OZONE				
	Emergency room visits for asthma <18 Y ICD9 493, ICD10 J45 J46	Ozone Maximum 1 h	RR=1.0116 (1.0067-1.0165) ↑10µg/m^3	CARB 2004
ADULTS/GENERAL POPULATION				
	Total mortality all causes ICD9 <800 ICD10 A00-R99	Ozone Maximum 8 h Summer	RR= 1.0031 (1.0017-1.0052) ↑10µg/m^3	Gryparis et al 2004 (APHEA 2)
	Respiratory mortality ICD9 460-519 ICD10 J00-J99	Ozone Maximum 8 h Summer	RR= 1.0113 (1.0074-1.0151) ↑10µg/m^3	Gryparis et al 2004 (APHEA 2)
	Cardiovascular mortality ICD9 390-459 ICD10 I00-I99	Ozone Maximum 8 h Summer	RR= 1.0046 (1.0022-1.0073) ↑10µg/m^3	Gryparis et al 2004 (APHEA 2)

To be coherent with mortality findings, it was decided, with the experts' advice, to include RRs of hospital admissions in the health impact assessment calculations, even if they were not statistically significant. More concretely, it was decided that if there was not any new RR published by the time of making the calculations, the RRs for respiratory hospital admissions from Anderson's meta-analysis could be used, although they were not statistically significant (see Table 3). The rationale for that is that if there is sufficient evidence to accept a causal relationship between air pollution and respiratory mortality -both in children-PM and adults-O_3- we should easily accept that there will also be an impact on hospital admissions.

Table 5. Complementary Exposure-response functions (ERFs) for health impact assessment on respiratory hospital admissions for children (particles) and adults (ozone)

	OUTCOME	POLLUTANT	RR	SOURCE
CHILDREN - PARTICLES				
	Respiratory hospital admissions 0-14 Y ICD9 460-519 ICD10 J00-J99	*PM_{10}* Daily Mean	*RR= 1.010 (0.998-1.021) ↑10µg/m^3*	*Anderson 2004*
ADULTS/GENERAL POPULATION				
	Hospital respiratory admissions 15-64 Y ICD9 460-519 ICD10 J00-J99	*Ozone Maximum 8 h*	*RR=1.001 (0.991-1.012) ↑10µg/m^3*	*Anderson et al 2004*

Environmental Agency, Berlin, Germany; Nikolaos Stilianakis: Institute for Environment and Sustainability, European Commission – JRC, Ispra, Italy.

	Hospital respiratory admissions >64 Y ICD9 460-519 ICD10 J00-J99	*Ozone Maximum 8 h*	*RR=1.005 (0.998-1.012) ↑10μg/m^3*	*Anderson et al 2004*

Finally, HIA needs defining the evaluation scenarios, i.e. the hypothetical scenario with which we want to compare the current air pollution situation. We calculate the impact on health of the (current) air pollution levels in the city that are above the pollution level of the evaluation scenario. In other words, the attributable number of health events (deaths, hospital admissions…) calculated for each scenario represents the number of events that would be prevented if, all other things being equal, air pollution levels were reduced to the evaluation scenario level. These evaluation scenarios are based on the objectives and limits established in 1999/30/CE, and 2002/3/CE Directives.

HIA scenarios

1 - HIA scenarios for PM_{10}

1.1.- Scenarios for HIA on **short-term** effects of PM_{10} and **cough, lower respiratory symptoms** in people under 18 year (<18), and **hospital respiratory admissions** in people under 15 year (< 15)

1.1.1 Reduction of PM_{10} levels to a 24-hour value of **50 μg/m^3** in all days exceeding this value (Limit of 1999/30/CE Directive)

1.1.2. Reduction of PM_{10} levels to a 24-hour value of **20 μg/m^3** in all days exceeding this value

1.1.3 Reduction **by 5 μg/m^3** of all the 24-hour values

1.2.- Scenarios for HIA on **long-term** effects of PM_{10} and **postneonatal mortality** (total, respiratory and sudden infant death syndrome-SIDS)

1.2.1 Reduction of the annual mean value of PM_{10} to a level of **40 μg/m^3** (Limit of 1999/30/CE Directive for 2005)

1.2.2 Reduction of the annual mean value of PM_{10} to a level of **20 μg/m^3** (Limit of 1999/30/CE Directive for 2010)

1.2.3 Reduction **by 5 μg/m^3** of the annual mean value of PM_{10}

2.- HIA scenarios on short-term effects of Ozone

1.2.1 Daily maximum 1-hour concentration and **emergency room visits for asthma** in people under 18 year (< 18)

1.2.1.1 Reduction of O_3 daily maximum 1-hour concentrations to a level of **180 μg/m^3** in all days exceeding this value (Information threshold of 2002/3/CE Directive)

1.2.1.2 Reduction **by 10 μg/m^3** of the daily maximum 1-hour concentrations

1.2.2 Daily maximum 8-hour moving average concentration and **mortality** in general population

1.2.2.1 Reduction of O_3 daily maximum 8-hour moving average concentrations to **120 μg/m^3** in all days exceeding this value (Limit for health protection of 2002/3/CE Directive)

1.2.2.2 Reduction **by 10 μg/m^3** in the daily maximum 8-hour moving average concentrations.

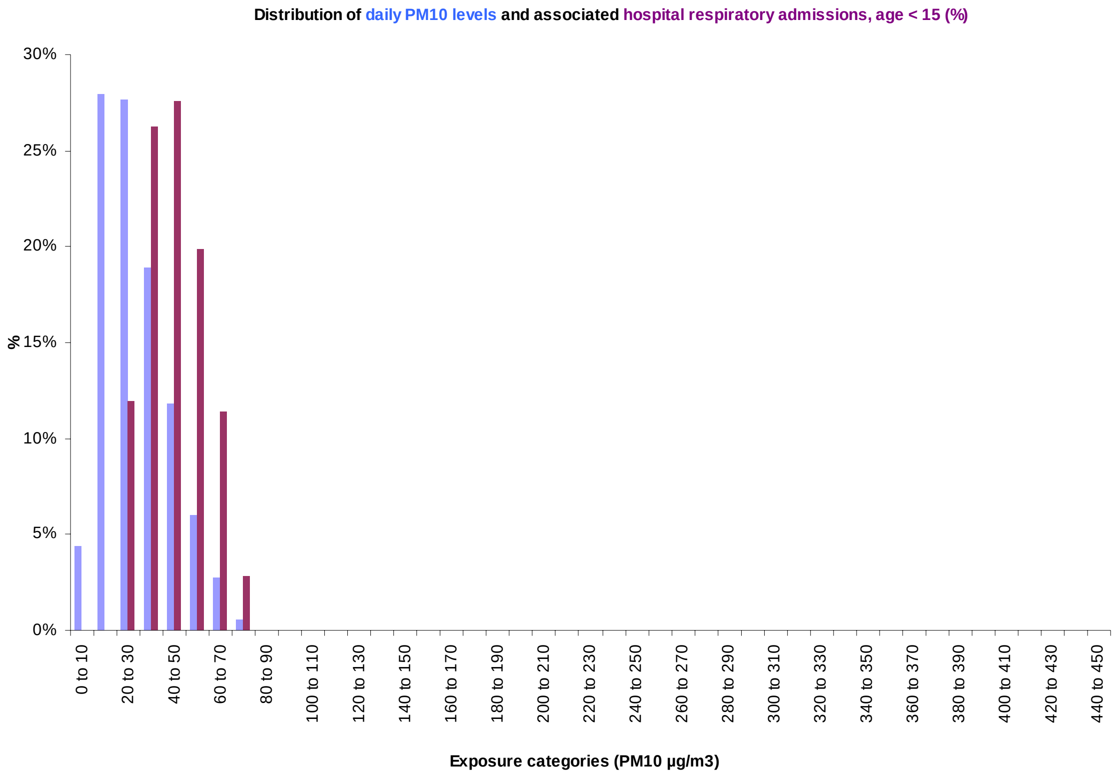
Findings

The annual number of postneonatal deaths attributable to PM_{10} levels higher than 20 µg/m^3 was 2,32 (95%CI: 1,06 – 3,64), which is equivalent to an annual rate of 11,40 deaths per 100 000 (95%CI: 5,21-17,89).

Table 6. Potential benefits of reducing PM_{10} levels. Absolute numbers and rates (per 100 000 children) (95% confidence limits) attributable to the health effects of PM_{10}.

	PM_{10} reduction	**Number of attributable cases per year**	**Annual rates (per 100.000)**
POSTNEONATAL MORTALITY	**Annual mean levels**		
Total	by 5 µg/m^3	0,97 (0,45-1,51)	4,36 (2,21-7,42)
	to 20 µg/m^3	2,32 (1,06-3,64)	11,40 (5,20-17,89)
	to 40 µg/m^3	0,00 (0,00-0,00)	0,00 (0,00-0,00)
Respiratory	by 5 µg/m^3	0,19 (0,09-0,29)	0,93 (0,44-1,42)
	to 20 µg/m^3	0,42 (0,2-0,68)	2,06 (0,98-3,34)
	to 40 µg/m^3	0,00 (0,00-0,00)	0,00 (0,00-0,00)
SIDS	by 5 µg/m^3	0,17 (0,10-0,23)	0,83 (0,49-1,13)
	to 20 µg/m^3	0,39 (0,22-0,55)	1,92 (1,08-2,70)
	to 40 µg/m^3	0,00 (0,00-0,00)	0,00 (0,00-0,00)
MORBIDITY	**Daily levels**		
Cough <18 y	by 5 µg/m^3	not available	not available
	to 20 µg/m^3	not available	not available
	to 50 µg/m^3	not available	not available
LRS <18 y	by 5 µg/m^3	not available	not available
	to 20 µg/m^3	not available	not available
	to 50 µg/m^3	not available	not available
Hospital respiratory admissions <15 y	by 5 µg/m^3	18,98 (-3,81-39,76)	6,83 (-1,37-14,31)
	to 20 µg/m^3	41,21 (-8,7-87,27)	14,84 (-2,94-31,41)
	to 50 µg/m^3	3,17 (-0,63-6,67)	2,16 (-0,43-4,56)

Fig. 4 shows the distribution of daily PM_{10} levels and associated percentage of cases. Bearing in mind the existing association between PM_{10} levels and hospital respiratory admissions for children (< 15 years) shown in the graphic, it might be suggested that measures that attempt to lower the air pollution levels throughout the whole year would have a positive impact in terms of public health. Apparently, that impact would be more beneficial than taking measures that only focus on a few days with the highest concentrations.



Regarding short-term effects of O_3, each reduction by 10 µg/m^3 of daily maximum 8-hour moving average concentrations would delay 26,84 (95%CI: 14,72 – 45,01) deaths per year in the study area, 17,37 (95%CI: 8,31 – 27,57) from cardiovascular diseases, and 7,75 (95%CI: 5,08 – 10,36) from respiratory causes.

Table 7. Potential benefits of reducing ozone daily levels. Absolute numbers and rates (per 100 000 inhabitants) (95% confidence limits) attributable to the health effects of ozone.

	OZONE reduction	**Number of attributable cases per year**	**Annual rates (per 100.000)**
MORTALITY	**Daily 8-h max**		
Total excluding external causes	by 10 µg/m^3	26,84 (14,72-45,01)	1,42 (0,78-2,38)
	to 120 µg/m^3	1,83 (1,00-3,08)	0,10 (0,05-0,16)
Cardiovascular	by 10 µg/m^3	17,37 (8,31-27,57)	0,92 (0,44-1,46)
	to 120 µg/m^3	1,21 (0,58-1,92)	0,06 (0,03-0,10)
Respiratory	by 10 µg/m^3	7,75 (5,08-10,36)	0,41 (0,27-0,55)
	to 120 µg/m^3	0,58 (0,38-0,78)	0,03 (0,02-0,04)
MORBIDITY	**Daily 1-h max**		
Emergency room visits for asthma <18 y	by 10 µg/m^3	not available	not available
	to 180 µg/m^3	not available	not available
	Daily 8-h max		
Hospital respiratory admissions 15-64 y	by 10 µg/m^3	2,50 (-22,46-29,94)	0,19 (-1,71-2,28)
	to 120 µg/m^3	0,17 (-1,48-2,01)	0,01 (-0,11-0,15)
Hospital respiratory admissions > 64 y	by 10 µg/m^3	20,99 (-8,40-50,38)	7,01 (-2,81-16,84)
	to 120 µg/m^3	1,47 (-0,58-3,54)	0,49 (-0,19-1,18)

NA: Not applicable if air pollution levels are lower than the scenario level

Discussion

In the year 2002, according to the HIA, if the 135 days with daily 8-hour maximum ozone levels were reduced by 10 $\mu g/m^3$, the consequent benefit of short-term effect would be roughly 26 deaths for the general population (or 1,42 deaths per 100 000 inhabitants). The corresponding reduction in excess cases for hospital admissions due to respiratory reasons for elder people (> 64 years) would be around 20 people.

Regarding children, if the levels of PM_{10} during the whole year 2002 had been reduced to 20 $\mu g/m^3$, the benefit of long-term effect would be around two postneonatal deaths (including all causes). The reduction in hospital admissions for respiratory causes (< 15 years) would be of about 41 children.

This scenario would be of particular interest from a public health point of view, despite the fact that the annual level of 20 $\mu g/m^3$ for PM_{10} is only mandatory by the year 2010. Portugal suffers from the influence of particles coming from natural sources (sea salt, dust from the desert, forest fires) and traffic sources (direct and resuspension), which makes it more difficult to comply with this limit.

Comparing the number of attributable cases when reducing annual PM_{10} levels by 5 $\mu g/m^3$ or to 20 $\mu g/m^3$, shows the greater impact that the latter situation would have on public health, in the terms of hospital admissions for respiratory reasons.

Concerning compliance with EC Directive limits, in 2002 the annual mean level of PM_{10} was 32 $\mu g/m^3$, below the limit value established for that year (55 $\mu g/m^3$). There was compliance with the daily mean level for 2002 (65 $\mu g/m^3$). But if we consider the daily limit value established for 2005 in the 1999/30/EC Directive (50 $\mu g/m^3$), in the year 2002, there were 54 values above 50 $\mu g/m^3$, which means there were more exceedences than the 35 permitted and 278 values above the limit value established for 2010 (20 $\mu g/m^3$).

Regarding ozone concentration in 2002, there were 7 values above the target value for the protection of human health established for 2010 in the 2002/3/EC Directive (120 $\mu g/m^3$, not to be exceeded more than 25 days per calendar year averaged over three years). There was only one 1-hour average value above the information threshold (180 $\mu g/m^3$).

It is important to mention that the stations used for this study were background stations and exceedences occurred mainly in traffic stations. This would give us a different perspective of what is necessary to do in what air quality and public health concerns.

When there is inconformity with the limit-values, the existing legislation imposes the development and implementation of a set of policies and measures that should permit, as soon as possible, the compliance with those limit-values and also the protection of human health. The legislation foresees as well the development of plans and measures that allow the maintenance of good levels of air quality (CCDR-LVT & FCT/UNL, 2005).

An important limitation of this HIA that should be considered is the fact that, in 2002, two out of five air monitoring stations for ozone and two of the three stations for PM_{10} only started working in September/October of that year. This means that in some cases a whole year of data wasn't available. Nevertheless, having analysed the data for those specific stations, one can assume that those data are consistent with the rest of the stations.

For this reason, it is not possible to compare these values with previous years because these stations started to monitor air quality by the end of 2001 and in the beginning of 2002.

Once more, it is important to emphasise that the stations used for this study were background stations and exceedences for PM_{10} occurred mainly in traffic stations.

Regarding morbidity data, the portuguese registry system is based on total hospital admissions (excluding emergencies), referring to discharges from hospitals of the National Health Service and are collected annually. Therefore, a margin of error should be considered when taking into account data that are related to certain periods of the year, such as "summer hospital admissions".

Air quality in Lisbon will continue to be studied by health and environment institutions and other sectors of civil society, in order to get a better identification of the pollution sources (Lisbon is not an homogeneous area), which will allow to better assess the effective measures for intervention. These measures will enable the improvement of the air quality in the city and the promotion of public health.

Some policy reports, such as the National Environmental Health Action Plan (NEHAP) and the National Programme on Environmental Health are being developed. The air quality is one of the main areas of interest and special attention to children will be given.

Some tools, such as the air quality forecast system, are also being implemented in order to inform public about air quality. This system that is still in its testing phase, allows to predict the ozone and NO_2 concentrations in the air, and soon will be applied for other pollutants such as particles. This forecast system is also a good communication tool due to the simple colour scale used that is of easy understanding.

Conclusions

This report shows that even small reductions in air pollution levels would have an impact on public health, which means that it is worthwhile to take actions in order to reduce these levels.

It was the first time that a HIA was developed in Lisbon and for that reason there were some limitations to the study, as mentioned before. Nevertheless, this can be a good starting point in order to more efficiently manage health problems related to air quality. Current results of this health impact assessment could be a useful tool in policy decision making for the different actors involved in air pollution management.

It would be interesting to carry on with this HIA for the next years, in order to acquire a historic evolution of the situation in this study area and to evaluate the impact of certain preventive measures that may be put in practice by the responsible institutions. Decisions on air quality management should take into account public health aspects.

Further steps should be adopted in order to reduce air pollution from traffic sources. Reducing traffic emissions requires a behaviour modification, and one of the ways of obtaining it is to objectively inform people about the effects of air pollution.

There is also much interest in assessing the health impact of ozone, especially during the summer season and in the context of studies which evaluate the role of climatic conditions, namely heat waves.

The communication to the general public has now to be developed in order to help them understand personal issues of the public decisions. It is of vital importance to inform inhabitants of the city about air quality and its impact on public health.

A set of measures needs to be implemented for the reduction of pollutant emissions, and more generally to make every inhabitant of the study area more aware of the potential health effects of air pollution and how they can modify their behaviour in order to participate in the improvement of air quality in Lisbon.

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