HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

ENHIS-1 PROJECT: WP5 HEALTH IMPACT ASSESSMENT

LOCAL CITY REPORT

ATHENS

Summary of main findings for Athens

In 2001 the PM_{10} annual mean (SD) was 67.8 (25.0) µg/m^3, above the 1999/30/EC Directive limit value for 2010 (20 µg/m^3), and above 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 109.0 (21.7), 74.4 and 146.5 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 9 total postneonatal deaths.

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 42 deaths per year in the general population in the study area, 31 from cardiovascular diseases, and 11 from respiratory causes.

Summary of HIA of outdoor air pollution in Athens 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	41.92	
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.0046 (1.0022-0.0073)		30.97	
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.0113 (1.0074-1.0151)		11.66	
Total postneonatal mortality	1 month-1 year	Corrected PM_{10}[3]	Year	Annual	1.048 (1.022-1.075)	Lacasaña et al 2005		1.09
Postneonatal respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.216 (1.102-1.342)			1.40
Postneonatal Sudden Infant Death Syndrom Mortality (ICD9 798.0 - ICD10 R95)					1.12 (1.07-1.17)	Woodruff 1997		0.11
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
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		not available
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	15 - 64 years	**O_3 8h max**	Summer		1.001 (0.991-1.012)		not available	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	> 64 years				1.005 (0.998-1.012)		not available	

[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

The city of Athens has a population of more than 3 million inhabitants, 15% of whom are over 65 years old. Athens lies in a valley totaling 350 km^2 surrounded by three mountains and the sea. The major axis of the valley runs from the north-east to the south-west for about 30 kilometers. Most industries lie close to the sea and the harbor of Piraeus in the south-western part of the city. The climate of Athens is typically Mediterranean. The mean daily temperature during the winter months is 9.9 ^{o}C and the minimal daily temperature falls below zero only few times per year. During the summer months the mean daily temperature is 25.8^{o}C and the mean value of the maximum daily temperature slightly exceeds 31 ^{o}C. Insolation is strong with average daily values on the order of 22 MJm^{-2} in the summer and 8 MJm^{-2} in the winter. The prevailing wind direction is north-north-east at the end of summer, in autumn and in the winter and south-south-west in spring and the beginning of the summer.

Because of the topography, the climate and the size of the population, air pollutants easily reach high concentrations in the Athens Basin. The main problems are the high ozone and particles concentrations.

Main causes of mortality in Greece for the general population are diseases of the circulatory system and malignant neoplasms whereas for children are conditions originating in the perinatal period and congenital anomalies. Since almost 30% of the Greek population is living in the Athens area, it is expected that the same pattern of mortality is followed.

In previous APHEIS health impact assessment we estimated that if the long-term PM_{10} pollution reduced to an annual mean value of 40 μg/m^3, 3068 deaths could have been avoided in the year 2001.In this report we will present the long-term effects of PM_{10} on postneonatal mortality (total, respiratory and sudden infant death syndrome) considering three scenarios in reducing PM_{10} levels as well as two scenarios in reducing daily maximum 8-hour moving average concentration and the short term effects on mortality in general population.

This work has been carried out within the framework of work package WP5 on health impact assessment of ENHIS-1 project (www.enhis.net).

Sources of air pollution

The main sources of air pollution are traffic, heating (in the winter) and industrial activity. The Ministry of Environment, Planning and Public Works, Division of Air Pollution and Noise Control (PERPA) indicates that about 70% of PM_{10} comes from vehicles (a large proportion from diesel-powered) and 30% from heating/industry.

Exposure data

The Ministry of Environment, Planning and Public Works has been responsible for monitoring air pollution in the Athens area since 1982. The monitoring network has recently been restructured and modernized and since year 2000, PM_{10} concentration is measured on a daily basis. For the year 2001 we used PM_{10} measurements from six station: Aristotelous (traffic), Goudi (traffic), Lykovrisi (suburban), Marousi (traffic), Peiraias (traffic) and Zografou (suburban background). For ozone, fourteen stations were used: Athinas (traffic), Geoponiki (suburban industrial), Liosia (suburban background), Lykovrisi (suburban), Marousi (traffic), Nea Smirni (urban background), Patission (traffic), Peiraias (urban background), Peristeri (urban background), Ag. Paraskeui (suburban background), Galatsi (urban background), Elefsina (suburban industrial), Zografou (suburban background) and Thrakomakedones (suburban background).

Ozone was measured using ultraviolet absorption and PM_{10} using beta attenuation (correction factor for automatic measurements of PM_{10} was 1.3).

Daily exposure indicator for PM_{10} has been calculated as the arithmetic mean of the daily concentrations of the stations. For 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 Athens was 67.8 (25.0) µg/m^3, and P5 and P95 of the daily mean values were, respectively, 32.3 µg/m^3 and 112.7 µg/m^3. The mean (SD) , P5 and P95 of the daily maximum 8hour moving average concentrations of O_3 were, respectively, 109.0 (21.7), 74.4 and 146.5 µg/ m^3, and those of the daily maximum 1-hour concentrations 101.0 (37.4), 49.2 and 164.3 µg/m3 (Table 1 and figures 1-3).

The E.C. directive for PM_{10} is asking for a gradual decrease of concentrations which should reach 40 mg/m3 for 2005. For the year 2001 the limit was 70 mg/m3 (to be exceeded less than 35 days) which is close to the median concentration in our data meaning that this value was exceeded about 45% of the days. The ozone limit value (120 mg/m3 to be exceeded less than 20 days) is very close to the 75th percentile of ozone distribution which implies that for about 25% of the days this value was exceeded. Distribution of ozone and PM_{10} levels is presented in figures 1,2 and 3.

Table 1. Descriptive statistics for ozone and PM_{10} levels in Athens, 2001.

	O3 8h - summer	O3 1h max - year	PM10 - year
Number	183	365	365
Minimum	63.1	33.0	11.4
Percentile 5	74.4	49.2	32.3
Percentile 25	93.4	72.7	49.8
Median	106.9	98.0	64.6
Percentile 75	123.4	123.8	81.5
Percentile 95	146.5	164.3	112.7
Percentile 98	157.1	194.3	127.0
Maximum	174.3	235.8	169.2
Daily mean	109.0	101.0	67.8
standard error	21.7	37.4	25.0
% missing values	0.0%	0.0%	0.0%

Fig. 1 Distribution of daily O3 8h max in Athens, summer 2001

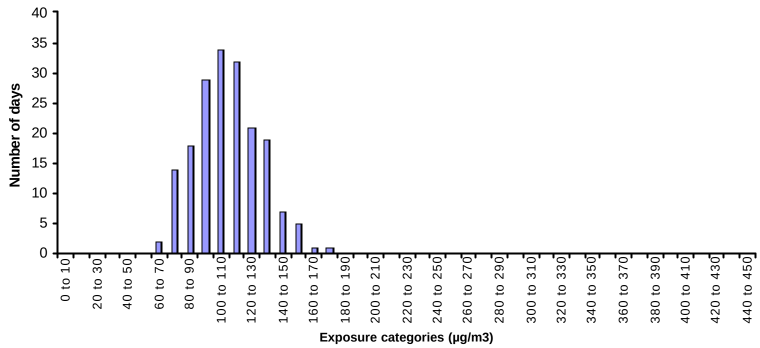


Fig. 2 Disrtibution of daily O3 1h max in Athens, 2001

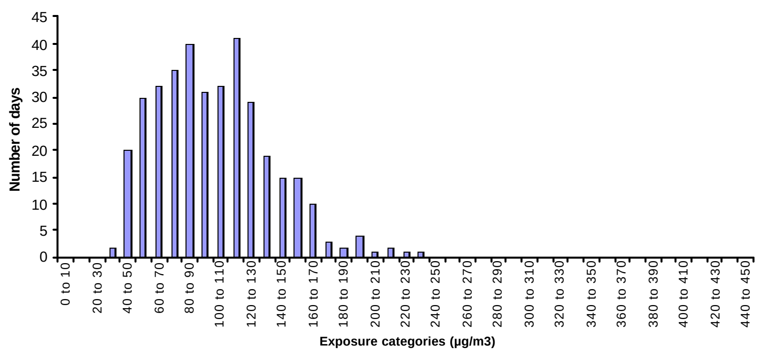
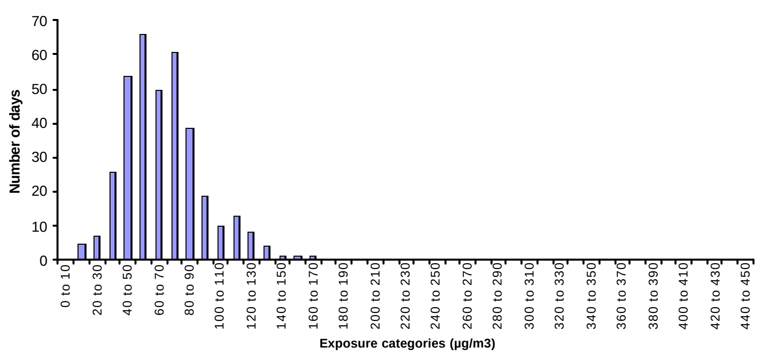


Fig. 3 Disrtibution of daily PM 10 in Athens, 2001



Health data

All cause and cause-specific mortality data for 2001, were provided by the National Statistical Service of Greece, following a specific request. Hospital admission data and other morbidity indicators are not collected in Greece on a regular basis.

In Athens area, we had 47 postneonatal deaths in 2001. 15 of them were related with respiratory causes and 2 were due to sudden infant syndrome. In the same area, the daily mean number (SD) of total mortality (all ages) was 76 (11), of cardiovascular mortality was 38 (8) and of respiratory mortality was 6 (3).

Table 2. Descriptive statistics for health outcomes in Athens, 2001

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			47	153.6*			
Respiratory *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99	15	49*			
Sudden infant death syndrome *ICD9 798.0 – ICD10 R95*	798.0	R95	2	6.5*			
GENERAL POPULATION MORTALITY							
Total mortality all causes *ICD9 <800 ICD10 A00-R99*	<800	A00-R99			76 (11.0)	2.11	
Cardiovascular mortality *ICD9 390-459 ICD10 I00-I99*	390-459	I00-I99			38 (7.6)	1.2	
Respiratory mortality *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99			6 (2.8)	0.2	
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					not available
Hospital respiratory admissions - Age 15 -64 years	460-519	J00-J99					not available
Hospital respiratory admissions - Age > 64 years	460-519	J00-J99					not available

* this is an approximation because the population data used is 0-1year (not 1month-1year)

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 3 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].

Table 3. 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 2). 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.

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

Table 4. Complementary Exposure-response functions (ERFs) for health impact assesment 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/m³*	*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/m³*	*Anderson et al 2004*
	Hospital respiratory admissions >64 Y ICD9 460-519 ICD10 J00-J99	*Ozone Maximum 8 h*	*RR=1.005 (0.998-1.012) ?10µg/m³*	*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/m³** 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/m³** in all days exceeding this value

1.1.3 Reduction **by 5 µg/m³** 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/m³** (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/m³** (Limit of 1999/30/CE Directive for 2010)

1.2.3 Reduction **by 5 µg/m³** 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 ?g/m^3 was 9 (95%CI: 4 – 15), which is equivalent to an annual rate of 0.3 deaths per 100 000 (95%CI: 0.1-0.5).

Table 5. 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}.

	PM10 reduction	**Number of attributable cases per year**	**Annual rates (per 100.000)**
POSTNEONATAL MORTALITY	**Annual mean levels**		
Total	by 5 µg/m^3	1.09 (0.50-1.69)	0.03 (0.02-0.05)
	to 20 µg/m^3	9.42 (4.11-15.49)	0.30 (0.13-0.49)
	to 40 µg/m^3	5.73 (2.57-9.17)	0.18 (0.08-0.29)
Respiratory	by 5 µg/m^3	1.40 (0.68-2.16)	0.04 (0.02-0.07)
	to 20 µg/m^3	9.11 (3.48-18.13)	0.29 (0.11-0.57)
	to 40 µg/m^3	6.28 (2.70-11.01)	0.20 (0.08-0.35)
SIDS	by 5 µg/m^3	0.11 (0.07-0.15)	0.003 (0.002-0.005)
	to 20 µg/m^3	0.84 (0.45-1.30)	0.03 (1.41-4.08)
	to 40 µg/m^3	0.54 (0.30-0.80)	0.02 (0.94-2.51)
MORBIDITY	**Daily levels**		
Cough <18 y	by 5 µg/m^3	not available	not available
	to 20 µg/m^3	-	-
	to 50 µg/m^3	-	-
LRS <18 y	by 5 µg/m^3	-	-
	to 20 µg/m^3	-	-
	to 50 µg/m^3	-	-
Hospital respiratory admissions <15 y	by 5 µg/m^3	-	-
	to 20 µg/m^3	-	-
	to 50 µg/m^3	-	-

Regarding short-term effects of O_3, each reduction by 10 μg/m^3 of daily maximum 8-hour moving average concentrations would delay 42 (95%CI: 23 - 70) deaths per year in the study area, 31 (95%CI: 15 - 49) from cardiovascular diseases, and 11 (95%CI: 7 - 16) from respiratory causes.

Table 6. 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	41.92 (22.99-70.32)	1.31 (0.72-2.21)
	to 120 μg/m^3	19.58 (10.72-32.89)	0.61 (0.34-1.03)
Cardiovascular	by 10 μg/m^3	30.97 (14.81-49.15)	0.97 (0.46-1.54)
	to 120 μg/m^3	14.72 (7.03-23.40)	0.46 (0.22-0.73)
Respiratory	by 10 μg/m^3	11.66 (7.63-15.58)	0.37 (0.24-0.49)
	to 120 μg/m^3	5.99 (3.91-8.03)	0.19 (0.12-0.25)
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	-	-
	Daily 8-h max		
Hospital respiratory admissions 15-64 y	by 10 μg/m^3	-	-
	to 120 μg/m^3	-	-
Hospital respiratory admissions > 64 y	by 10 μg/m^3	-	-
	to 120 μg/m^3	-	-

Discussion

In 2001 E.C. standards for both PM_{10} and ozone have been exceeded. The fact that 5 out of six monitoring stations for PM_{10} are characterized as "traffic" could be one reason for this, since about 70% of PM_{10} is related to traffic. On the other hand the climate is an important factor in favor of high ozone concentrations.

HIA results show significant benefits in preventing early mortality by reducing both PM_{10} and ozone levels. Specifically, reduction of PM_{10} levels to 40 μg/m3 (EC limit value for 2005) could prevent 6 premature postneonatal deaths, which is about 13% of total postneonatal deaths and 40% of respiratory postneonatal deaths in 2001. For ozone, a reduction by 10 μg/m3 could prevent 42 premature deaths in total, 31 due to cardiovascular and 11 due to respiratory causes.

Conclusion

Athens has difficulty in reaching the E.C. regulated standards for both PM_{10} and ozone. Due to the topography and climate, relatively low level of emission results in relatively high air pollution. However, in recent years there is a policy to reduce the use of private cars and improve the quality of fuel. Reduction of the pollutant levels to the E.C. standards will prevent a considerable number of premature deaths.

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