HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

ENHIS-1 PROJECT: WP5 HEALTH IMPACT ASSESSMENT

LOCAL CITY REPORT

Vienna, Austria

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Summary of main findings for Vienna

In 2002 the PM_{10} annual mean (SD) was 30 (17.3) 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 89.9 (22.1), 43.2 and 120.8 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 4.8 total postneonatal deaths. Reducing PM_{10} daily mean values to 20 µg/m^3 would further prevent 106 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 24.3 deaths per year in the general population in the study area, 19 from cardiovascular diseases, and 4.1 from respiratory causes. In terms of hospital admissions, this would represent 7 respiratory admissions in the adult population (between 15 and 64 years of age) and 22.7 in the population over 65 years.

Summary of HIA of outdoor air pollution in Vienna 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	24.3	
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.0046 (1.0022-0.0073)		19	
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.0113 (1.0074-1.0151)		4.1	
Total postneonatal mortality	1 month- 1 year	Corrected PM_{10}[3]	Year	Annual	1.048 (1.022-1.075)	Lacasaña et al 2005		1.7
Postneonatal respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.216 (1.102-1.342)			0
Postneonatal Sudden Infant Death Syndrom Mortality (ICD9 798.0 - ICD10 R95)					1.12 (1.07-1.17)	Woodruff 1997		0.4
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		43.4
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	15 - 64 years	**O_3 8h max**	Summer		1.001 (0.991-1.012)		7	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	> 64 years				1.005 (0.998-1.012)		22.7	

[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

- Vienna is the capital of Austria. With its population of approx. 1.5 Mio it lies at the eastern and of the Alps. In the west it is surrounded by the hills of the Vienna Woods but in the east the land opens to the Pannonian Basin. This enables a good mixing of air on most days. Air pollution episodes with high particulate matter are mostly observed in winter with inversion or with masses of air transport from industrial centers in South-Eastern Europe. Ozone peaks on hot summer days in the outskirts of Vienna.
- This work has been carried out within the framework of work package WP5 on health impact assessment of ENHIS-1 project (www.enhis.net).
- In this report we present HIA results in children for PM10 as was decided in the ENHIS coordinating meeting. Additionally the impact of ozone is studied for the general population.
- This is the first time Vienna takes part in the APHEIS network. Therefore we also performed a HIA for the total population based on the PM_{10} and health data of the year 2002. All other things being equal, the reduction of the annual average levels of PM_{10} by only 5 µg/m^3 (to 25 µg/m³) would prevent 335 (204 – 474) premature deaths. Reducing PM_{10} daily mean values of those days that surpass the current limit value of 50 µg/m³ to that value would only prevent 17.3 (11.5 – 23.1) deaths (additionally). Further on this would prevent 67.4 hospital respiratory admissions.

Sources of air pollution

PM_{10} daily mean values exceed the limit value of the European Union (50 µg/m³) at most monitoring sites for at least some days. On the other hand the annual mean value is at al sites is below the limit value (40 µg/m³). There is no clear trend in PM air pollution in Vienna. Until 2003 the PM concentrations seemed to increase but 2004 again saw lower values so that the year 2003 must be considered an exceptional year with high pollution episodes due to special weather situations. If the frequency of exceptionally high pollution episodes will increase with the continuing climate change is still controversial.

High pollution days are linked to certain weather scenarios that cannot be influenced by local measures. Therefore the city cannot sufficiently reduce short term high pollution peaks while a moderate reduction of the everyday local emission of PM seems feasible.

The Viennese EPA (MA 22, 2005) estimates that on high pollution days 60% of the PM pollution at background stations is derived from foreign sources and only 25% originate in Vienna. But on top of these background exposure a considerable local impact is seen at curbside stations and at the stations located in the vicinity of industries (e.g. Liesing, see figure 1a).

Exposure data

- Air pollution data were provided by the Viennese EPA. Before 2002 particulate matter was principally measured as TSP and only in 2002 routine PM_{10} monitoring was introduced. The first monitoring sites that were operated throughout the whole year of 2002 were situated in Liesing (at an industrial site) and on Schafberg (in the outskirts of Vienna). So both sites are not representative for the population exposure. In the following years a good temporal correlation between Liesing and the sites located in urban living areas (Gaudenzdorf, Belgradplatz) were observed, with Liesing exhibiting constantly higher values. So the daily PM_{10} values for 2002 the data from Liesing were used but applying a weighting factor based on the 2003 and 2004 comparison with the sites at Gaudenzdorf Belgradplatz.

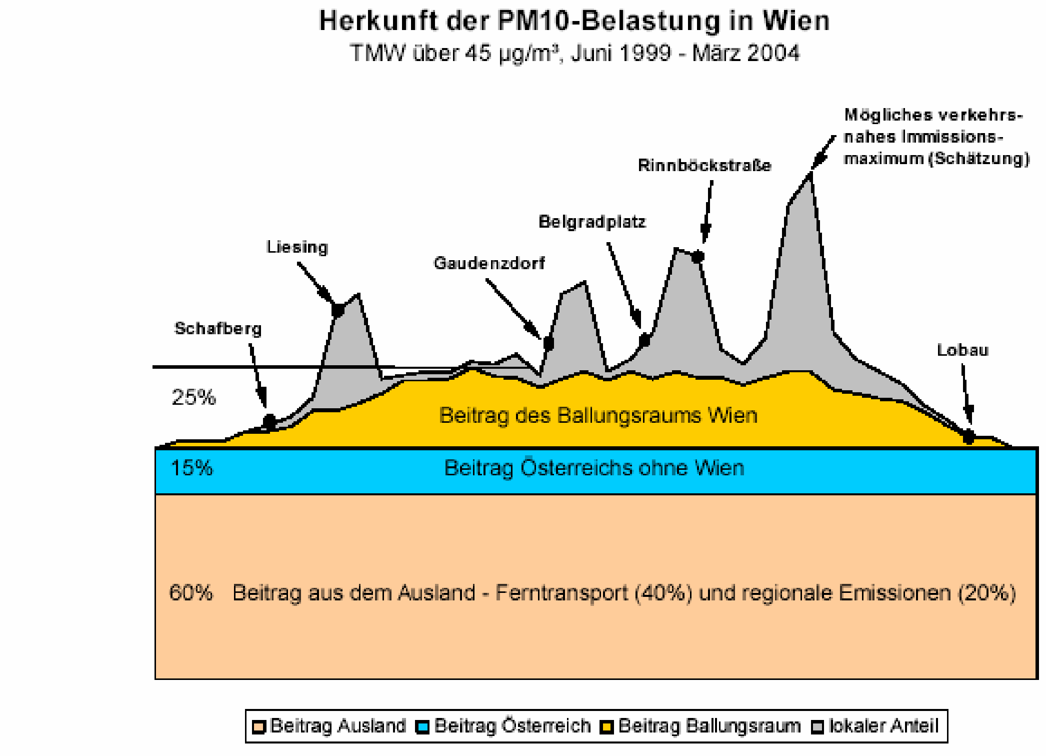


Figure 1a: Sources of PM10 on high pollution days in Vienna:

Foreign sources (near and far), Austrian, Viennese, and Local

- Ozone: There are several monitoring station for ozone in Vienna. Some are situated in the countryside outside the city where ozone levels are usually higher than in the living areas. Curbside stations on the other hand underestimate the true exposure. But generally speaking the spatial distribution of ozone is rather smooth. So it was decided that one monitoring station would be sufficient to represent the population exposure. For this purpose the monitoring station “Stephansplatz” was chosen which lies in the center of the city but is not influenced by local transport or industry (pedestrian zone). The daily maximum 1-hour indicator has been calculated for all days of the year while the daily maximum 8-hour moving average of each day was analyzed for the summer period (1st April to 30th September).
- AP data description: The annual mean level (SD) of PM_{10} in Vienna was 30 (17) µg/m^3, and P5 and P95 of the daily mean values were, respectively, 9 µg/m^3 and 65 µg/m^3. The mean (SD), P5 and P95 of the daily maximum 8-hour moving average concentrations of O_3 were, respectively, 90 (22), 43 and 121 µg/ m^3, and those of the daily maximum 1-hour concentrations 97 (25), 57 and 131 µg/m3 (Table 1 and figures 1-3).

A summary of the air pollution findings (ozone and PM_{10}) is provided in figures 1 –3 and in table 1. Concerning ozone the long-term objective for the protection of human health (maximum daily 8-hour mean of 120 µg/m³) was only exceeded in approx. 5% of all summer days while the Information threshold (1 hour average 180 µg/m³) was never reached.

Table 1. Descriptive statistics for ozone and PM_{10} levels in Vienna (2002)

	O3 8h - summer	O3 1h max - summer	PM10 - year
Number	182	182	365
Minimum	23.29	27.18	4.75
Percentile 5	43.19	57.37	9.14
Percentile 25	76.25	80.99	16.24
Median	94.09	100.21	25.18
Percentile 75	104.02	112.11	38.66
Percentile 95	120.83	131.10	65.44
Percentile 98	131.09	154.70	72.50
Maximum	137.78	170.95	87.40
Daily mean	89.86	96.96	29.59
standard error	22.05	25.17	17.33
% missing values	1	1	0

Fig. 1: Distribution of daily O3 8h max Vienna, summer 2002

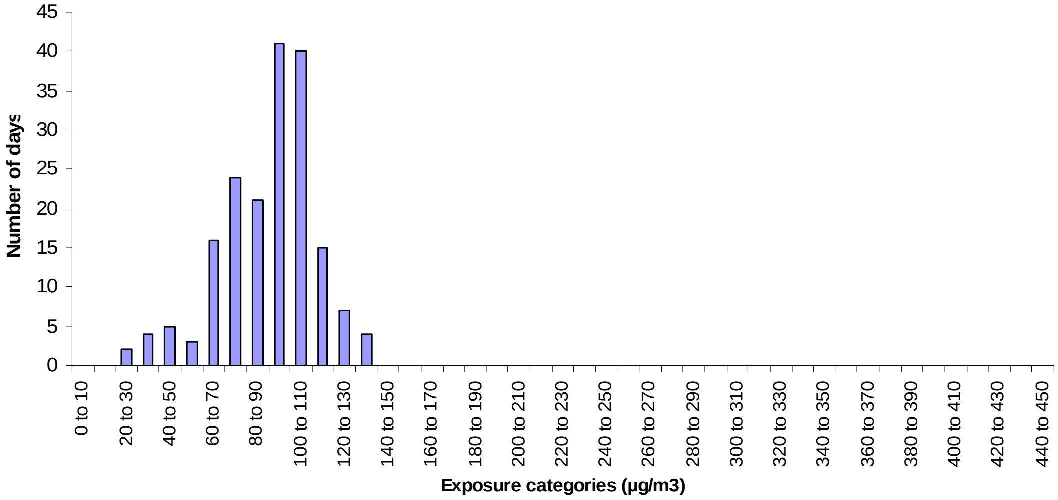


Fig. 2: Distribution of daily O3 1h max in Vienna, whole year 2002

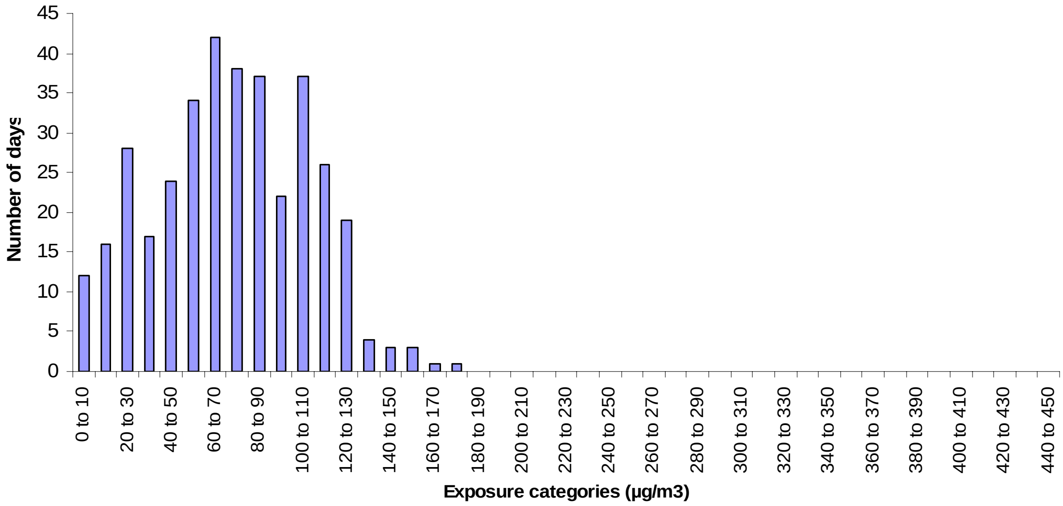
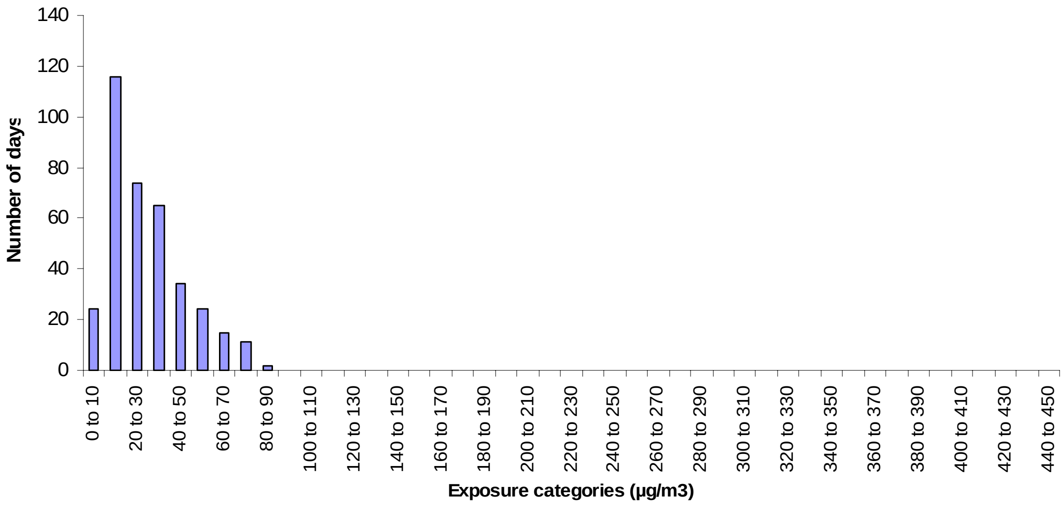


Fig. 3: Distribution of daily mean PM 10 in Vienna for 2002



Health data

- Mortality data per day with diagnoses (ICD 10) and per 5-year age-group were provided by *Statistics Austria*. The data source is based on death certificates and autopsy records and is of good quality.
- Hospital admissions (for respiratory diseases) were also obtained from Statistics Austria. Due to privacy reasons only admissions for the whole year (per 5-year age group) and no daily data were provided. The data are based on the reports from hospitals at discharge of the patients.
- Other health outcomes wee not available.

Mortality in the first year of life is generally low. No deaths due to respiratory causes were observed in 2002. On the whole 94 children died in the first year of life in 2002, 8 of which under the diagnosis of SIDS.

On average 44 people died in Vienna each day. The year 2002 exhibited a clear seasonality with the highest death rate in winter. More than 50% of all deaths are due to cardiocirculatory causes.

Table 2. Descriptive statistics for health outcomes in Vienna (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			94	600			
Respiratory	460-519	J00-J99	0	0			
Sudden infant death syndrome	798.0	R95	8	51			
GENERAL POPULATION MORTALITY							
Total mortality all causes	<800	A00-R99			44 (8.1)	2.8	
Cardiovascular mortality	390-459	I00-I99			24 (5.8)	1.5	
Respiratory mortality	460-519	J00-J99			2 (1.5)	0.1	
MORBIDITY							
Cough					not available	not available	
Lower respiratory symptoms LRS					not available	not available	
Emergency room visits for asthma - Age < 18 years	493	J45-J46			not available	not available	
Hospital respiratory admissions - Age < 15 years	460-519	J00-J99					3916
Hospital respiratory admissions - Age 15 -64 years	460-519	J00-J99					1314
Hospital respiratory admissions - Age > 64 years	460-519	J00-J99					3864

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].

[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 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.

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/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*
	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 3.2 (95%CI: 1.5 – 5.0), which is equivalent to an annual rate of 20.5 deaths per 100 000 (95%CI: 9.4 - 32).

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	2.5 (1.2 – 3.9)	10.8 (5.0 – 16.8)
	to 20 µg/m^3	4.8 (2.2 – 7.5)	20.5 (9.4 – 32.0)
	to 40 µg/m^3	N.A.	N.A.
Respiratory	by 5 µg/m^3	0	0
	to 20 µg/m^3	0	0
	to 40 µg/m^3	N.A.	N.A.
SIDS	by 5 µg/m^3	0.4 (0.2 – 0.6)	2.6 (1.5 – 3.6)
	to 20 µg/m^3	0.8 (0.4 – 1.1)	4.8 (2.8 – 6.8)
	to 40 µg/m^3	N.A.	N.A.
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	43.4 (-8.7 – 90.9)	19.1 (-3.8 – 39.9)
	to 20 µg/m^3	106.3 (-21 – 225.8)	46.6 (-9.2 – 99.1)
	to 50 µg/m^3	16.1 (-3.2 – 34.1)	7.1 (-1.4 – 15)

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	24.3 (13.3 – 40.7)	1.6 (0.9 – 2.6)
	to 120 µg/m^3	1.2 (0.6 – 2)	0.1 (0 – 0.1)
Cardiovascular	by 10 µg/m^3	19 (9.1 – 30.2)	1.2 (0.6 – 1.9)
	to 120 µg/m^3	0.9 (0.5 – 1.5)	0.1 (0 – 0.1)
Respiratory	by 10 µg/m^3	4.1 (2.7 – 5.5)	0.3 (0.2 – 0.4)
	to 120 µg/m^3	0.2 (0.1 – 0.3)	0
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	7 (-63.1 – 84.1)	0.7 (-5.9 – 7.8)
	to 120 µg/m^3	0.3 (-3 – 4)	0 (-0.3 – 0.4)
Hospital respiratory admissions > 64 y	by 10 µg/m^3	22.7 (-9.1 – 54.4)	9.3 (-3.7 – 22.2)
	to 120 µg/m^3	1.1 (-0.4 – 2.7)	0.5 (-0.2 – 1.1)

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

Regarding short-term effects of O_3, each reduction by 10 µg/m^3 of daily maximum 8-hour moving average concentrations would delay 24.3 (95%CI: 13.3 – 40.7) deaths per year in the study area, 19.1 (95%CI: 9.1 – 30.2) from cardiovascular diseases, and 4.1 (95%CI: 2.7 – 5.6) from respiratory causes.

Discussion

In the developed world urban air pollution accounts for approximately 1% of the total mortality (WHO, 2002) and thus there is the leading environmental burden of disease. Numerous studies from various continents have established the close link between air pollution and an even growing number of health problems ranging from increased number and severity of respiratory symptoms, adverse pregnancy outcomes, morbidity measures (e.g. hospital and emergency room admissions), lung cancer, and mortality (from cardiovascular and respiratory causes). Therefore it is no longer necessary to prove the impact of air pollution but to inform the public about its consequences and to propose and encourage abatement strategies.

No threshold has been found in epidemiological studies for the health effects of air pollution. Therefore a health impact assessment in every city will result in a certain number of attributable mortality and morbidity.

The particulate air pollution (which was not of key interest in this year's investigation of APHEIS) seems to have a greater impact on the health of the Viennese population than ozone. Although for PM10 only the limit value for the daily average and not for the annual average is exceeded in Vienna a moderate reduction of PM10 overthe whole year would yield better results than (less feasable) attemps to substantially reduce the exposure on high pollution days only to comply with the European limit values.

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Annex: figures from the all-cities report