HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

ENHIS-1 PROJECT: WP5 HEALTH IMPACT ASSESSMENT

LOCAL CITY REPORT

Rotterdam

Rotterdam Public Health Service

(Exposure data provided by DCMR Environmental Protection Agency)

Summary of main findings for Rotterdam

In 2003 the PM_{10} annual mean (SD) was 43.0 (11.0) 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 84.6 (21.1), 48.0 and 141.0 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 1.5 total postneonatal deaths.

Considering the general city population reduction of PM_{10} daily mean values to 20 µg/m^3 would delay 572 deaths per year (assuming all other things being equal). Reduction of the level in 2003 with 5 µg/m^3 would delay 129 deaths a year. In both cases 'delay' means dying a few (up to 10) years later.

Regarding short term effects of PM_{10} (within 40 days after exposure) 36 deaths would delay with a few months when PM10 levels would reduce with 5 µg/m^3, assuming all other factors do not change. In terms of hospital admissions, this would represent 37 respiratory admissions and 14 cardiovascular hospital admissions in the total population.

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 9 deaths per year in the general population in the study area, 5 from cardiovascular diseases and 4 from respiratory causes. In terms of hospital admissions, this would represent 3 respiratory admissions in the adult population (15-64 years) and 4 in the population over 64 years.

Summary of Health Impact Assessment of outdoor air pollution in Rotterdam in ENHIS-1

Health outcome	Population	Pollutant	Period	Mean type	RR (for 10 μg.m3 increase)	References	Number of attributable cases by scenario[1]	
Mortality							**Ozone: Reduction by 10 μg.m3**	**PM10: Reduction by 5 μg/m3**
Short term effects (0-1 day) 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	9,36	
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.0046 (1.0022-0.0073)		4,62	
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.0113 (1.0074-1.0151)		3,50	
Total mortality excluding external causes (ICD9 < 800 - ICD10 A00-R99)	All ages	Corrected PM10 24 h	Year	Daily	1.006 (1.004 – 1.008)	WHO 2003		18,14
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.009 (1.005 – 1.013)			9,05
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.013 (1.005 – 1.021)			4,16
Short term effects (< 40 days) Total mortality excluding external causes (ICD9 < 800 - ICD10 A00-R99)	All ages	Corrected PM10 24 h	Year	Daily	1.01227 (1.0081 – 1.0164)	Zanobetti et al 2002		36,17
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.01969 (1.0139-1.0255)	Zanobetti et al 2003		18,97
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.04206 (1.0109 – 1.0742)	Zanobetti et al 2003		12,01
Long term effects Total mortality excluding external causes (ICD9 < 800 - ICD10 A00-R99)	All ages	Corrected PM10	Year	Annual	1.043 (1.026 – 1.061)	Künzli et al 2000		129,02
Total postneonatal mortality	1 month- 1 year	Corrected PM_{10}[3]	Year	Annual	1.048 (1.022-1.075)	Lacasaña et al 2005		0,35
Postneonatal respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.216 (1.102-1.342)			not available
Postneonatal Sudden Infant Death Syndrom Mortality (ICD9 798.0 - ICD10 R95)					1.12 (1.07-1.17)	Woodruff 1997		0,28

Summary of Health Impact Assessment of outdoor air pollution in Rotterdam 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]	
Morbidity							**Ozone: Reduction by 10 µg.m^3**	**PM10: Reduction by 5 µg/m^3**
Emergency room visits for asthma (ICD-9 codes 493, ICD-10 codes J45, J46)	< 18 years	O_3 1h max			1.0115 (1.0067-1.0163)	CARB 2004	Not available	
Cough	< 18 years	Measured PM_{10}	Year		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				1.010 (0.998-1.021)		Not available	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	15 - 64 years	O_3 8h max	Summer	Daily	1.001 (0.991-1.012)	Anderson et al 2004	2,49	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	> 64 years				1.005 (0.998-1.012)		4,06	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	All ages	Measured PM_{10}	Year		1.006 (1.003 – 1.009)	Le Tetre et al 2002		36,56
Cardiovascular hospital admissions (ICD9 390-429 – ICD10 I00-I52)	All ages				1.0114 (1.0062-1.0167)	Apheis 2003		13,94

[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] 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 Rotterdam lies within the industrial area region called Rijnmond. Therefore industries are an important local source of air pollution, next to traffic. Harbor activities and ship transport by the Maas River are other sources of air pollution in Rotterdam.

The city population contains 599,651 people in 2003. Twenty-one percent of the Rotterdam inhabitants is younger then 18 years and 15% is older then 64 years.

The outdoor air quality in Rotterdam has improved during the last decennia, mostly due to successful measures in the industries. Concentrations of sulphur dioxide (SO_2), benzene, lead and benzo(a)pyreen are below EU limits in Rotterdam. This is not the case for particulate matter (PM_{10}) and nitrogen dioxide (NO_2). EU limits for annual mean values of both PM_{10} and NO_2 are exceeded on specific locations close to busy roads in Rotterdam. The EC limit for daily values of PM_{10} is exceeded in a larger part of the city. This problem is not limited to specific locations, since it is less related to local emissions.

In 2003 levels for PM_{10} (particulate matter) are higher compared to the years before (and compared to 2004). The monitoring station in the city centre measured annual means below EC limit of 40 µg/m^3 from 1999 to 2002 (ranging from 35.5 to 39.5 µg/m^3). In 2003 the PM_{10} annual mean was 43.0 µg/m^3. In 2004 the PM_{10} annual mean decreased to 36.3 µg/m^3. Also ozone (O_3) levels were temporarily higher in 2003. During the last decade the number of days with 8 hour maximum ozone concentrations higher then 120 µg/m^3 were below the EU limit of 25 days. Higher air pollution levels in 2003 were mainly due to the extraordinary good weather conditions. Average wind velocity was extremely low which prevented air pollution to disperse. The high amount of sun shine caused relatively high ozone levels.

The regional DCMR Environmental Protection Agency yearly publishes an environmental monitoring report of the Rijnmond region (‘Milieumonitoring Stadsregio Rotterdam’ or MSR). Since 2003 the Public Health Service of Rotterdam cooperates in this exercise regarding the subject air pollution, which resulted in addition of health indicators. Health Impact Assessment based on measured exposure levels estimates short term health effects of PM_{10} and ozone (hospital admissions and mortality rates). Long term effects of PM_{10} are assessed every five year period. The MSR method for HIA differs from the Apheis method. At first slightly different dose response relationships (Relative Risks) are used. Second, MSR is carried out on a regional level, while Apheis focuses on the city of Rotterdam. The third difference between the MSR method and the APHEIS method is that the latter estimates health gain considering a certain amount of reduction or air pollution levels while in the MSR method only total health effects are estimated.

Rotterdam started participating in the Apheis project not earlier then in 2005. Therefore it was decided to do health impact assessment (HIA) not only for the new Apheis indicators, but to calculate also the previous indicators of the third year of Apheis. This report presents the main results of both exercises.

HIA is done for the components PM_{10} and ozone considering hospital admissions and mortality both in adult population and in children below 1 year of age (postneonatal mortality). Hospital admissions related to ozone exposure are studied for the elderly population (over 64 years) separately.

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 total concentration of PM_{10} in the Rijnmond region is a result of both local emissions, emissions elsewhere and natural background levels (like e.g. sea salt and soil particles). Table 1 presents the contribution of these sources to the regional PM_{10} concentration (source: DCMR Environmental Protection Agency).

Table 1 Main sources of PM_{10} in Rijnmond in 2003

Source (year)	Industry (%)	Road traffic (%)	Shipping (%)	Other sources, e.g. heating (%)	Sources elsewhere (%)	Natural sources (%)
2003	4	7	8	2	32	47

The contents of table 1 yields for general concentration levels. On a local level, the contribution of road traffic can be much higher (up to over 30%).

Exposure data

Monitoring stations

Monitoring of air pollution in Rotterdam and its surrounding region Rijnmond is organized by the DCMR Environmental Protection Agency. Although PM_{10} and O_3 is measured by respectively 7 and 6 monitoring stations in the Rijnmond region, only two stations can be considered as background stations. The other stations are too much influenced by industry or traffic to give information about general exposure levels. The reason for selecting only one monitoring station to provide the exposure data for the Apheis project, is its location in the city centre. The other monitoring station is located in neighbor municipality of Schiedam. However, ozone has not been measured during the whole year of 2003 on this location. Therefore, the PM_{10} exposure data are provided by the city centre background station and the background station in Schiedam provides ozone exposure levels.

Measured indicators

PM_{10}: 24 hours average (whole year);

O_3: 1 hour maximum of daily moving average (whole year) and

O_3: 8-hour maximum of daily moving average (summer period = 1st April to 30th September).

Measuring method

PM_{10} is measured using an automated ß-gauge method. Compared to gravimetric methods, the automated method underestimates the PM concentration. Therefore, for the long-term health impact assessment, which uses relative risks based on gravimetric methods, a correction factor of 1.3 was applied to the original data (according to the recommendations by the EC working group on particulate matter with respect to EC directive 1999/30/EC). For short-term effects by PM_{10} the original measured levels are used, while for the long term calculations the corrected levels are used.

Exposure data

The annual mean level (SD) of PM_{10} in Rotterdam was in 2003: 43.0 (11.0) µg/m^3, and P5 and P95 of the daily mean values were, respectively, 27.4 µg/m^3 and 74.8 µg/m^3, which is above the annual mean EC limit value (40 µg/m^3). Also the EC limit for daily PM_{10} levels was exceeded. In 2003 on 81 days the PM_{10} 24 hour levels was above 50 µg/m^3 while exceeding this level is only allowed on 35 days a year maximally according to EC limits. Figure 1 shows the distribution of daily PM_{10} levels in Rotterdam in 2003.

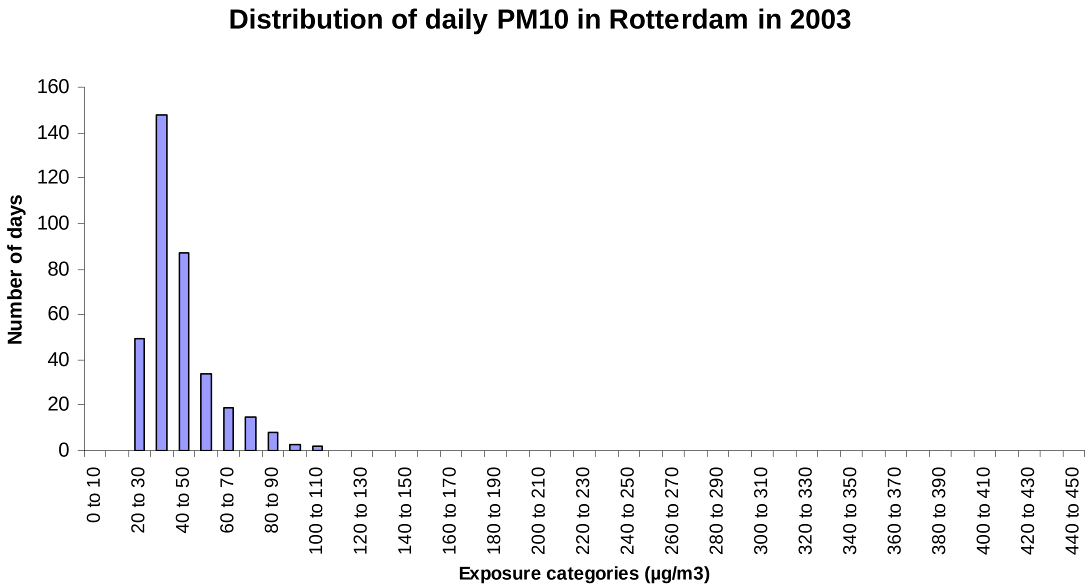
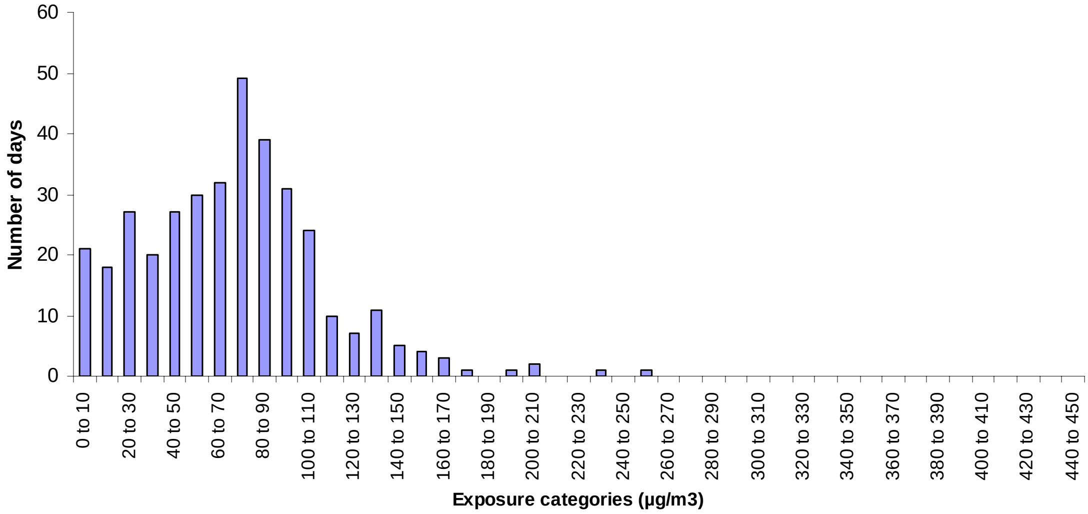


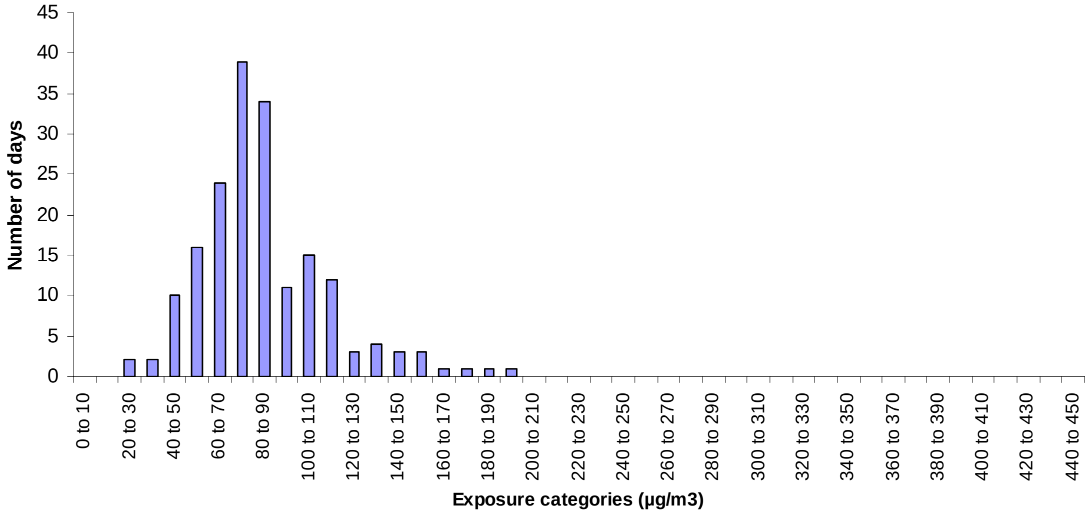
Figure 1 shows that on 233 days (64%) in 2003 the PM_{10} level was between 30 and 50 µg/m^3. On 50 days (14%) the PM_{10} level was below 30 and 81 days (22%) reached PM_{10} levels above 50 µg/m^3.

The mean (SD), P5 and P95 of the daily maximum 8-hour moving average concentrations of O_3 were, respectively, 84.6 (21.1), 48.0 and 141.0 µg/m^3, and those of the daily maximum 1-hour concentrations 70.9 (31.1), 9.1 and 138.8 µg/m. Figure 2 and figure 3 show the distribution of respectively daily maximum 8-hour moving average and daily maximum 1-hour concentrations of O_3.

Distribution of daily O3 1h max in Rotterdam in 2003



Distribution of daily O3 8h max in Rotterdam - summer 2003



The EC Limit for O_3 of 180 µg/m^3 was only exceeded on 5 days in 2003.

Table 2 gives information on both PM_{10} and ozone exposure data.

Table 2. Descriptive statistics for ozone and PM_{10} levels in Rotterdam in 2003

	O3 8h – summer	**O3 1h max - year**	**PM10 - year**
Number	182	364	365
Minimum	28	4	24
Percentile 5	48	9	27
Percentile 25	68	42	33
Median	80	71	39
Percentile 75	97	92	48
Percentile 95	141	139	75
Percentile 98	160	165	84
Maximum	198	252	105
Daily mean	85	71	43
standard error	29	41	15
% missing values	0.55%	0.27%	0.00%

Health data

Source for mortality data is Statistics Netherlands (Centraal Bureau voor de Statistiek, CBS). CBS collects mortality data both manually and automatically to guarantee high quality data. All causes of death in Rotterdam in 2003 are reported (no missing data).

Hospital admission data are collected by the National Hospital Register (Prismant). A recent quality control study showed that 99% of the admission data were correct. Only one percent of the data in the national register appeared to differ from information in local hospital administrations.

In 2003 15 cases of postneonatal mortality occurred. Five of these deaths were caused by sudden infant death syndrome (SIDS). No cases of respiratory postneonatal mortality did occur. Therefore HIA for this health outcome is not included.

In the general population 6194 inhabitants of Rotterdam died in 2003 (external causes of death excluded), 2085 by cardiovascular diseases and 675 by respiratory diseases.

No data are available for lower respiratory symptoms and cough, neither for emergency room visits for asthma. Therefore, HIA for these health outcomes are excluded from the study.

In 2003, 4762 Rotterdam citizens were hospitalized due to cardiovascular diseases. The number of hospital respiratory admissions was 6715, of which 5025 persons were aged 15-64 years and 1691 were older then 64 years. This health outcome is not available for persons below the age of 15 causing exclusion for HIA.

Table 3. Descriptive statistics for health outcomes in Rotterdam in 2003 (n.a. means not available)

Health outcome	ICD9	ICD10	Annual number	Annual rate (per 100 000)	Daily mean	Daily rate (per 100 000)
POSTNEONATAL MORTALITY						
Total			15	196	0.041	0.54
Respiratory *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99	0	0	0	0
Sudden infant death syndrome *ICD9 798.0 – ICD10 R95*	798.0	R95	5	65	0.014	0.18
GENERAL POPULATION MORTALITY						
Total mortality all causes (excluding external causes) *ICD9 <800 ICD10 A00-R99*	<800	A00-R99	6194	1033	16.97	2.83
Cardiovascular mortality *ICD9 390-459 ICD10 I00-I99*	390-459	I00-I99	2085	348	5.71	0.95
Respiratory mortality *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99	675	113	1.85	0.31
MORBIDITY						
Cough			n.a.	n.a.	n.a.	n.a.
Lower respiratory symptoms LRS			n.a.	n.a.	n.a.	n.a.
Emergency room visits for asthma - Age < 18 years *ICD9 493, ICD10 J45 J46*	493	J45-J46	n.a.	n.a.	n.a.	n.a.
Hospital respiratory admissions - Age < 15 years *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99	n.a.	n.a.	n.a.	n.a.
Hospital respiratory admissions - Age 15 -64 years	460-519	J00-J99	5025	1231	13.77	3.37
Hospital respiratory admissions - Age > 64 years	460-519	J00-J99	1691	1937	4.63	5.31
Hospital respiratory admissions (all ages)	460-519	J00-J99	6715	1120	18.40	3.07
Hospital cardiovascular admissions (all ages)	390-429	I00-I52	4762	794	13.05	2.18

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

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)
Total mortality all causes ICD9 <800 ICD10 A00-R99	Corrected PM10 24 h Year	RR = 1.006 (1.004 – 1.008) ↑10μg/m^3 Short term 0-1 day	WHO 2003
Respiratory mortality ICD9 460-519 ICD10 J00-J99	Corrected PM10 24 h Year	RR = 1.009 (1.005 – 1.013) ↑10μg/m^3 Short term 0-1 day	WHO 2003
Cardiovascular mortality ICD9 390-459 ICD10 I00-I99	Corrected PM10 24 h Year	RR = 1.013 (1.005 – 1.021) ↑10μg/m^3 Short term 0-1 day	WHO 2003
Total mortality all causes ICD9 <800 ICD10 A00-R99	Corrected PM10 24 h Year	RR= 1.01227 (1.0081 – 1.0164) ↑10μg/m^3 Short term < 40 days	Zanobetti et al 2002
Respiratory mortality ICD9 460-519 ICD10 J00-J99	Corrected PM10 24 h Year	RR = 1.04206 (1.0109 – 10742) ↑10μg/m^3 Short term < 40 days	Zanobetti et al 2003
Cardiovascular mortality ICD9 390-459 ICD10 I00-I99	Corrected PM10 24 h Year	RR = 1.01969 (1.0139 – 1.0255) ↑10μg/m^3 Short term < 40 days	Zanobetti et al 2003
Total mortality all causes ICD9 <800 ICD10 A00-R99	Corrected PM10 annual Year	RR = 1.043 (1.026 – 1.061) ↑10μg/m^3 Long term	Künzli et al 2000

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

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 5. 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
	Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	Measured PM10 24 h	RR=1.006 (1.003-1.009) ↑10µg/m^3	LeTetre et al 2002
	Cardiovascular hospital admissions (ICD9 390-429 – ICD10 I00-I52)	Measured PM10 24 h	RR=1.0114 (1.0062-1.0167) ↑10µg/m^3	Apheis 2003

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 (not available in Rotterdam), **hospital respiratory admissions** in people under 15 year (not available in Rotterdam) and **hospital respiratory admissions and total, respiratory and cardiovascular mortality**[3] in the general population.

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

[3] For mortality: acute health effects of PM_{10} on 0-1 days and cumulative health effects of PM_{10} up to 40 days after exposure are estimated (Zanobetti et al 2002 and Zanobetti et al 2003).

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) and **total mortality** in the general population.

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 (not available in Rotterdam),

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 **total, respiratory and cardiovascular mortality** in general population and **respiratory hospital admissions** in people under 15 years (not available in Rotterdam), between 15 and 64 years and above 64 years of age.

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

Short term effects of PM_{10}

Regarding short-term effects of PM_{10} each reduction by 5 µg/m^3 of daily concentrations would delay 18 (95%CI: 12-24) deaths per year in the study area, 9 (95%CI: 5-13) from cardiovascular diseases, and 4 (95%CI: 2-7) from respiratory diseases. This is equivalent to an annual rate of 3 deaths per 100 000 (95%CI: 2-4). Taking into account the acute health effects of PM_{10} up to 40 days after exposure each reduction by 5 µg/m^3 of daily concentrations would delay[4] 36 (95%CI: 24-48) deaths per year in the study area, 19 (95%CI: 13-25) from cardiovascular diseases, and 12 (95%CI: 3-21) from respiratory diseases. This is equivalent to an annual rate of 6 deaths per 100 000 (95%CI: 4-8).

Each reduction of PM_{10} by 5 µg/m^3 of daily concentrations would prevent 37 (95%CI: 20-53) respiratory hospital admissions and 14 (95%CI: 7-21) cardiovascular hospital admissions, which is equivalent to an annual number of 6 respiratory admissions per 100 000 (95%CI: 3-9) and 2 cardiovascular admissions per 100 000 (95%CI:1-3).

[4] Victims of both acute (0-1 day) and cumulative (< 40 days) short term effects of PM_{10} die a few months earlier (Zanobetti 2003). Thus, reduction of PM_{10} levels would delay the death of these persons with a few months.

Table 6. Potential benefits of reducing PM_{10} daily levels in Rotterdam. Annual level attributable numbers and rates (per 100 000 inhabitants) (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)**
MORTALITY (0-1 day after exposure)	**Daily mean levels**		
Total excluding external causes	by 5 µg/m³	18.14 (12.10 -24.17)	3.03 (2.02-4.03)
	to 50 µg/m³	13.32 (8.87- 17.79)	2.22 (1.48-2.97)
	to 20 µg/m³	85.23 (56.69 -113.90)	14.22 (9.46-19.00)
Cardiovascular	by 5 µg/m³	9.05 (5.03-13.06)	1.51 (0.84-2,18)
	to 50 µg/m³	6.76 (3.74-9.79)	1.13 (0.62-1.63)
	to 20 µg/m³	42.89 (23.72-62.23)	7.15 (3.96-10.38)
Respiratory	by 5 µg/m³	4.16 (1.60-6.71)	0.69 (0.27-1.12)
	to 50 µg/m³	3.18 (1.21-5.17)	0.53 (0.20-0.86)
	to 20 µg/m³	19.96 (7.61-32.54)	3.33 (1.27-5.43)
MORTALITY (cumulative within 40 days after exposure)			
Total excluding external causes	by 5 µg/m³	36.17 (23.90-48.29)	6.03 (3.99-8.05)
	to 50 µg/m³	27.51 (18.10-36.90)	4.59 (3.02-6.15)
	to 20 µg/m³	173.05 (113.70-232.39)	28.86 (18.96-38.76)
Cardiovascular	by 5 µg/m³	18.97 (13.41-24.53)	3.16 (2.24-4.09)
	to 50 µg/m³	15.03 (10.56-19.56)	2.51 (1.76-3.26)
	to 20 µg/m³	92.70 (65.01-120.85)	15.46 (10.84-20.16)
Respiratory	by 5 µg/m³	12.01 (3.41-21.03)	2.00 (0.57-3.51)
	to 50 µg/m³	10.75 (2.71-19.50)	1.79 (0.45-3.25)
	to 20 µg/m³	62.85 (15.65-114.65)	10.48 (2.61-19.12)
MORBIDITY	**Daily mean levels**		
Hospital respiratory admissions (all ages)	by 5 µg/m³	36.56 (19.91-53.48)	6.10 (3.32-8.92)
	to 50 µg/m³	27.67 (14.98-40.72)	4.62 (2.50-6.79)
	to 20 µg/m³	174.47 (94.33-257.14)	29.10 (15.73-42.89)
Hospital cardiovascular admissions (all ages)	by 5 µg/m³	13.94 (6.98-20.90)	2.33 (1.16-3.49)
	to 50 µg/m³	10.24 (5,11-15.40)	1.71 (0.85-2.57)
	to 20 µg/m³	65.53 (32.65-98.62)	10.93 (5.45-16.45)
MORBIDITY	**Daily levels**		
Cough <18 y	by 5 µg/m³	not available	not available
	to 20 µg/m³	not available	not available
	to 50 µg/m³	not available	not available
LRS <18 y	by 5 µg/m³	not available	not available
	to 20 µg/m³	not available	not available
	to 50 µg/m³	not available	not available

Long term effects of PM_{10}

The annual number of postneonatal deaths attributable to PM_{10} levels higher than 20 $\mu g/m^3$ was 1.54 (95%CI: 0.69 – 2.44), which is equivalent to an annual rate of 20 deaths per 100 000 (95%CI: 9-32). Reduction of PM_{10} concentration by 5 $\mu g/m^3$ would prevent 0.35 (95%CI 0.16-0.54) case of postneonatal mortality.

Reducing the PM_{10} levels to 20 $\mu g/m^3$ would delay[5] the number of deaths annually by 572 (95%CI 342-821), which is equivalent to an annual rate of 95 deaths per 100 000 (95%CI: 57-137). A decrease of annual PM_{10} levels below EU limit of 40 $\mu g/m^3$ would delay 78 (95%CI 48-111) deaths per year. A general reduction of the PM_{10} concentration of 5 $\mu g/m^3$ would delay 129 (95%CI 78-182) deaths yearly.

Table 7. Potential benefits of reducing PM_{10} levels in Rotterdam. Absolute numbers and rates (per 100 000) (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 $\mu g/m^3$	0.35 (0.16-0.54)	4.56 (2.09-7.04)
	to 20 $\mu g/m^3$	1.54 (0.69-2.44)	20.08 (9.00-31.82)
	to 40 $\mu g/m^3$	0.21 (0.10-0.33)	2.74 (1.30-4.30)
Respiratory	by 5 $\mu g/m^3$	not available	not available
	to 20 $\mu g/m^3$	not available	not available
	to 40 $\mu g/m^3$	not available	not available
Sudden Infant Death Syndrom (SIDS)	by 5 $\mu g/m^3$	0.28 (0.16-0.39)	3.65 (2.09-5.09)
	to 20 $\mu g/m^3$	1.15 (0.65-1.68)	15.00 (8.48-21.91)
	to 40 $\mu g/m^3$	0.17 (0.10-0.24)	2.22 (1.30-3.13)
MORTALITY			
Total	by 5 $\mu g/m^3$	129.02 (78.34-182.24)	21.52 (13.07-30.40)
	to 20 $\mu g/m^3$	572.32 (342.30-821.25)	95.46 (57.09-136.98)
	to 40 $\mu g/m^3$	78.46 (47.72-110.63)	13.09 (7.96-18.45)

[5] Chronic exposure to PM_{10} is related with shortening of life time (mostly due to dying from cardiovascular diseases and long cancer). Reduction of PM_{10} levels would delay the death of the victims with a few years up to 10 years (Künzli 2001).

Short term effects of ozone

Regarding short-term effects of O_3, each reduction by 10 µg/m^3 of daily maximum 8-hour moving average concentrations would delay 9 (95%CI: 5-16) deaths per year in the study area, 5 (95%CI: 2-7) from cardiovascular diseases and 4 (95%CI: 2-5) from respiratory causes.

Reducing daily maximum 8-hour moving average O_3 concentrations would prevent 2 persons in the age of 15-64 and 4 persons above 64 years for hospitalization caused by respiratory disease. Confidence limits of these results show that these outcomes are not statistically significant.

Table 8. Potential benefits of reducing ozone daily levels in Rotterdam. 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	9.36 (5.31-15.69)	1.56 (0.89-2.62)
	to 120 µg/m^3	2.58 (1.41-4.34)	0.43 (0.24-0.72)
Cardiovascular	by 10 µg/m^3	4.62 (2.21- 7.33)	0.77 (0.37-1.22)
	to 120 µg/m^3	1.30 (0.62 - 2.07)	0.22 (0.10-0.35)
Respiratory	by 10 µg/m^3	3.50 (2.29 - 4.67)	0.58 (0.38-0.76)
	to 120 µg/m^3	1.07 (0.70 - 1.44)	0.18 (0.12-0.24)
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 y	by 10 µg/m^3	not available	not available
	to 120 µg/m^3	not available	not available
Hospital respiratory admissions 15-64 y	by 10 µg/m^3	2.49 (-22.38 – 29.84)	0.61 (-5.48-7.31)
	to 120 µg/m^3	0.67 (-5.90-8.17)	0.16 (-1.44-2.00)
Hospital respiratory admissions > 64 y	by 10 µg/m^3	4.06 (-1.62- 9.75)	4.65 (-1.86-11.17)
	to 120 µg/m^3	1.15 (-0.45-2.79)	1.32 (-0.52-3.20)

HIA findings for 2001

As mentioned earlier, air pollutions levels were extraordinary high in 2003. Therefore, it was decided to show not only HIA results using exposure data of 2003. In appendix 1 HIA results based on 2001 exposure data are presented.

Discussion

Interpreting of study results

The study results show benefits of improvement of air quality in Rotterdam also on levels below EC limits. This yields especially for PM_{10}[6]. The study outcomes emphasize the fact a no-effect level (below which no health effects occur) does not exist for PM_{10}. Thus, all reductions in concentrations levels help preventing health effects.

Benefits in terms of health gain are largest when reducing PM_{10} levels, both in terms of number deaths delayed (and hospital admissions prevented) and in terms of the amount of delay: a few years up to 10 years (Künzli et al 2001).

Health gain by reducing air pollution levels in Rotterdam is limited considering only ozone levels. Current ozone levels are not that high that an improvement would prevent a large amount of cases of hospitalization and early deaths. However, still nine deaths would delay and six hospital admissions would be prevented when ozone levels are reduced by 10 $\mu g/m^3$.

Study limitations

Health gain of reducing air pollutions levels is estimated in this study by using measured exposure data of 2003. Because 2003 had extraordinary weather conditions air pollution levels of PM_{10} and O_3 were relatively high (annual mean of PM_{10} in 2001 was 37.1 $\mu g/m^3$ compared to 43.0 $\mu g/m^3$ in 2003). Therefore the study results slightly overestimate the health gain by improving air quality in Rotterdam. However, comparison between the results using 2003 exposure data with the HIA outcomes when 2001 exposure data are used (see appendix 1) show the overestimation is limited. As an example the outcome for long term PM_{10} exposure to mortality in the general population is described. When PM_{10} levels are reduced to 20 $\mu g/m^3$ 419 (95%CI 252-598) deaths would delay annually according to exposure data 2001, against 572 deaths when exposure data of 2003 are used. The results of a reduction of the PM_{10} concentration by 5 $\mu g/m^3$ show a very small difference between the 2003 and 2001 outcome: 126 (95%CI 76-178) delayed deaths compared to 129. Appendix 1 shows results using 2001 exposure data in detail.

The HIA gives a general indication of possible health gain by reducing PM_{10} and O_3 levels. However for the whole city of Rotterdam just one measuring station was used for exposure levels. On a more local level, for example locations close to busy roads, the results are not directly applicable. To prevent future health problems caused by road traffic on similar spots, urban development should plan spatial functions like living efficiently and precisely on a small scale level.

Measurements to improve air quality

In the Netherlands EC limits for air quality are connected with urban planning processes on the level of legislation. Therefore, since 2005 (when PM_{10} EC limits became active) urban development plans have been tested on air quality by the highest national public court (Raad van State). In cases where EC limits are exceeded the Raad van State did not permit the urban plans. The crucial reason for restricting urban development was in most cases exceeding of the EC limit for PM_{10} for daily level of 50 $\mu g/m^3$ for more then 35 days a year. In a large part of the Netherlands (mainly the western and southern part of the country) this EC limit is expected to be exceeded also in the future, even when measures are taken. This problem results in a broad discussion in the Netherlands about air quality, in particular with respect to unconnecting EC limits from urban planning processes. The main question in this discussion is how to establish compact urban planning in an area with a relatively bad outdoor air quality, preventing health

[6] E.g. Although the annual mean of PM_{10} was below the EC limit of 40 $\mu g/m^3$ in 2001 the study results show health gain when concentrations would reduce (see appendix 1).

problems and preventing urbanization of the small amount of green space between the four large cities (Rotterdam, The Hague, Amsterdam and Utrecht).

The Rotterdam Public Health Service (Rotterdam PHS) is taken part in this discussion on a local and regional level. Rotterdam PHS cooperates in the process of developing local and regional air quality policy. Partners in this process are amongst others the local urban planning department and Environmental Protection Agency DCMR. In the discussion the Rotterdam PHS emphasizes the need for source measurements, in particular focussing on particulate matter and the part of PM_{10} related to fossil fuel combustion. Furthermore Rotterdam PHS encourages sustainable solutions and encourages research and implementation of alternative fuels like e.g. bio-ethanol and hydrogen techniques. In addition, the PHS advises in urban planning processes in the city.

The HIA findings of this study will be helpful in the above mentioned PHS activities. The study results subscribe that efficient environmental policy that leads to reduction of air pollution levels will have a substantial amount of health gain for the citizens of Rotterdam. Regarding the discussion about the EC limit for daily PM_{10} values the HIA findings show that a reduction of PM_{10} values below the level of 50 $\mu g/m^3$ would delay 28 deaths (95%CI 18-37) and 19 cardiovascular hospital admissions and 12 respiratory hospital admissions per year in Rotterdam.

The HIA findings of APHEIS provides information to show local government, policy makers and urban planners the health benefits of improving outdoor air quality in the city. Adding this information to the regional HIA for environmental monitoring makes it possible to discuss about air quality in quantitative terms of health gain. One local measure to improve air quality will never be sufficient in terms of health gain, but a combination of a number of measures may reduce air pollution levels with such an amount that it will lead to a healthier situation for Rotterdam citizens.

Conclusion

Improvement of air quality in Rotterdam should be focused on PM_{10}. Reducing PM_{10} levels could prevent both short term and long term health effects. Especially the latter are of concern, because of the relatively large amount of inhabitants affected and the loss of life years that can reach up to 10 years (Künzli et al 2001). In addition, for the component PM_{10} there is prove for effects on postneonatal mortality. Reduction of PM_{10} by 5 $\mu g/m^3$ shows to prevent 0,35 case of postneonatal mortality. This seems like a small impact, but this outcome is equivalent with 5 cases per 100 000 children on a yearly basis. Therefore, it can be considered as a constructive health gain.

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APPENDIX 1 HIA results using 2001 exposure data

The appendix shows the HIA results using 2001 exposure data (descriptive statistics in the table below).

Descriptive statistics for ozone and PM_{10} levels in Rotterdam in 2001

	O3 8h – summer	O3 1h max – year	PM10 - year
Number	183	361	365
Minimum	17	4	21
Percentile 5	37	9	25
Percentile 25	58	45	30
Median	70	65	34
Percentile 75	85	82	40
Percentile 95	115	121	58
Percentile 98	145	151	75
Maximum	172	219	105
Daily mean	73	65	37
Standard Deviation	19	25	8
% missing values	0.55%	0.28%	0.00%

Potential benefits of reducing PM_{10} daily levels in Rotterdam. Annual level attributable numbers and rates (per 100 000 inhabitants) (95% confidence limits) attributable to the health effects of PM_{10}.

	PM_{10} Reduction	**Number of attributable cases per year**
MORTALITY (0-1 day after exposure)	**Daily mean levels**	
Total excluding external causes	by 5 µg/m^3	17.76 (11.84 -23.66)
	to 50 µg/m^3	5.30 (3.52-7.08)
	to 20 µg/m^3	61.53 (40.96-82.17)
Cardiovascular	by 5 µg/m^3	9.30 (5.17-13.42)
	to 50 µg/m^3	2.83 (1.56-4.10)
	to 20 µg/m^3	32.48 (17.99-47.06)
Respiratory	by 5 µg/m^3	3.92 (1.51-6.32)
	to 50 µg/m^3	1.22 (0.46-1.99)
	to 20 µg/m^3	13.83 (5.29-22.48)
MORTALITY (cumulative within 40 days after exposure)		
Total excluding external causes	by 5 µg/m^3	35.54 (23.49-47.46)
	to 50 µg/m^3	11.00 (7.23-14.78)
	to 20 µg/m^3	125.11 (82.32-167.76)
Cardiovascular	by 5 µg/m^3	19.62 (13.87-25.38)
	to 50 µg/m^3	6.35 (4.45-8.28)
	to 20 µg/m^3	70.37 (49.45-91.55)
Respiratory	by 5 µg/m^3	11.51 (3.00-20.14)
	to 50 µg/m^3	4.24 (1.06-7.78)
	to 20 µg/m^3	43.63 (11.03-79.02)
MORBIDITY	**Daily mean levels**	
Hospital respiratory admissions (all ages)	by 5 µg/m^3	36.40 (19.82-53.25)
	to 50 µg/m^3	11.21 (6.06-16.53)
	to 20 µg/m^3	127.85 (69.25-188.07)
Hospital cardiovascular admissions (all ages)	by 5 µg/m^3	14.41 (7.21-21.59)
	to 50 µg/m^3	4.39 (2.14-6.47)
	to 20 µg/m^3	49.92 (24.90-75.05)
MORBIDITY	**Daily levels**	
Cough <18 y	by 5 µg/m^3	not available
	to 20 µg/m^3	not available
	to 50 µg/m^3	not available
LRS <18 y	by 5 µg/m^3	not available
	to 20 µg/m^3	not available
	to 50 µg/m^3	not available

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

	PM10 reduction	Number of attributable cases per year
POSTNEONATAL MORTALITY	**Annual mean levels**	
Total	by 5 µg/m^3	0.34 (0.16-0.53)
	to 20 µg/m^3	1.13 (0.51-1.78)
	to 40 µg/m^3	Not applicable (annual mean level below 40)
Respiratory	by 5 µg/m^3	not available
	to 20 µg/m^3	not available
	to 40 µg/m^3	Not applicable (annual mean level below 40)
Sudden Infant Death Syndrom (SIDS)	by 5 µg/m^3	not available
	to 20 µg/m^3	not available
	to 40 µg/m^3	Not applicable (annual mean level below 40)
MORTALITY		
Total	by 5 µg/m^3	125.87 (76.42-177.79)
	to 20 µg/m^3	418.93 (251.82-597.98)
	to 40 µg/m^3	not applicable (annual mean level below 40)

Potential benefits of reducing ozone daily levels in Rotterdam. 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
MORTALITY	**Daily 8-h max**	
Total excluding external causes	by 10 µg/m^3	9.42 (5.16-15.79)
	to 120 µg/m^3	1.23 (0.68-2.08)
Cardiovascular	by 10 µg/m^3	4.88 (2.34-7.75)
	to 120 µg/m^3	0.65 (0.31-1.04)
Respiratory	by 10 µg/m^3	3.40 (2.23-4.55)
	to 120 µg/m^3	0.49 (0.32-0.66)
MORBIDITY	**Daily 1-h max**	
Emergency room visits for asthma <18 y	by 10 µg/m^3	not available
	to 180 µg/m^3	not available
	Daily 8-h max	
Hospital respiratory admissions <15 y	by 10 µg/m^3	not available
	to 120 µg/m^3	not available
Hospital respiratory admissions 15-64 y	by 10 µg/m^3	2.61 (-23.50-31.33)
	to 120 µg/m^3	0.33 (-2.97-4.06)
Hospital respiratory admissions > 64 y	by 10 µg/m^3	3.76 (-1.51-9.04)
	to 120 µg/m^3	0.51 (-0.20-1.22)