HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

ENHIS-1 PROJECT: WP5 HEALTH IMPACT ASSESSMENT

LOCAL CITY REPORT

Copenhagen

Summary of main findings for Copenhagen

In 2001 the PM_{10} annual mean (SD) measured in urban background was 21 (11) µg/m^3,1 µg/m^3 above the 1999/30/EC Directive indicative limit value for 2010 (20 µg/m^3), and 19 µg/m^3 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 68(15), 45 and 92 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 0,05 total postneonatal deaths. Reducing PM_{10} daily mean values to 20 µg/m^3 would prevent (not available in Denmark emergency room visits for asthma, not available in Denmark coughs, not available in Denmark lower respiratory symptoms) and11,7 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 10,2 deaths per year in the general population in the study area, 5,9 from cardiovascular diseases, and 3,7 from respiratory causes. In terms of hospital admissions, this would represent 1,9 respiratory admissions in the adult population and 11,8 in the population over 64 years.

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

Health outcome	**Population**	**Pollutant**	**Period**	**Mean type**	**RR from literature (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	10,24	
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.0046 (1.0022-0.0073)		5,92	
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.0113 (1.0074-1.0151)		3,74	
Total postneonatal mortality	1 month- 1 year	Corrected PM_{10}[3]	Year	Annual	1.048 (1.022-1.075)	Lacasaña et al 2005		0,20
Postneonatal respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.216 (1.102-1.342)			0,08
Postneonatal Sudden Infant Death Syndrom Mortality (ICD9 798.0 - ICD10 R95)					1.12 (1.07-1.17)	Woodruff 1997		0
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	0,16	
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		12,63
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	15 - 64 years	O_3 8h max	Summer		1.001 (0.991-1.012)		1,88	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	> 64 years				1.005 (0.998-1.012)		11,81	

[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

Copenhagen, the capital of Denmark and local authority for 590,224 inhabitants, is a major port. Denmark is comprised of several islands and a peninsula that borders Germany. Copenhagen is situated on one of several islands (called Sjaelland).

The population density is high compared with the rest of the country and other Nordic cities, population density is currently at 5,800 people per sq km.

The climate of Copenhagen is temperate coastal climate with cool summers and mild winters. July is normally the warmest month with an average temperature of just below 20°C. February is generally the coldest with an average of just below 0°C.

Air pollution, especially with particulate matter, from transport and local heating of houses by wood burning stoves, is becoming a public health issue in Copenhagen.

Denmark is largely affected by pollution from other European countries. Total emissions in Europe are about 100 times larger than Danish emissions, and will therefore have a huge impact on Danish air quality (Palmgren et al., 2005).

Main causes of mortality in Copenhagen are cancer, ischemic heart diseases, other heart and vascular diseases. Main causes of morbidity in the general population are diseases of the stomach and intestines, musculoskeletal system, pregnancy, delivery and the perinatal period, the lungs, the heart and great vessels among other diseases. The mortality of children (< 18 years old) is low. Child mortality may be related to accidents, congenital anomalies, endocrine or respiratory diseases. Asthma and allergy among children is common.

Previously health impact assessment (HIA) of air pollution in Copenhagen has been carried out by TRIP, a Centre for Transport Research on environmental and health Impacts and Policy. TRIP was an open research centre linking researchers from different universities and other research institutions in collaboration on for example health outcomes and traffic generated air pollution.

Calculations from the municipality of Copenhagen showed that in 1999 100 - 280 cases of premature deaths were attributable to PM10. The medical officer of Copenhagen has subsequently announced that these number of attributable cases is based on a conservative assessment, and that the actual number may be even higher. The calculations also showed that exposure to PM10 causes 190-540 extra hospitals admissions mostly among persons suffering of lung diseases and elderly (Palmgren et al. 2003).

A resent study of daily levels of ambient air pollution in the Copenhagen area and daily airway symptoms among 411 COPSAC (COPenhagen Study of Asthmatic Children), children with atopic predisposition for asthma and other hypersensitivity diseases, followed from their birth to the age of 18 months, found consistent associations between high levels of air pollution measured at the street stations on Jagtvej and H.C. Andersens Boulevard and incidences of wheezing during the following days by several of the children living in central Copenhagen. Among children living further away from the centre of the city, the associations found between air pollution and symptoms were much less consistent. The respiratory symptoms were related especially to the observed levels of carbon oxide and nitrogen oxides (NOX), which are generated mostly by traffic. Associations were also found between the recorded levels of PM10 and ultrafine particles, however, to a much smaller degree (Andersen J. Z. et al., 2005).

AIRPOLIFE is a ongoing Danish Centre of Execellence on Air Pollution and Health. The Centre will focus on the measurement of air pollutants, biomarkers for individual exposure, genetically conditioned sensitivity, epidemiology and mechanisms research – in addition to cost benefit analyses, health risk communication and research ethics.

This report presents HIA results in children, and in the general population, in adults and in population over 64 years, for PM10 and ozone.

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

Particulate matter with an aerodynamic diameter smaller than 10µm are referred to as PM10. The main sources for PM10 are resuspended dust and combustion. The analysis of existing data from Copenhagen has shown that the most important contribution to PM10 in urban background is long range transported primary and secondary particles created in the atmosphere by oxidation of nitrogen dioxide and sulphur dioxide. (> 90%). The contribution from traffic at busy streets in central Copenhagen, e.g. H.C. Andersens Boulevard (> 60,000 vehicles per day) and Jagtvej (> 22,000 vehicles per day) is significant (> 30%). More than 50% of the traffic contribution is coarse particles, e.g. from road dust and wear of road surface, tires, brakes etc. (Palmgren et al. 2003).

Ozone (O3) is an air pollutant on gas phase, which is formed by photochemical reactions (i.e. by the influence of sunlight) between nitrogen oxides and volatile organic compounds (VOC's). The VOC's has natural origin, however the major source are emitted by incomplete combustion. The major part of the ozone measured in Denmark originates from sources located outside the country. Usually the highest concentrations are found at rural and urban background sites. Ozone is removed by NO at street level.The highest concentrations are measured during summer periods with warm and sunny weather.

The limit value of PM10 on 50 µg/m3, not to be exceeded more than 35 times per year and to comply with in 2005, was in 2003 exceeded at 2 out of 4 street stations. At all stations both indicative limit values to be met in 2010 (annual average value on 20 µg/m3 and 50 µg/m3 not to be exceeded more than 7 times per year) were exceeded at all stations (including the rural station Keldsnor). PM10 is 60-70% of TSP. The trend of TSP has been clear decreasing the last 15 years, except at HCAB.

The ozone level was in 2003, more or less, the same at all rural and urban background stations and no clear trend is observed. The information threshold on 180 µg/m3 was not exceeded. The target values were not exceeded, but the long-term objectives of max 8 hours on 120 µg/m3 were exceeded at all urban background and rural stations. The long term objective for AOT40 at 6000 µg/m3 *hours were exceeded in a few cases (Kemp K. & Palmgren F., 2004)

Exposure data

The air measurement data from 2001 were obtained at the near-city background station (station no. 2090) (12^{o} 7'34" E, 55^{o}41'14" N) placed in Lille Valby, about 25 km west of the city centre of Copenhagen, in a flat area with agricultural activity. The nearest town is Roskilde with 50,000 inhabitants about 6 km south of the air monitor station. A north-south going highway with a traffic density of a few thousands cars per day is passing 1.5 km west of the station. Beyond this the activities of industry and traffic are limited in the area. 24 h measurements of TSP, elements and SO_2 as well as ½ h measurements of NO, NO_2, SO_2 and O_3 are conducted at the station.

Since the beginning of September 2000 the National Environmental Research Institute (NERI) has been responsible for operating the Air Quality Monitoring program in the Greater Copenhagen Area in cooperation with the local authorities, the municipality of Copenhagen.

Ambient air is drawn through filters and the mass concentration of the total suspended particles (TSP) or PM10 in the ambient air is measured . by weighing (gravimetric) the filters. PM10 is sampled with a sampler equiped with a PM10 sampling inlet. The air flow through the filters is 40 l/min for TSP and 16.7 l/min for PM10 collection.

Ozone was analyzed by the use of UV-absorption at 254 nm. The ratio between the absorption in the measurement cell with sample air and with absorption in the cell with ozone selectively removed permit calculation of the ozone concentration. The measuring range is 0 -500 ppb, at a air flow rate of 0.6-0.8 l/min. The lower detection limit is less than 1 ppb. Precision ± 5 %. Water vapour dilute the sample. Routine checks consist of automatic zero point check every day around midnight with zero- air from a generator, and "span" check by a built-in O_3-generator. Calibration at the laboratory: of ozone from a generator traceable to NIST. Checked against a NIST reference photometer once a year.

PM10 daily exposure indicator has been calculated as the arithmetic mean of the daily concentrations of the stations.

The daily maximum 1-hour of ozone 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 average from 9 am to 5 pm of the stations for the summer period (1st April to 30th September).

The annual mean level (SD) of PM10 in urban background in Copenhagen was 21 (11) µg/m^3, and P5 and P95 of the daily mean values were, respectively, 8 µg/m^3 and 41µg/m^3. The mean (SD) , P5 and P95 of the daily maximum 8-hour average concentrations of O_3 were, respectively, 68 (15), 45 and 92 µg/ m^3, and those of the daily maximum 1-hour concentrations 68 (19), 36 and 96 µg/m3 (Table 1 and figures 1-3)

The measured values of PM10 were *1 µg/m^3 above the 1999/30/EC Directive limit value for 2010 (20 µg/m^3), and 19 µg/m^3 below that established for 2005 (40 µg/m^3).* The measured values of ozone were below the *Directive limit values that were established for 2010 (no more than 25 days per year exceeding a daily* maximum 8-hour moving average of *120 µg/m^3).The 1-hour maximum were also below the permitted limit established for information for 2003 (180 µg/m^3) and for warning for 2003 (no more than 3 hours exceeding 240 µg/m^3).*

Table 1 summarizes the air pollution levels of ozone and PM10 measured in Copenhagen, 2001.

Figures 1, 2 and 3 shows the distribution of air pollution clustered by the number of days in different exposure categories of the concentration of ozone and PM10. Figure 1 and 2 illustrate that the exposure to high levels of ozone were only measured on a few days in Copenhagen in the summer of 2001. Figure 3 illustrates that approximately half of the days were exposed to concentrations of PM10 less than 20 µg/m^3 and that the other half of 2001 were exposed to concentrations above 20 µg/m^3 .

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

	O3 8h – summer	**O3 1h max – year**	**PM10 - year**
Number	178	358	316
Minimum	30	8	3
Percentile 5	45	36	8
Percentile 25	58	54	14
Median	67	68	20
Percentile 75	77	79	26
Percentile 95	92	96	41
Percentile 98	97	107	51
Maximum	120	169	74
Daily mean	68	67	21
standard error	15	19	10
% missing values	2,73	1,92	13,42

Figure 1 Distribution of daily O3 8h max in Copenhagen. Summer 2001

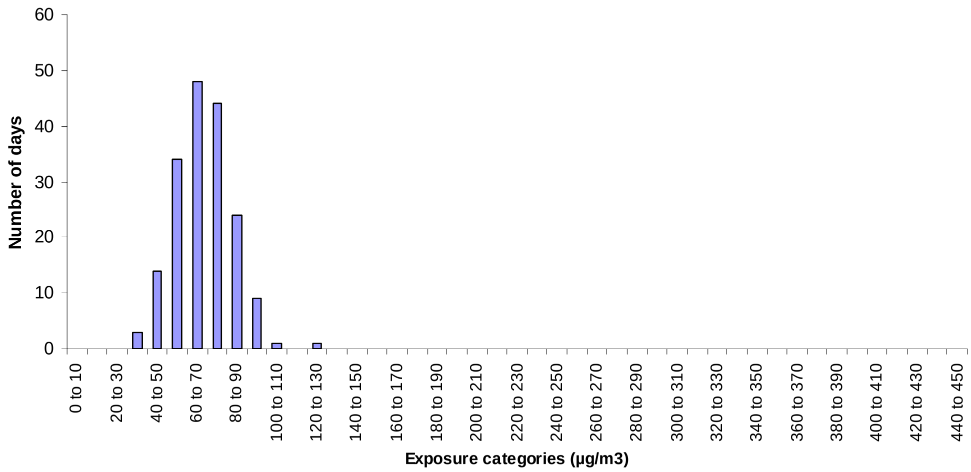


Figure 2 Distribution of daily O3 1h max in Copenhagen. Summer 2001

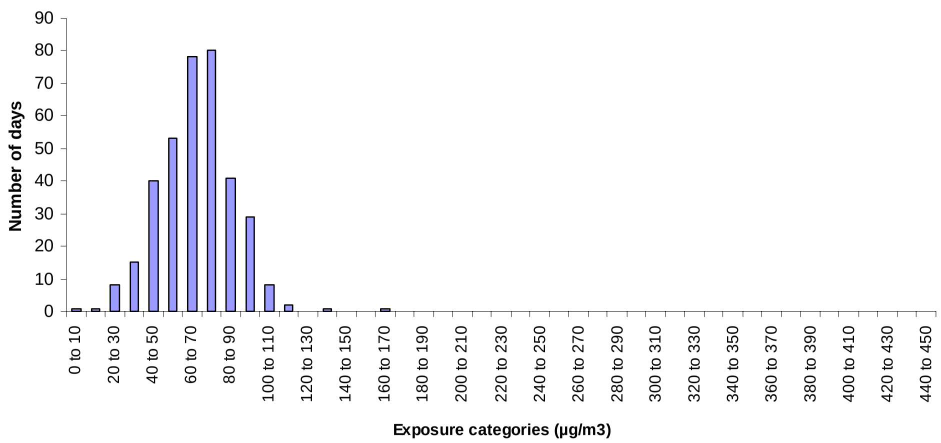
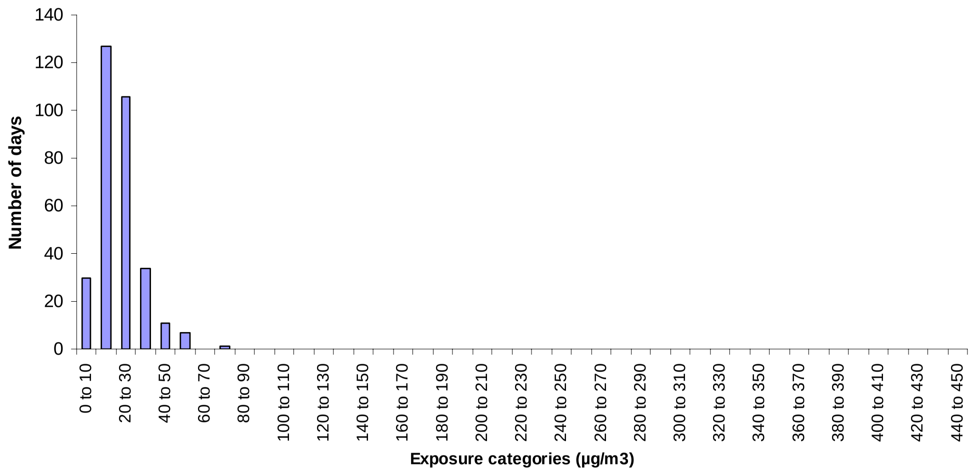


Figure 3 Distribution of daily PM10 in Copenhagen. 2001



Health data

The mortality data from 2001 were compiled from the Danish databank (Denmark's Statistics). The National Board of Health has provided all other health indicators used. Data on lower respiratory symptoms and cough were not available due to the fact that these morbidity endpoints are not registered in Denmark (Please note this is not confirmed).

Table 2 summarizes the health outcomes registered in Copenhagen, 2001. Out of 11 postneonatal deaths one case was due to respiratory causes. In average 19 deaths occur every day. 7 of these cases are caused by cardiovascular mortality and 2 are caused by respiratory mortality. The daily average of emergency room visit is 0.11 for children (< 18 years old). The annual incidence rate of respiratory hospital admissions per 100,000 persons are 3385 younger children (< 15 years), 744 adults(15 - 64 years old) and 6735 elderly (> 64 years of age), respectively.

Table 2. Descriptive statistics for health outcomes in Copenhagen, 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			11	not available			
Respiratory *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99	1	not available			
Sudden infant death syndrome *ICD9 798.0 – ICD10 R95*	798.0	R95	0	not available			
GENERAL POPULATION MORTALITY							
Total mortality all causes *ICD9 <800 ICD10 A00-R99*	<800	A00-R99			18,95 (4,52)	3,21	
Cardiovascular mortality *ICD9 390-459 ICD10 I00-I99*	390-459	I00-I99			7,44 (2,69)	1,26	
Respiratory mortality *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99			1,99 (1,44)	0,34	
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			0,11 (0,33)	0,12	
Hospital respiratory admissions - Age < 15 years *ICD9 460-519 ICD10 J00-J99*	460-519	J00-J99					3384,9
Hospital respiratory admissions - Age 15 -64 years	460-519	J00-J99					743,9
Hospital respiratory admissions - Age > 64 years	460-519	J00-J99					6735,3

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

[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.

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/m³** in all days exceeding this value (Information threshold of 2002/3/CE Directive)

1.2.1.2 Reduction **by 10 µg/m³** 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/m³** in all days exceeding this value (Limit for health protection of 2002/3/CE Directive)

1.2.2.2 Reduction **by 10 µg/m³** in the daily maximum 8-hour moving average concentrations.

Findings

The annual number of postneonatal deaths attributable to PM_{10} levels higher than 20 $\mu g/m^3$ was 0.05 (95%CI: 0.03 – 0.08) which is equivalent to an annual rate of number not available deaths per 100 000 (95%CI: not available).

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/m³	0,20 (0,09 – 0,31)	not available
	to 20 µg/m³	0,05 (0,03 – 0,08)	not available
	to 40 µg/m³	0	not available
Respiratory	by 5 µg/m³	0,08 (0,04 – 0,12)	not available
	to 20 µg/m³	0,02 (0,01 – 0,03)	not available
	to 40 µg/m³	0 (0 – 0)	not available
SIDS	by 5 µg/m³	0	not available
	to 20 µg/m³	0	not available
	to 40 µg/m³	0	not available
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
Hospital respiratory admissions <15 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

Regarding short-term effects of O_3, each reduction by 10 µg/m³ of daily maximum 8-hour average concentrations would delay 10.24 (95%CI: 5.62 – 17.18) deaths per year in the study area, 5.92 (95%CI: 2.83 – 9.39) from cardiovascular diseases, and 3.74 (95%CI: 2.45 – 4.99) 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	10,24 (5,65 - 17,18)	not available
	to 120 µg/m^3	0	not available
Cardiovascular	by 10 µg/m^3	5,92 (2,83 – 9,39)	not available
	to 120 µg/m^3	0	not available
Respiratory	by 10 µg/m^3	3,74 (2,45 – 4,99)	not available
	to 120 µg/m^3	0	not available
MORBIDITY	**Daily 1-h max**		not available
Emergency room visits for asthma <18 y	by 10 µg/m^3	0,16 (0,09 – 0,23)	not available
	to 180 µg/m^3	0	not available
	Daily 8-h max		
Hospital respiratory admissions 15-64 y	by 10 µg/m^3	1,88 (-16,94 – 22,58)	not available
	to 120 µg/m^3	0	not available
Hospital respiratory admissions > 64 y	by 10 µg/m^3	11,81 (-4,71 – 28,35)	not available
	to 120 µg/m^3	0	not available

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

Discussion

Despite the fact that both PM10 and ozone measured in Copenhagen, 2001 were below the currently Directive limits, which is established for protection of human health, the findings of this study indicate that reduction of these critical air pollutants by 5 µg PM10/m^3 and 10 µg/m^3 of daily maximum 8-hour average ozone concentrations, respectively, would delay a number of attributable cases of morbidity as well as mortality. The total number of attributable cases of postneonatal deaths which could be delayed by reduction of PM10 by 5 µg/m^3 is calculated to be 0.20 cases a year. For ozone the exposure levels were especially below the limit values. However, regarding short-term effects of ozone, reduction by 10 µg/m^3 of daily maximum 8-hour average concentrations would delay 10.2 deaths per year in Copenhagen, 5.9 from cardiovascular diseases, and 3.7 from respiratory causes.

A major limitation of the study is that the impact of other relevant exposures such as (?)other air pollutants not are included. Individual susceptibility related to culture (lifestyle, time-and-activity pattern), body weight, race, diseases, genetic background etc. are also ignored in the scenarios. Another potential bias of the study design is that the air data from the stationary monitor station do not perfectly represent the individual personal exposure levels. Sampling of a finer fraction of the PM10 may be a better indicator than mass measurement in relation to potential health impacts.

The number of deaths attributable to air pollution with particles and ozone in Copenhagen is less than the number of death caused by overweight or by smoking habits, but possibly in a comparable size with the risk factor of exposure to passive smoking.

As a member country of EU the regulatory authority of Copenhagen aim to reduce air pollution by introducing environmental zones in the downtown of Copenhagen in which heavy vehicles with particles filters or engines of EURO 5 norms only are allowed. For a few days a year the inner city is car free.

Conclusion

The findings of this study indicate that reduction of air pollutants with PM10 and ozone by 5 µg PM10/m^3 and 10 µg/m^3 of daily maximum 8-hour average ozone concentrations, respectively, would delay a number of attributable cases of morbidity as well as mortality.

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