

HEALTH IMPACT ASSESSMENT OF AIR POLLUTION

ENHIS-1 PROJECT: WP5 HEALTH IMPACT ASSESSMENT

LOCAL CITY REPORT

ROUEN

Summary of main findings for Rouen

In 2001 the PM_{10} annual mean (SD) was 21 (9) $\mu\text{g}/\text{m}^3$, above the 1999/30/EC Directive limit value for 2010 (20 $\mu\text{g}/\text{m}^3$), and below that established for 2005 (40 $\mu\text{g}/\text{m}^3$). 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 83 (29), 46 and 148 $\mu\text{g}/\text{m}^3$.

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 $\mu\text{g}/\text{m}^3$ would prevent 0.08 total postneonatal deaths. Reducing PM_{10} daily mean values to 20 $\mu\text{g}/\text{m}^3$ would prevent 5 hospital respiratory admissions of children under 15 years old.

As far as short-term effects of O_3 in summer are concerned, all other things being equal, each reduction by 10 $\mu\text{g}/\text{m}^3$ of the daily maximum 8-hour moving average concentrations would delay 5.4 deaths per year in the general population in the study area, 2.5 from cardiovascular diseases, and 1.1 from respiratory causes. In terms of hospital admissions, this would represent 0.5 respiratory admissions in the adult population and 2.6 in the population over 64 years.

Summary of HIA of outdoor air pollution in Rouen 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	5.39		
Cardiovascular mortality (ICD9 390-459 - ICD10 I00-I99)					1.0046 (1.0022-0.0073)		2.54		
Respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.0113 (1.0074-1.0151)		1.10		
Total postneonatal mortality	1 month-1 year	Corrected PM ₁₀ ³	Year	Annual	1.048 (1.022-1.075)	Lacasaña et al 2005		0.19	
Postneonatal respiratory mortality (ICD9 460-519 - ICD10 J00-J99)					1.216 (1.102-1.342)			0.00	
Postneonatal Sudden Infant Death Syndrom Mortality (ICD9 798.0 - ICD10 R95)					1.12 (1.07-1.17)	Woodruff 1997		0.11	
Morbidity									
Emergency room visits for asthma (ICD-9 codes 493, ICD-10 codes J45, J46)	< 18 years	O ₃ 1h max	Year	Daily	1.0115 (1.0067-1.0163)	CARB 2004	not available		
Cough	< 18 years	Measured PM ₁₀			1.0407 (1.0202-1.0511)	Ward and Ayres 2004			not available
Lower respiratory symptoms LRS	< 18 years	Measured PM ₁₀			1.0407 (1.0202 -1.617)	Ward and Ayres 2004			not available
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	< 15 years	Measured PM ₁₀			1.010 (0.998-1.021)	Anderson et al 2004		5.22	
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	15 - 64 years	O ₃ 8h max	Summer	1.001 (0.991-1.012)	0.46				
Hospital respiratory admissions (ICD9 460-519 - ICD10 J00-J99)	> 64 years			1.005 (0.998-1.012)	2.64				

¹ For ozone: absolute reduction by 10 µg/m³. For PM₁₀: absolute reduction by 5 µg/m³.

² Definition of summer period : 01 April – 30 September

³ PM₁₀ reference papers for HIA on postneonatal mortality use gravimetric methods to measure PM₁₀. 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 agglomeration of Rouen is located 120 km to the North-west of Paris and covers an area of 320 km². In 1999, the population of this area was approximately 448 000 inhabitants (15% of 65 years +). The study area includes 43 municipalities.

Rouen is situated in a basin surrounded by hills that, added to weak winds and/or thermal inversion phenomena, limit the dispersion of the air pollutants. There are mainly Southwest dominant winds, which push the air pollution of the industrial area towards the center of the town. The morning fogs are rather frequent. The minimum and maximum temperature averages were respectively 6.8°C and 14.3°C, in 2001. These temperatures were close to that realised over 30 years.

The city has a large industrial area along the Seine: petrochemistry and chemistry. Main sources of pollution are industry and traffic. Industrial emissions, like SO₂, show a trend toward a decrease over the last years, but levels of pollutants near industries, are above limit values. PM₁₀ levels are stable and ozone levels vary from one year to the next according to the sunning. To decrease pollution, two political frameworks organize the public air quality management: the regional plan for air quality (PRQA) and the plan for air protection (PPA) for Rouen's agglomeration which will be finished to write in 2006.

- in Rouen's study area, main causes of mortality in general population are cardiovascular diseases and bronchopulmonary cancers. The main causes of infant mortality are conditions arising during the perinatal period and congenital anomalies.
- Previous health impact assessments (HIA) of air pollution were conducted for the European program APHEIS and the French program PSAS-9, and were in favour of the measures taken to reduce emissions. The analysis of APHEIS 3 report have estimated that reduction of the long-term PM pollution to the levels of PM_{2.5} of 15 µg/m³ would reduce mortality in Rouen by 37 deaths in one year, which would save 20 years of expected life for starting year of simulation. If the daily means of PM₁₀ have been kept under 20 µg/m³, 8 deaths and 32 hospital admissions could have been avoided in the year 2001. In PSAS-9 report, the analysis show that a reduce of 10% of air pollution would save about 11 deaths.
- To complete these results, this report presents HIA results obtained for Rouen area. After a brief description of air pollution sources, exposure and health data, the results of the HIAs conducted on postneonatal mortality, cardiovascular and respiratory mortality, and respiratory hospital admissions in relation with ozone (short-term) and PM₁₀ (short- and long-term) are presented.
- 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 table shows the distribution of air pollution's sources in the region of Haute-Normandie (inventory emissions of Haute-Normandie 2000).

Table 1. Main sources of air pollution

Source	Industry (%)	transport (%)	Residential/ tertiary sector (%)	Agriculture (%)
SO ₂	92%	4%	2%	2%
NO _x	35%	38%	2%	25%
PM ₁₀	48%	31%	16%	5%

Principal sources of air pollution were traffic and industry. Rouen's share of regional air pollution emissions is estimated at 17 % for sulphur dioxide (SO₂) and 12 % for nitrogen dioxide (NO₂) and PM₁₀. 92 % of Rouen's SO₂ emissions are due to industry. Road traffic and industry share the responsibility for the NO_x emissions. Ozone levels depend on sunning and other pollutants like NO₂ and VOC (volatile organic components) which are mainly produced by traffic.

Exposure data

- A permanent automated air pollution network (Air Normand) provides air pollution data. The agglomeration is covered by 14 fixed stations including 4 urban. Ozone is measured in 6 stations by UV adsorption method. PM₁₀ are measured by automatic analyzer TEOM (Tapered Element Oscillating Microbalance) in 2 stations.
- How indicators have been calculated:

The stations used to construct pollution indicators were selected in the city area according to the following criteria: the ambient urban stations had to be correlated (correlation ≥ 0.70) and to present close mean levels of pollution. For PM₁₀, 2 urban stations were selected, and 6 stations for ozone.

 - PM₁₀: daily exposure indicator has been calculated as the arithmetic mean of the daily concentrations of the stations. For HIA purpose for chronic exposure, ENHIS recommended to correct TEOM PM₁₀ in order to make up for losses of volatile compounds, because the corresponding RRs were obtained using gravimetric PM₁₀ as a measure of exposure. In Rouen, as part of the French national pilot program for PM surveillance, specific polynomial regression has been used for each city PM₁₀ correction. The coefficients of these regressions were derived from parallel PM₁₀ measurements within each city¹.
 - Ozone: the daily maximum 1-hour indicator has been calculated as the arithmetic mean of the 1-hour maximum of the stations. The daily maximum 8-hour moving averages of each day have been calculated as the arithmetic mean of the maximum 8-hour moving averages of the stations for the summer period (1st April to 30th September).
- AP data description:

The annual mean level (SD) of TEOM PM₁₀ in Rouen was 21 (9) $\mu\text{g}/\text{m}^3$, and P5 and P95 of the daily mean values were, respectively, 12 $\mu\text{g}/\text{m}^3$ and 38 $\mu\text{g}/\text{m}^3$.
 The annual mean level (SD) of corrected PM₁₀ in Rouen was 22 (10) $\mu\text{g}/\text{m}^3$, and P5 and P95 of the daily mean values were, respectively, 12 $\mu\text{g}/\text{m}^3$ and 41 $\mu\text{g}/\text{m}^3$.
 The mean (SD), P5 and P95 of the daily maximum 8-hour moving average concentrations of O₃ in summer were, respectively, 83, 46 and 148 $\mu\text{g}/\text{m}^3$, and those of the daily maximum 1-hour concentrations (entire year) 71, 27 and 141 $\mu\text{g}/\text{m}^3$ (Table 1 and figures 1-3).
 In 2001 the PM₁₀ annual mean (21 $\mu\text{g}/\text{m}^3$), was above the 1999/30/EC Directive limit value for 2010 (20 $\mu\text{g}/\text{m}^3$) but below the one established for 2005 (40 $\mu\text{g}/\text{m}^3$).

¹ Jean-Luc HOUDRET, François MATHE. Programme pilote national de surveillance des particules PM₁₀ et PM_{2.5}. Ecole des mines de Douai, Département Chimie et environnement, Etude n°10. 2003

The figures 1, 2 and 3 represent the distributions of levels of the 3 indicators: O₃ 8h, O₃ 1h and PM₁₀. Levels most often present were between 70 and 80 µg/m³ for ozone 8h in summer and between 10 and 30 µg/m³ for corrected PM₁₀ in year 2001. Maximum Ozone 8h levels were higher than 120 µg/m³ during 23 days in 2001 and respect thus target value for 2010 (120 µg/m³ not to be exceeded on more than 25 days per calendar year averaged over three years). The directive limit value for 2010 for PM₁₀ was exceeded 47% of the days in 2001.

Table 1. Descriptive statistics for ozone and PM₁₀ levels in Rouen for 2001

	O3 8h - summer	O3 1h max - year	Corrected PM ₁₀ - year
Number	183	365	365
Minimum	32,0	7,2	6
Percentile 5	46,2	26,9	11
Percentile 25	64,5	51,5	16
Median	79,3	66,9	20
Percentile 75	93,5	84,8	25
Percentile 95	147,7	141,3	41
Percentile 98	157,5	160,9	50
Maximum	190,1	221,0	83
Daily mean	83,2	71,4	22
standard error	28,6	32,4	10
% missing values	0.00%	0.00%	0,00%

Fig 1. Distribution of O3 8h max in Rouen area - summer 2001

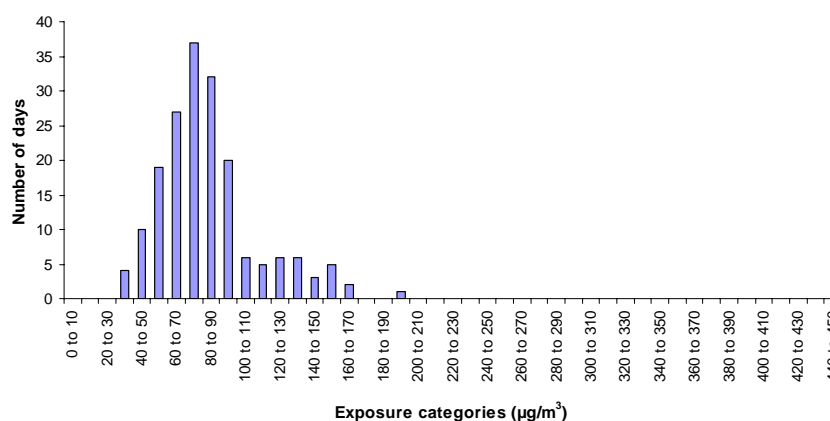


Fig 2. Distribution of O3 1h max in Rouen area - year 2001

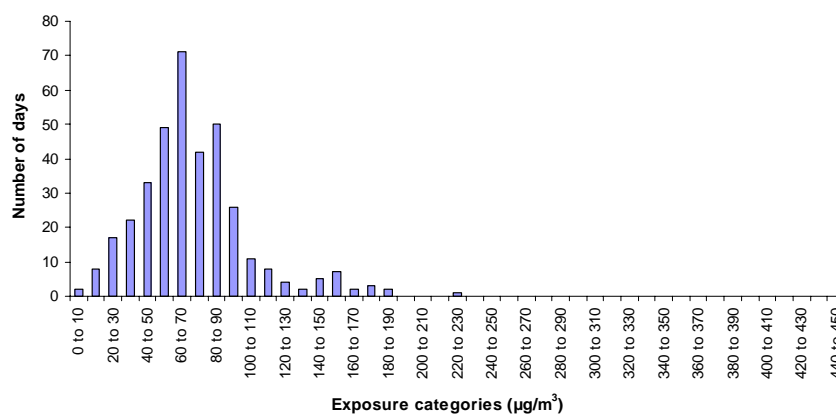
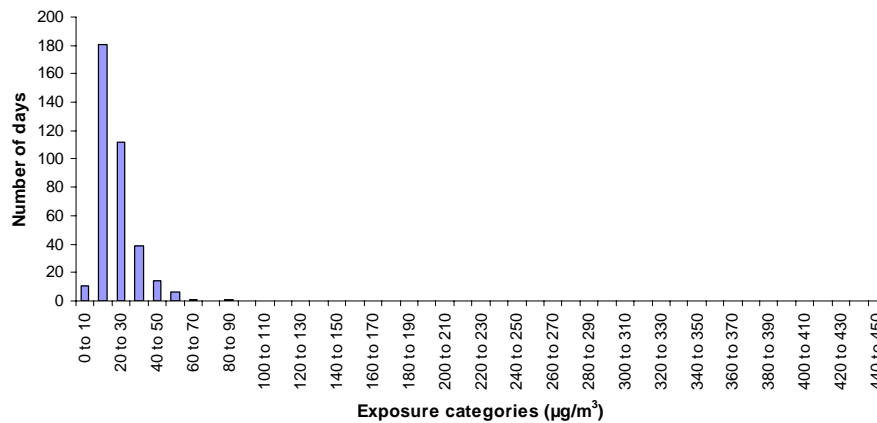


Fig 3. Distribution of PM10 in Rouen area - year 2001



Health data

- Mortality data were provided by the Information Department specialised in mortality data (CepiDC) at the National Health and Medical Research Institute (INSERM) for year 2001. There are no missing data, and a quality control program is applied. Death causes for year 2001 were coded according to ICD-10. Most of the coding (about 80%) was automated.
- Hospital admissions data for respiratory diseases were extracted by the French Institute of Public Health (InVS) from the hospital information system PMSI (Programme de médicalisation des systèmes d'information) for public and private hospitals in Rouen. Respiratory diseases are coded with ICD10 and available for year 2001.
- Data concerning specifically emergency hospital admissions, emergency room visit for asthma, cough or lower respiratory syndromes were not available for Rouen study area, and hence no HIA was conducted for these indicators.

Description of the health outcomes analyzed for HIA are shown in Table 2 in terms of number of cases and rates per 100 000.

Table 2. Descriptive statistics for health outcomes in Rouen area, 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			8	148			
Respiratory ICD9 460-519 ICD10 J00-J99	460-519	J00-J99	0	0			
Sudden infant death syndrome ICD9 798.0 – ICD10 R95	798.0	R95	2	37			
GENERAL POPULATION MORTALITY							
Total mortality all causes ICD9 <800 ICD10 A00-R99	<800	A00-R99			9.7 (3.3)	2.2	
Cardiovascular mortality ICD9 390-459 ICD10 I00-I99	390-459	I00-I99			3.1 (1.8)	0.7	
Respiratory mortality ICD9 460-519 ICD10 J00-J99	460-519	J00-J99			0.6 (0.7)	0.1	
MORBIDITY							
Cough					not available		
Lower respiratory symptoms LRS					not available		
Emergency room visits for asthma - Age < 18 years ICD9 493, ICD10 J45 J46	493	J45-J46			not available	not available	
Hospital respiratory admissions - Age < 15 years ICD9 460-519 ICD10 J00-J99	460-519	J00-J99					1 317.7
Hospital respiratory admissions - Age 15 -64 years	460-519	J00-J99					309.3
Hospital respiratory admissions - Age > 64 years	460-519	J00-J99					1 618.1

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 Apehis team² 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 WP5³.

² 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:

³ 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-O₃- 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 PM₁₀

1.1.- Scenarios for HIA on **short-term** effects of PM₁₀ 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 PM₁₀ levels to a 24-hour value of **50 µg/m³** in all days exceeding this value (Limit of 1999/30/CE Directive)

1.1.2. Reduction of PM₁₀ levels to a 24-hour value of **20 µg/m³** in all days exceeding this value

1.1.3 Reduction **by 5 µg/m³** of all the 24-hour values

1.2.- Scenarios for HIA on **long-term** effects of PM₁₀ and **postneonatal mortality** (total, respiratory and sudden infant death syndrome-SIDS)

1.2.1 Reduction of the annual mean value of PM₁₀ to a level of **40 µg/m³** (Limit of 1999/30/CE Directive for 2005)

1.2.2 Reduction of the annual mean value of PM₁₀ to a level of **20 µg/m³** (Limit of 1999/30/CE Directive for 2010)

1.2.3 Reduction **by 5 µg/m³** of the annual mean value of PM₁₀

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 O₃ 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 O₃ 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 corrected PM₁₀ levels higher than 20 µg/m³ was 0.08 (95%CI: 0.04 – 0.13), which is equivalent to an annual rate of 1.55 deaths per 100 000 (95%CI: 0.72-2.40).

Table 5. Potential benefits of reducing PM₁₀ levels. Absolute numbers and rates (per 100 000 children) (95% confidence limits) attributable to the health effects of PM₁₀.

PM ₁₀ reduction			
POSTNEONATAL MORTALITY	Corrected Annual mean levels	Number of attributable cases per year	Annual rates (per 100.000)
Total	by 5 µg/m ³	0.19 (0.09 – 0.29)	3.44 (1.58 – 5.33)
	to 20 µg/m ³	0.08 (0.04 – 0.13)	1.55 (0.72 – 2.40)
	to 40 µg/m ³	NA	NA
Respiratory	by 5 µg/m ³	0.00	0.00
	to 20 µg/m ³	0.00	0.00
	to 40 µg/m ³	NA	NA
SIDS	by 5 µg/m ³	0.11 (0.07 – 0.15)	2.04 (1.21 – 2.86)
	to 20 µg/m ³	0.05 (0.03 – 0.07)	0.93 (0.55 – 1.30)
	to 40 µg/m ³	NA	NA
MORBIDITY	Measured 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	
Hospital respiratory admissions <15 y	by 5 µg/m ³	5,22 (-1.05 – 10.93)	6,47 (-1.30 – 13.54)
	to 20 µg/m ³	4,21 (-0.84 – 8.88)	5,21 (-1.04 – 10.99)
	to 50 µg/m ³	0,11 (-0.02 – 0.22)	0,13 (-0.03 – 0.28)

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

Regarding short-term effects of O₃, each reduction by 10 µg/m³ of daily maximum 8-hour moving average concentrations would delay 5.39 (95%CI: 2.96 – 9.05) deaths per year in the study area, 2.54 (95%CI: 1.21 – 4.02) from cardiovascular diseases, and 1.10 (95%CI: 0.72 – 1.46) 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.

Emergency room visits for asthma <18 y	OZONE reduction by 10 µg/m ³ to 180 µg/m ³	Number of attributable cases per year	Annual rates (per 100.000)
		not available	not available
MORTALITY	Daily 8-h max		
Total	by 10 µg/m ³	5.39 (2.96 – 9.05)	1.20 (0.66 – 2.02)
	to 120 µg/m ³	1.63 (0.89 – 2.74)	0.36 (0.20 – 0.61)
Cardiovascular	by 10 µg/m ³	2.54 (1.21 – 4.02)	0.57 (0.27 – 0.90)
	to 120 µg/m ³	0.78 (0.37 – 1.24)	0.17 (0.08 – 0.28)
Respiratory	by 10 µg/m ³	1.10 (0.72 – 1.46)	0.24 (0.16 – 0.33)
	to 120 µg/m ³	0.37 (0.24 – 0.49)	0.08 (0.05 – 0.11)
MORBIDITY	Daily 1-h max		
	Daily 8-h max		
Hospital respiratory admissions 15-64 y	by 10 µg/m ³	0.46 (-4.15 – 5.53)	0.15 (-1.39 – 1.85)
	to 120 µg/m ³	2.64 (-1.06 – 6.34)	0.05 (-0.40 – 0.55)
Hospital respiratory admissions > 64 y	by 10 µg/m ³	2.64 (-1.06 – 6.34)	3.91 (-1.56 – 9.39)
	to 120 µg/m ³	0.82 (-0.32 – 1.97)	1.21 (-0.48 – 2.92)

Discussion

- In order to decrease potential exposure misclassification, the study area was defined using population exposure homogeneity criteria: this area doesn't present any discontinuance in

urbanisation, the work-place of the majority of working inhabitants was located in the area and, air pollution data homogeneity (close means and high correlation coefficients) was checked on multi-sites measurements time series. For PM₁₀ levels, the correction factors must be used cautiously because the proportion of volatile matter within the particles varies according to multiple factors (meteorological conditions, chemical composition of particles...). The use of new methods of measurement (Sampler equilibration system, for example) avoiding loss of volatile matter might be a better way of assessing PM₁₀ exposure for the purpose of long-term HIA.

- Mortality data are highly reliable and hence don't represent a major source of uncertainty for the results of the present HIAs. The principal source of uncertainty of health data lies in hospital admissions data. Indeed these data correspond to total admissions and not only emergency admissions due to the registry organisation. It can lead to overestimate the health impact assessment because included planned admissions can't be related to exposure.
- In Rouen study area, daily ozone 8-h max levels were higher than 120 µg/m³ during 23 days in 2001 and respect target value for 2010 (120 µg/m³ not to be exceeded on more than 25 days per calendar year averaged over three years). However, there is a significant number of deaths (total, cardiovascular and respiratory) attributable to daily ozone 8-h max levels above 120µg/m³ (respectively about 1.63, 0.78 and 0.37, see table 6). Hence, compliance with 2010 objectives for ozone would induce health benefits for the population in terms of deaths, and probably of hospital admissions. Reduction of daily 8-h max levels of ozone by 10µg/m³ would induce more health benefits in terms of mortality (respectively 5.39, 2.54 and 1.1 for total, cardiovascular and respiratory mortality).
- PM₁₀ levels are below the 2005 limit values (40µg/m³) but above that planned for 2010 (20µg/m³). Hence, there are no attributable cases for the scenario corresponding to a reduction of the annual mean to 40µg/m³. Regarding children, infant mortality is quite low (like in Europe) and consequently, the expected attributable number of deaths related to air pollution is also very low. However, the results show that the compliance with 2010 limit value for PM₁₀ would certainly induce health benefits in the study area.
- The number of attributable cases may seem small when it's compared with the number of deaths attributable to other risk factors, especially tobacco smoking. However, air pollution exposure concerns everyone, whereas exposure to other risk factors may be easier to control at the individual scale.

Conclusion

These results complete those presented in the report Apheis 3 for the agglomeration of Rouen with an estimation of the impact of particles PM₁₀ and Ozone. They confirm that medical profits can be potentially obtained by the improvement of the quality of the air even air pollution is right now moderate.

The results from the present HIAs will allow to sensitive the decision makers and general public with the impact of the air pollution, and particularly PM₁₀ on the young children's health. This impact, even weak, is significant and cannot thus be neglected. It may help promoting measures aiming at reducing air pollutant emissions, especially traffic which takes part in majority in the production of ozone. These results and those stem from the European program APHEIS and the French program PSAS-9, were used to the PPA of Rouen and to justify the construction of Rouen's bypass.

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