HEALTH IMPACT ASSESSMENT OF PM_{10} EXPOSURE IN THE CITY OF CAEN, FRANCE: IS ELIMINATING AIR POLLUTION PEAKS ENOUGH?

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ABSTRACT

Air pollution in Caen, a city in northwestern France, comes mainly from motor vehicles. The aim of this study was to assess the public health impact of both acute (with immediate or short-term effects) and chronic (with long-term effects) exposure to PM_{10} (particulate matter <10 µm). The standard World Health Organisation (WHO) methodology for a Health Impact Assessment (HIA) was used to calculate the attributable deaths and hospital admissions. Population exposure was estimated from PM_{10} concentrations collected by the local air quality measurement network. The relative risks were modelled with exposure-risk functions established in epidemiologic studies in the general population. The APHEA-2 program, which combines European time-series studies, was used to assess effects from acute exposures and a meta-risk was calculated from cohort studies to assess the effects of chronic exposure. The health impact of chronic exposure from 1998 through 2002 was estimated at 168 (101-238) deaths. Acute exposure (relative to a baseline level of 10 µg/m^3) led to 26 (17-35) deaths and 43 (22-67) hospital admissions during this period. A 10% daily decrease in pollution would reduce the number of expected deaths from short-term exposure by 19%, while achieving compliance with European Union regulations (daily mean in 2010: 50 µg/m^3) would reduce them by less than 3%. Because the health impact of the pollution in Caen is due mainly to relatively moderate levels, reducing everyday pollution levels through long-term regulation would be more beneficial than avoiding pollution peaks.

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INTRODUCTION

Methodological progress in epidemiologic studies since the 1990s (Bell et al., 2004; Goldberg et al., 2003) has made it possible to show that air pollution today, when industrial pollution has decreased but automobile pollution has increased, still affects population health.

The metropolitan area of Caen is home to 173 000 inhabitants, nearly all living and working in this area (INSEE, 1999). The quality of air in this city is influenced primarily by motor vehicle emissions (Fontell et al., 1997). In 1999 the short-term health impact of urban air pollution in Caen was assessed, on the basis of data from October 1997 through October 1998 (Glorennec et al., 2002). More recent literature includes epidemiologic studies estimating the long-term impact of pollution on mortality and articles on the respective advantages and limitations of short- and long-term health impact assessments (HIA) (McMichael et al., 1998; Quenel et al., 1999). In November 2000, the World Health Organisation released recommendations on this topic (WHO, 2001). This progress in epidemiology led public health professionals to consider whether HIAs that also cover long-term effects would be useful at local levels.

The goals of this study were thus to meet the regulatory obligations of the French Clean Air Act (Journal officiel de la Republique Francaise, 1997) to assess the health effects of air pollution and to provide information about its local effects to the public. Accordingly, we sought to assess the public health impact of both acute (with short-term effects) and chronic (with long-term effects) exposure to PM_{10}. The presentation of epidemiologic results cannot always be easily interpreted by local decision-makers, who nonetheless manage French transportation policy; the interface between science and policy must be strengthened. Accordingly, in order to help improve the effectiveness of public policy-making, we sought to compare the health impact of two types of strategies: avoidance of pollution peaks and decreasing the mean pollution level.

Methods

Health impact was assessed by calculating the number of attributable cases, according to the method recommended by WHO (1999). The proportion of cases attributable to a causal risk factor is described by (Glorennec and Quénel, 1999):

$$Pa = \frac{f\,(RR-1)}{1+f\,(RR-1)} \text{ or } \frac{RR-1}{RR} \text{ if } f = 1$$

where
Pa: proportion or fraction of attributable cases;
RR: relative risk;
f: prevalence of exposure.
Na = Pa * N

where
Na: number of cases attributable to air pollution; and
N: total number of cases (incidence).

The endpoints we studied were effects that have been demonstrated in epidemiologic studies conducted in the general population at comparable exposure levels and for which local incidence data were available. They included mortality for all causes except accidents (ICD S00-X59) and hospital admissions for respiratory (ICD J00-J99) and cardiovascular (ICD I00-I99) causes.

We used exposure-risk functions reported by time-series epidemiologic studies to examine immediate effects of PM_{10} exposure and cohort studies to look at the long-term effects. The estimators we used (cf. Table 1) are those recommended by the French Institute for Public Health Surveillance (Pascal and Cassadou, 2003) and are based on studies from the European APHEA-2 program (Atkinson et al., 2001; Künzli et al., 2000). The relative risks were calculated from these exposure-risk relations.

Table 1: Relative risks (RR) for a 10 µg/m^3 increase of PM_{10}.

Pollutant	Indicator	Lower	Mid	Upper	source
PM_{10}	Short term mortality	1.004	1.006	1.008	APHEA2
	Short term respiratory morbidity > 65 years	1.006	1.009	1.013	APHEA2
	Short term cardiac morbidity	1.002	1.005	1.008	APHEA2
	Short term cardiac morbidity > 65 years	1.004	1.007	1.01	APHEA2
	Short term mortality, adults > 30 years	1.026	1.043	1.061	Kunzli 2000

The exposure levels were measured by AirCOM, the local air quality measurement network. Daily exposure levels (Table 2) were based on the arithmetic mean of the daily data for the two available PM_{10} sensors from 1 April 1998 through 31 March 2002.

Table 2. Estimated outdoor PM_{10} exposure (µg/m^3). Caen 1998-2002.

	PM_{10} (µg/m^3)
Min	2
P 5	7
P 25	12
P 50	17
P 75	25
P 95	42
Max	87
Daily mean	19
Standard deviation	11.4
% missing values	1%

CepiDC provided the data for mortality from all causes except accidents (ICD 10 = S00-X59) for adults (>30 years) residing in the study area: 562 deaths during winter months and 526 in summer (Caen April 1998-April 2002). The hospital admissions data came from the medical information department of the Caen University Hospital Centre (Table 3).

Table 3: Number of hospital admissions for cardiovascular (ICD I00 to I99) and respiratory (ICD J00 to J99) disorders at the Caen UHC.

	I00 to I99 15-64 years	≥ 65 years	Total	J00 to J99 15-64 years	≥ 65 years	Total
Total study period	2033	4841	6899	1559	2218	5167
Annual mean	407	968	1380	312	444	1033
Total summer period	934	2381	3329	731	969	2161
Mean annual summer	187	476	666	146	194	432
Total winter period	1099	2460	3570	828	1249	3006
Mean annual winter	220	492	714	166	250	601

We used Excel©-based EIS-PA software (Franke, 2003) to calculate health impact, relative to a reference level of 10 µg/m^3, considered as the "no pollution" (or background) level. Daily time series of pollution levels make it possible to calculate the impact of each exposure level.

For acute exposures, we assessed:

- the health impact of a 10% reduction in daily pollution levels, which would correspond to "moderate" improvement in air pollution,
- daily compliance with the EU recommended daily mean for 2010 (50 µg/m^3).

Results

Table 4 summarises the impact of the air pollution over the study period.

Table 4: Health impact of outdoor PM_{10}. Caen 1998-2002.

	Health effect	Attributable cases (95% CI)
	Mortality	26 (17-35)
Short-term	Hospital admissions, respiratory causes	16 (11-23)
	Hospital admissions, cardiovascular causes	27 (11-44)
Long-term	Mortality	168 (101-238)

As shown in Figure 1, if we consider the effects due to short-term exposure, a daily reduction of 10% in the pollution level would reduce the number of deaths by 19%, while daily compliance with the European standard of 50 µg/m^3 would yield an improvement of only 2.5 %.

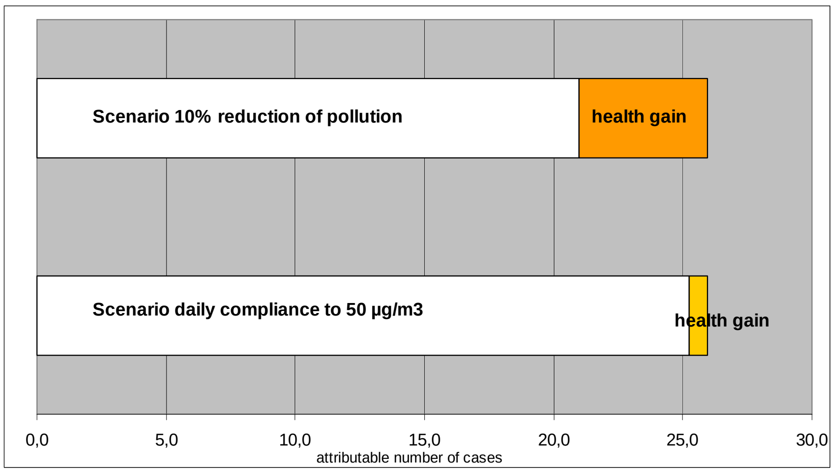

Figure 1. Health effectiveness of particulate air pollution policy scenarios, 1998-2002.

Figure 2 illustrates the health impact of different levels of exposure to air pollution. Approximately two thirds of this effect comes from pollution levels less than 40 µg/m^3.

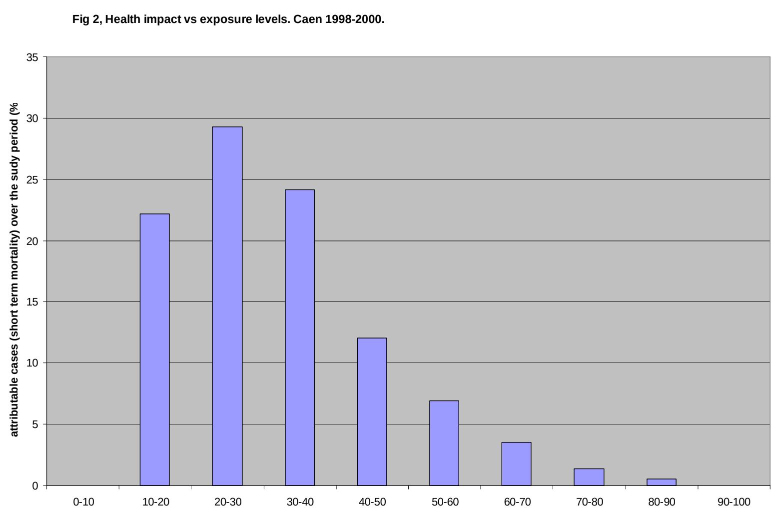

Figure 2. Health impact vs exposure levels. Caen 1998-2000.

DISCUSSION AND CONCLUSIONS

The concept of attributable risk presupposes that the relation between air pollution and health is causal. That is, the risk attributable to a risk factor can be calculated only if there is serious evidence of causality between exposure and disease (Coste and Spira, 1991). This causality is increasingly evident for particles (Dab et al., 2001). Because of the correlations between different air pollutants, however, this concept of attributable risk must be understood to apply to exposure to air pollution as a whole. We approach this complex chemical mixture through pollution indicators, here PM_{10}.

In the field of urban air pollution, exposure-risk functions are based on observations in humans at low exposure levels; extrapolation from animals to humans or from high to low doses is not required. On the other hand, we applied relations established elsewhere to our study area, although we cannot be certain of the validity of this procedure. That is, the same pollution indicator may be a tracer of different pollution profiles, especially, for example, if the automobile fleets in the two places differ (France has a larger proportion of diesel engines than many other countries). The exposure-risk functions we used for the short-term effects come from the APHEA-2 (Katsouyanni et al., 2001) program and are based on observations in several cities of western Europe. They should thus be robust and applicable to France. For the long-term effects, the same functions used by Künzli et al. (2000) from US cohort studies (Dockery et al., 1993; Pope et al., 1995) were applied. These studies estimated exposure based on an annual mean level of PM_{10}, data which is also available for Caen. We chose not to use the study by Hoek et al. (2002), although it was European, because its exposure indicator was constructed in conditions different from ours: it used a mix of regional and local exposure data. We also chose not to use the most recent and most powerful study, by Pope et al. (2002), because its exposure-risk relations were based upon $PM_{2.5}$ and not PM_{10}. On the other hand, we used the risk function from Pope et al. (2002) and a $PM_{2.5}/PM_{10}$ coefficient of 0.7 to analyse the sensitivity of our results: this yielded 109 (27-218) deaths for long-term exposure in the study area during the study period, compared with 168 (101-238) with the risk function we used initially.

For morbidity, we took into account only the respiratory effects leading to hospitalisation, even though it is likely that only a small fraction of the population with pollution-related respiratory problems go to the hospital; the impact of pollution on morbidity is therefore underestimated. Künzli et al. (2000), for example, calculated that there are approximately 135 000 asthma attacks annually in France, but “only” 19 000 hospital admissions attributable to air pollution. Local asthma prevalence data are required to assess the impact of pollution on such health endpoints as asthma attacks, and local authorities must plan to conduct asthma surveys if they want this relevant impact to be assessed.

Use of only two PM sensors to assess exposure undoubtedly results in less than optimally reliable estimates. Nevertheless these two sensors are located in areas representative of the study area, and wider-scale air quality measurements were taken previously to choose the sensor locations.

The baseline exposure level is an especially sensitive parameter in calculating impact. Choosing a lower baseline (e.g., 7.5 µg/m^3), as Künzli et al. (2000) did, increases the impact of the same pollution measurements. With this lower baseline, there are 32 (21-42) short-term deaths, compared with 26 (17-35) with a 10 µg/m^3 baseline.

Because of these limitations, the results should be interpreted as orders of magnitude. These results are not sufficiently accurate to measure the precise impact of particulate air pollution in Caen nor to predict the exact impact of policies. They are, however, accurate enough to yield general conclusions that can be used in setting local air quality policies.

The results show that air pollution, even at moderate levels below the current recommended standards, affects the population's health. Moreover, although the relative risks associated with air pollution are modest, the large fraction of exposed persons leads to a substantial collective impact.

This impact is expressed by effects that are simultaneously short- and long-term. The long-term effects are, as our results suggest (cf. Table 4), higher in terms of mortality; they exceed the simple addition of the short-term effects (Künzli et al., 2001). Long-term exposure promotes the development of chronic diseases (Künzli et al., 2001), including lung cancer (Pope et al., 2002; Cohen, 2000). The short-term effects are often described as affecting specific population groups, children or the elderly, often with preexisting diseases (Filleul et al., 2003; Gouveia and Fletcher, 2000). Nevertheless, those affected were not often terminally ill (Schwartz, 1994;

Brunekreef and Holgate, 2002). Estimates of reduced life expectancy remain uncertain; Finkelstein recently showed (Finkelstein et al., 2004) that living near a heavily-trafficked road reduces life expectancy by 2.5 years.

Because these long-term effects are due to exposure over long periods of time, improvement of the air quality will only slowly produce long-term benefits (Leksell and Rabl, 2001). Accordingly, for example, the effects in the study by Pope et al. (2002) are associated with exposure averaged over 16 years: a short-term diminution of x% will thus take 16 years to produce the totality of its expected effects.

Episodes of high pollution often monopolize the debate about air pollution. The underlying idea is that if their consequences were mastered, the air pollution issue would be resolved. That is simply not true (Dab et al., 1998), even when we consider only the effects of acute exposures. Although "high pollution" days have the greatest daily impact, their low frequency (cf. Figure 2) means that they play a limited role compared with the consequences of moderate air quality throughout an entire year. As we showed, daily compliance with the European standard of 50 $\mu g/m^3$ would yield an improvement of only 2.5%. Even reducing PM_{10} levels above 40 $\mu g/m^3$ (EU regulatory level for an annual mean in 2005), by limiting traffic when bad dispersion conditions are forecast, would reduce the annual air pollution health burden by only 6%. Moreover, pollution peaks do not contribute much to long-term exposure, the impact of which is greater than acute exposure. In practice, this means that a local risk management policy aimed exclusively at avoiding exposures exceeding regulatory levels will have only a marginal impact on public health.

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