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Denis Bard, Olivier Laurent, Laurent Filleul, Sabrina Havard, Séverine Deguen, Claire Segala, Gaëlle Pédrone, E. Rivière, Charles Schillinger, L. Rouil, et al.

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# Exploring the joint effect of atmospheric pollution and socioeconomic status on selected health outcomes: an overview of the PAISARC project

D Bard<sup>1,8</sup>, O Laurent<sup>1</sup>, L Filleul<sup>2</sup>, S Havard<sup>1</sup>, S Deguen<sup>1</sup>, C Segala<sup>3</sup>, G Pedrono<sup>3</sup>, E Rivière<sup>4</sup>, C Schillinger<sup>4</sup>, L Rouil<sup>5</sup>, D Arveiler<sup>6</sup> and D Eilstein<sup>7</sup>

<sup>1</sup> Ecole Nationale de la Santé Publique, Rennes, France

<sup>2</sup> CIRE Aquitaine, Bordeaux, France

<sup>3</sup> Sepia-Santé, Melrand, France

<sup>4</sup> ASPA, Schiltigheim, France

<sup>5</sup> INERIS, Verneuil-en-Halatte, France

<sup>6</sup> Registre des Cardiopathies Ischémiques du Bas-Rhin, Laboratoire d'épidémiologie et de santé publique-EA 1801, Université Louis Pasteur, Strasbourg, France

<sup>7</sup> Institut de Veille Sanitaire, Saint Maurice, France

E-mail: [dbard@ensp.fr](mailto:dbard@ensp.fr)

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## Abstract

Health socioeconomic gradients are well documented in developed countries, but incompletely explained. A portion of these health inequalities may be explained by environmental exposures. The objective of PAISARC is to explore the relations between socioeconomic status, air pollution exposure and two selected health outcomes—asthma exacerbations and myocardial infarction—at the level of a small area. The study design is ecological, using data available from the national census, with the residential block (French IRIS, 2000 people on average, National Institute of Statistics—INSEE) as the statistical unit. The setting is the Greater Strasbourg metropolitan area (450 000 inhabitants) in eastern France. We first constructed a socioeconomic status index, using 1999 national census data and principal component analysis at the resolution of these census blocks. Air pollution data were then modeled at the same resolution on an hourly basis for the entire study period (2000–2005). Health data were obtained from various sources (local emergency networks, the local population-based coronary heart disease registry, health insurance funds) according to the health outcome. We present here the initial results and discuss the methodological approaches best suited for the forthcoming steps of our project.

**Keywords:** air pollution, socioeconomic factors, asthma, myocardial infarction, small area analysis

## 1. Introduction

In most industrialized countries, socioeconomic gradients in the morbidity and mortality rates for respiratory [1, 2] and cardiovascular diseases [3, 4] are well documented: lower

socioeconomic status (SES) is a greater risk factor for these adverse health outcomes. Socioeconomic inequalities in health can partly be attributed to biological and behavioral factors (such as smoking, alcohol consumption and physical activity), psychosocial factors (stress and social support), material living circumstances and access to health care [5].

<sup>8</sup> Author to whom any correspondence should be addressed.

**Table 1.** Distribution of emergency visits for asthma attacks by sex and age group.

Age group	Males No. cases (%)	Females No. cases (%)	Unspecified sex No. cases (%)	Total No. cases (%)
All ages	1680 (35.5)	2369 (50.1)	680 (14.4)	4729 (100)
0–10	52 (3.1)	34 (1.4)	454 (66.8)	540 (11.4)
10–20	74 (4.4)	146 (6.2)	196 (28.8)	416 (8.8)
20–40	321 (19.1)	605 (25.5)	26 (3.8)	952 (20.1)
40–65	535 (31.8)	601 (25.4)	2 (0.3)	1138 (24.1)
65+	673 (40.1)	963 (40.7)	1 (0.1)	1637 (34.6)
Unspecified age	25 (1.5)	20 (0.8)	1 (0.1)	46 (1.0)

Another portion of these inequalities may be explained by environmental exposures, especially exposure to urban air pollution [6]. The objective of the PAISARC project (air pollution, socioeconomic disparities, asthma and myocardial infarction) is to explore the relations between SES, environmental exposures and health outcomes on a small-area ecological basis. Specifically, we study the relations between short-term exposure to atmospheric pollution and two health outcomes: (i) asthma exacerbations (PAISA project [7]), and (ii) myocardial infarction (PAISIM project [8]). Such a small-area approach has not yet been employed in Europe for these health outcomes.

## 2. Methodology

### 2.1. Setting, statistical unit

The setting of our study is the Greater Strasbourg metropolitan area, which is, according to the 1999 national census, an urban area of 450 000 inhabitants distributed among 28 municipalities in eastern France. The statistical unit is the French census residential block (IRIS for *Ilôts Regroupés pour l'Information Statistique*), a sub-municipal division used by the National Institute for Statistics and Economic Studies (INSEE). Each French municipality is thus subdivided according to its demographic and geographic size into one or more blocks (effective mean of 2000 inhabitants). This unit is the smallest geographic area in France for which demographic and socioeconomic information from the national census is available. It is comparable in terms of population size to the US census block group, which according to Krieger [9] is a relevant geographic area for describing socioeconomic inequalities in health. Greater Strasbourg is subdivided into 190 blocks. Sixteen blocks covering a very small population (0.2% of the total population) were removed from the study.

### 2.2. Socioeconomic data

INSEE provided demographic and socioeconomic data from the 1999 national population census for each block. To synthesize information from these data, we decided to build a new census-based deprivation index by a principal component analysis (PCA) at the block resolution [10]. For our analyses, we initially selected 52 quantitative standardized variables that describe numerous aspects of SES (including education, income, occupation, and housing characteristics). To construct

**Table 2.** Distribution of  $\beta_2$ -agonist short-term bronchodilator drug sales for people aged 0–40 years by sex and age group.

Age group	Males No. cases (%)	Females No. cases (%)	Total No. cases (%)
0–40	9488 (54.0)	8070 (46.0)	17 558 (100)
0–10	3356 (35.4)	1903 (23.6)	5 259 (29.9)
10–20	1969 (20.7)	1395 (17.3)	3 364 (19.1)
20–40	4163 (43.9)	4772 (59.1)	8 935 (50.9)

a single numerical index for all the blocks, we decided to maximize the variance (the inertia) of the first component by deleting all the variables weakly correlated with it and the variables with a contribution lower than the average. All analyses were carried out with SAS<sup>®</sup> software (*SAS Institute Inc., Cary, NC, USA*).

To compare our deprivation index with other such scales, we also calculated deprivation with the two most popular indices in the literature, both British: Carstairs' [11] and Townsend's [12]. We had to modify Carstairs' slightly, since British and French socioeconomic categories do not match exactly. We estimated the convergence between our SES index and these indices with Pearson's correlation coefficient (*r*). More details can be found elsewhere [10].

We used ArcGIS<sup>™</sup> software (*ESRI Inc., France*) to map the socioeconomic disparities in Greater Strasbourg.

### 2.3. Health data

**2.3.1. PAISA project: asthma exacerbations.** Two emergency healthcare networks in Greater Strasbourg (SAMU and SOS Médecins) provided data about emergency visits by physicians for asthma attacks from January 1, 2000, through December 31, 2005 (*n* = 4729 cases, all ages). Table 1 presents the distribution of cases by sex and age group.

$\beta_2$ -agonist (short-term) bronchodilator drugs are standard and effective prescription treatments for asthma exacerbation episodes. These drugs are also used to treat chronic obstructive pulmonary disease. Since this disease is quite rare below the age of 40, we searched databases of all five national or local health insurance funds for 2004 data about daily sales of  $\beta_2$ -agonist drugs to people in our study area younger than 40. About 17 000 prescriptions for asthma exacerbations were recorded (table 2).

**Table 3.** Distribution of cases of myocardial infarction in people aged 35–74 years, by sex and age group.

	Males No. cases (%)	Females No. cases (%)	Total No. cases (%)
Age group	912 (76.5)	281 (23.5)	1193 (100)
35–54	347 (38.0)	70 (24.9)	417 (35.0)
55–74	565 (62.0)	211 (75.1)	776 (65.0)

2.3.2. *PAISIM project: onset of myocardial infarction.* The local population-based coronary heart disease registry [13] furnished data about myocardial infarction in people aged 35–74 years, recorded between January 1, 2000, and December 31, 2003 ( $n = 1193$  cases). The distribution of cases by sex and age group is presented in table 3.

Data on emergency visits for acute coronary syndromes also came from the Strasbourg healthcare network (SAMU) for the period from January 1, 2000, through December 31, 2005 ( $n = 1177$  cases, all age groups).

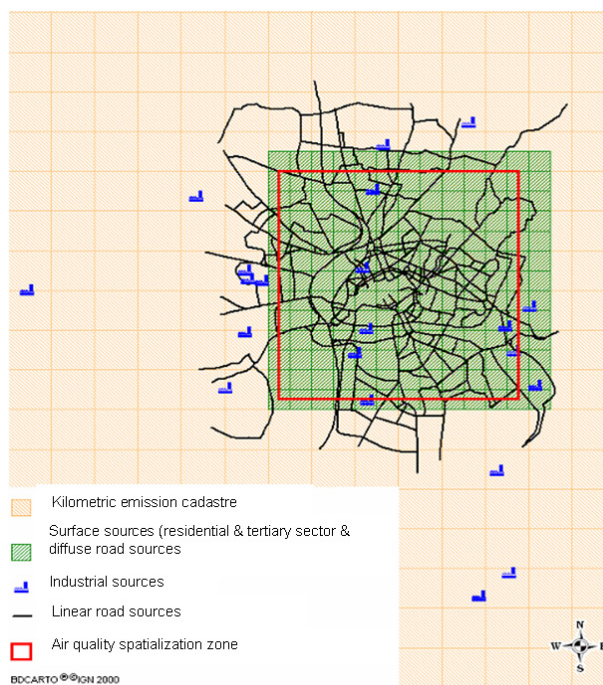
Health outcomes were geocoded to each patient’s residence block. For each health outcome and each block, we calculated incidence rates by age group (and by sex when possible). We also calculated age-standardized incidence ratios (SIR), using health event rates of the Greater Strasbourg population by age group to compute the number of cases expected in each IRIS.

2.4. Air pollution data

Hourly ambient concentrations of five pollutants (PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub> and CO) were modeled by the local air quality monitoring network (Association pour la Surveillance et l’Etude de la Pollution Atmosphérique-ASPA) for each block and the entire study period (January 1, 2000–December 31, 2005). They used ADMS Urban [14], a deterministic model that integrates emissions inventories (figure 1), meteorological data supplied by Météo-France (the French national meteorology service), and background pollution measurements as input parameters.

Since ADMS Urban can take into account only a limited number of the countless emission sources in Greater Strasbourg, we had to select the main sources contributing to the city’s ambient air pollution. ASPA’s Emiss’air tool was used to rank emission sources according to their contribution to ambient air pollution. Selected emission sources were linear sources (main roads), surface sources (diffuse road sources and residential and tertiary emissions) and punctual sources (the main polluting industries). The remaining (less important) emission sources were integrated in a kilometric emission cadastre. Hourly temporal profiles were attributed to road and residential sources, for a better fit to actual hourly emissions.

For each pollutant, we calculated average concentrations for the entire study period (2000–2005). The result is mapped (figure 2) with ArcGIS™ software. NO<sub>2</sub> and CO concentrations were noticeably higher in Strasbourg’s urban center, where high traffic density and residential and tertiary sources massively emit these pollutants. PM<sub>10</sub> concentrations, mostly due to regional pollution episodes, are much more



**Figure 1.** ASPA’s emissions inventory for Greater Strasbourg.

homogeneous over Greater Strasbourg. Nonetheless, traffic and urban and residential emissions tend to increase PM<sub>10</sub> concentrations slightly in the urban center. SO<sub>2</sub> concentrations, although more elevated in the north because of the oil refinery there, are relatively weak all across Greater Strasbourg. As usual [15], the spatial distribution of O<sub>3</sub> is the inverse of that of NO<sub>2</sub>, due to ‘competitive’ chemical reactions (‘scavenging effect’) between these two pollutants.

In a future stage of PAISARC, the French National Institute for Industrial Environment and Risks (INERIS) will assess the uncertainty of the air pollution modeling, thereby making it possible to analyze the effects of modeling uncertainty on the expected associations between air pollution, deprivation, and health outcomes.

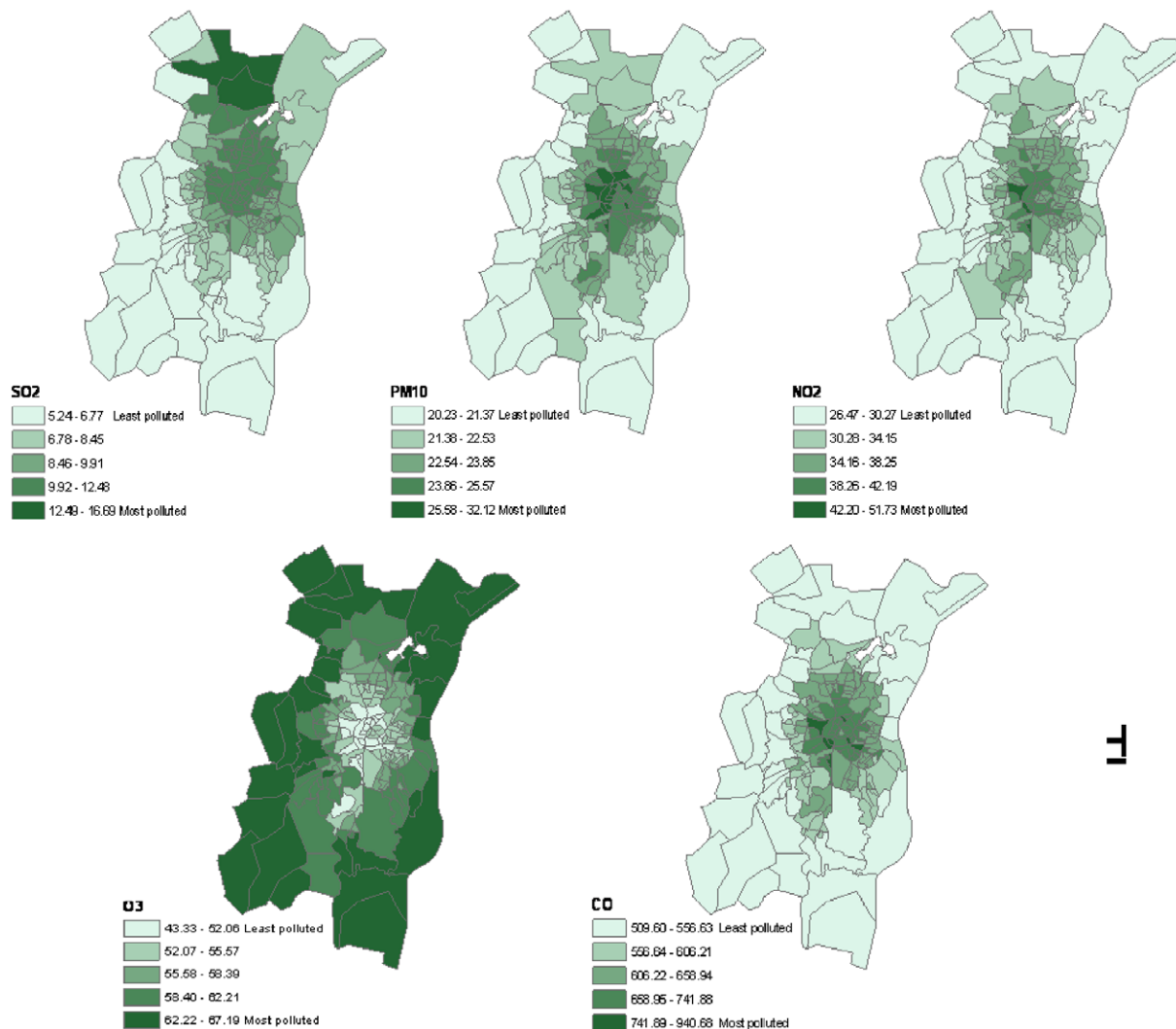
2.5. Statistical analyses

Statistical analyses will feature three steps.

- (1) Studying the associations between the spatial distribution of health outcome rates and socioeconomic disparities across residence blocks (assessed by our SES index).
- (2) Studying the associations between the spatial distribution of ambient pollutant concentrations and socioeconomic disparities across residence blocks (also assessed by the SES index).
- (3) Testing SES as a potential modifying factor in the relation between air pollution and health outcomes.

In this paper, we present only the preliminary results about the construction of an SES index and the relation between the index and the distribution of health outcome rates, assessed using Pearson’s coefficients of correlation.





**Figure 2.** Spatial distribution 2000–2005 of average concentrations of each pollutant across the study area: SO<sub>2</sub> ( $\mu\text{g m}^{-3}$ ), PM<sub>10</sub> ( $\mu\text{g m}^{-3}$ ), NO<sub>2</sub> ( $\mu\text{g m}^{-3}$ ), O<sub>3</sub> ( $\mu\text{g m}^{-3}$ ) and CO ( $\mu\text{g m}^{-3}$ ).

### 3. Preliminary results

#### 3.1. Deprivation index

Nineteen variables were retained for the construction of the deprivation index (66% total inertia explained by the first component). They cover all the aspects of SES that we initially considered: unemployment, education, income, family structure (single-parent families), material wealth and well-being. The blocks with the lowest index values are the most favored, while the blocks with the highest index values are the most deprived (figure 3). Mapping the index highlights its socioeconomic gradient, from the most favored blocks (suburbs) to the most deprived (urban center and intermediate districts). Our index presents a high internal consistency as measured by Cronbach’s alpha coefficient (0.92).

It is strongly correlated with Carstairs’ ( $r = 0.97$ ;  $p$  value  $< 0.01$ ) and Townsend’s ( $r = 0.96$ ;  $p$  value  $< 0.01$ ) indices. A

positive and significant spatial autocorrelation was detected in the SES index (Moran’s  $I = 0.54$ ;  $p$  value  $< 0.01$ ).

*3.1.1. Association between deprivation index and distribution of health outcome rates.* To reduce the instability of extreme rates due to a sometimes very low number of incident cases by block, we smoothed our data with an empirical Bayesian approach, using STIS™ software [16], except for drug sales, where smoothing was not warranted in view of the much greater number of events per IRIS.

Figures 4–6 present the resulting age-adjusted SIR of health outcomes according to our deprivation index. A linear inverse gradient was observed between the deprivation index and the age-adjusted SIR of emergency calls for asthma (figure 4); the greater the deprivation of the block, the higher the age-adjusted SIR ( $r = 0.77$ ;  $p$  value  $< 0.01$ ). The same pattern was observed for the age-adjusted SIR of  $\beta_2$ -agonist sales, which was also clearly associated ( $r = 0.31$ ,  $p < 0.01$ ).

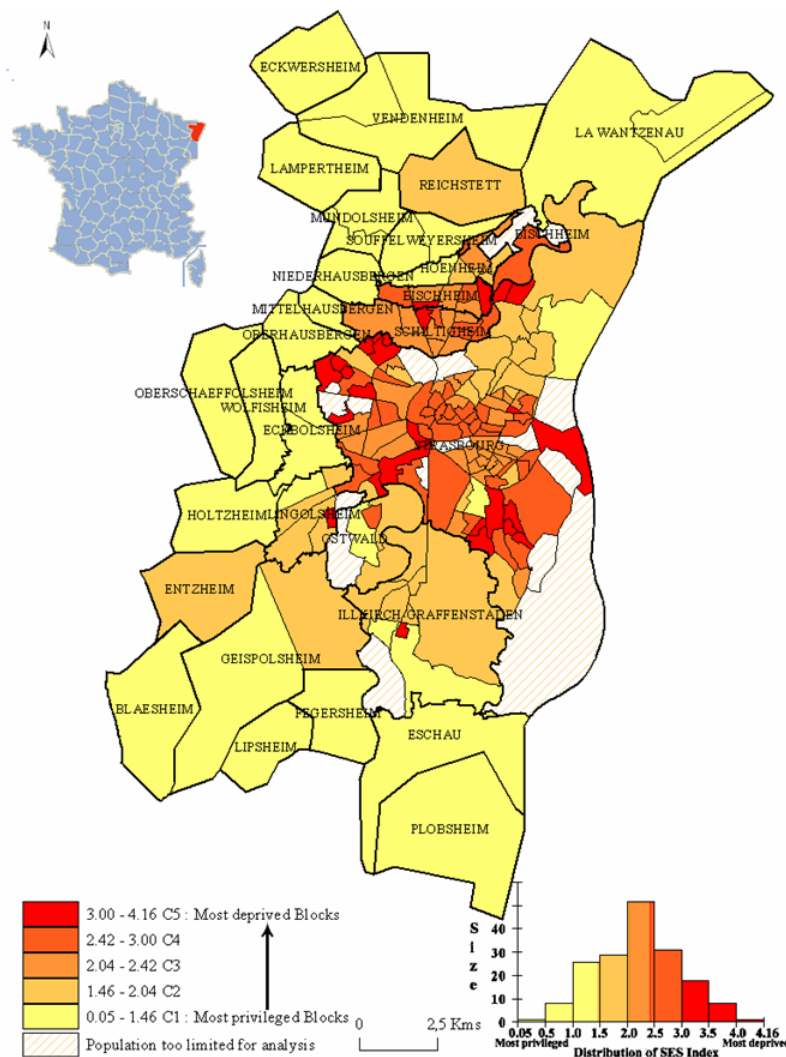


Figure 3. Distribution of deprivation index in Greater Strasbourg at the block scale.

with the degree of deprivation (figure 5). These results, obtained from two complementary indicators, show a strong consistency.

For the age-adjusted SIR of myocardial infarction in men, the association was weaker ( $r = 0.16$ ;  $p$  value  $< 0.05$ ) (figure 6).

Results for emergency calls for asthma are in accordance with data already published for hospitalizations and emergency room visits for asthma [17–19]. Our results on  $\beta_2$ -agonist sales and deprivation are consistent with those of a previous study [20]. We observed a statistically significant association between SES and the risk of myocardial infarction, which was nonetheless weaker than expected according to the literature [3, 4]. We believe that this is at least partly due to the low number of cases by geographic unit, which makes the rate estimates highly unstable. More appropriate models, such as hierarchical Bayesian models, should be considered to study these associations. These models smooth health data better and thus reduce rate instability.

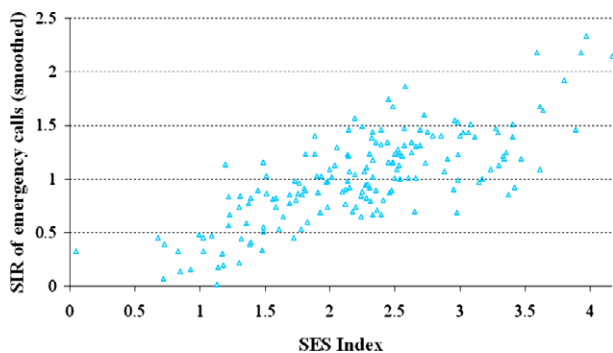
For each data item, spatial autocorrelations will be assessed using Moran’s index [21], using STIS™ software [16]. If detected, they will be taken into account in future refined analyses.

#### 4. Conclusion: ongoing analyses

We will refine the statistical analyses of the associations between health outcome rates and deprivation by smoothing rates with alternative approaches and taking spatial autocorrelation into account where needed.

In the next step of PAISARC, we will study the distribution of ambient air pollutant concentrations according to deprivation, taking spatial autocorrelation into account.

In the third stage, we will use case-crossover and time-series analyses to test SES as an interaction factor in the relations between the ambient atmospheric concentration of each of the selected pollutants and health outcomes. These analyses will be adjusted for potential confounders: long-term



**Figure 4.** Age-standardized incidence rates of emergency calls for asthma according to SES (local empirical Bayesian smoothing, both genders, all age groups). Index values increase with area deprivation.

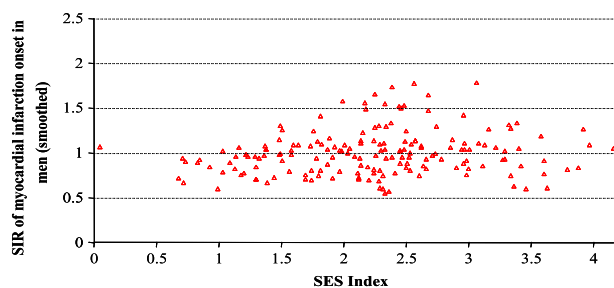


**Figure 5.** SIR of  $\beta_2$ -agonist short-term bronchodilator drug sales according to SES (both genders, age 0–40). Index values increase with area deprivation.

trends, seasonality, meteorological factors, influenza episodes, and pollen concentrations in air (for asthma only). We will test different lags (0–5 days) between the average concentration of each pollutant and health outcomes. Specific lag times will also be tested for potential confounders (meteorological variables, influenza incidence, and pollen concentrations).

The case-crossover analyses will be carried out for each block and each pollutant separately. The results will be tested for homogeneity: if the hypothesis of heterogeneity is rejected, a meta-risk (meta-odds ratio) will ultimately be computed for the Greater Strasbourg metropolitan area for each pollutant from all block-specific odds ratios. If this hypothesis is not rejected, analyses of variance will be conducted, to test SES alternatively as a continuous and categorical variable. In addition, we will test both a fixed effect and a random effect of SES as an explanatory variable.

If sufficiently robust odds ratio (or relative risk) estimates are obtained from the case-crossover and time-series studies, they will be used to calculate the number of cases attributable to air pollution exposures, first for the whole population, then separately for differentially deprived sub-populations.



**Figure 6.** Age-standardized incidence rates of myocardial infarction onset according to SES, registry data (local empirical Bayesian smoothing, males, 35–74 age group). Index values increase with area deprivation.

Subsequent estimates of the health effects of air pollution in differentially deprived sub-populations would provide useful elements for explaining the socioeconomic health gradients observed in this metropolitan area.

Age- and sex-specific analyses will be carried out to the extent possible. In addition, we will also test the robustness of the SES index on another area at the block resolution to determine whether it is transposable to other French settings.

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