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Environmental Injustice in France

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ABSTRACT *This paper presents the first national study on environmental inequalities in France. It applies the Anglo-American concept of environmental justice, focusing on the distribution of environmental burdens, to the French setting and tests the hypothesis that poor and immigrant communities are disproportionately exposed to environmental risks. The location of eight types of hazardous sites (industrial and nuclear sites, incinerators, waste management facilities) and the socio-economic characteristics of populations are associated at the commune, or town, level for all 36 600 French towns. The analysis, descriptive and multivariate, uses simple and spatial regression techniques. It shows that towns with high proportions of immigrants tend to host more hazardous sites, even controlling for population size, income, degree of industrialization of the town and region. The study establishes the presence of environmental inequities in France and raises new public policy questions. However, it does not investigate the mechanisms that may explain inequities, which could include procedural injustices, land market dynamics and historical patterns of industrial and urban development.*

Introduction

The notion of 'environmental justice' is a concept of American origin. It refers to social injustices in the spatial distribution of environmental quality, to inequities in the social, economic, health and psychological impacts of pollution, and to the processes that lead to these disproportionate impacts. The distributional element of environmental justice, referred to as 'distributive justice' (Lake, 1996) or environmental 'outcome equity' (Cutter, 1995), focuses on the disproportionate burden of environmental risks that some social, economic and ethnic groups bear. The procedural element of environmental justice focuses on the mechanisms that lead to such inequities. They include intentional or structural discriminatory practices in the siting of polluting facilities or in the monitoring and enforcement of environmental regulations (sometimes referred to as environmental discrimination or racism), unbalanced public participation and impact on decision-making processes, and legal frameworks that favor polluters and put the burden of proof on communities. They also include land market dynamics and historical patterns of industrial and urban development and residential mobility which can create disproportionate environmental impacts. In this context, environmental justice can be defined as "the fair

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treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA 2001). Therefore, the term 'environmental justice' refers to fairness in environmental outcomes and processes (for more in-depth discussions of definitions, see Helfand & Peyton, 1999; Holifield, 2001).

Although it emerged in Civil Rights-type conflicts in the US in the 1980s, environmental justice now tends to be understood as an integral part of the broader Sustainable Development agenda (Agyeman *et al.*, 2003; Miller, 2004; Agyeman, 2005). The debate around environmental justice has also widened to encompass a broader understanding of 'the environment', e.g. including urban, residential, school and workplace environments (Schlosberg, 1999), as well as broader social issues, such as local social capital, self determination or food security (Pellow & Brulle, 2005).

Environmental inequalities are discriminatory decisions in the siting of hazardous sites, historical industrial development and urban settlement patterns, and land market mechanisms that tend to concentrate disenfranchised populations in polluted areas and pollution sources in disenfranchised neighborhoods. The mechanisms that lead to them are not inherently specific to any nation or culture. Although first demonstrated in the US in the 1970s and 1980s, environmental inequities have also been recently observed in Canada, the UK, and to a lesser extent in Australia, New Zealand, Germany, the Netherlands and Eastern Europe.

This paper presents the first national study of environmental inequality in France. It applies the concept of environmental justice, focusing only on its distributional dimension, to the French setting and tests the hypothesis that poor and immigrant communities are disproportionately exposed to environmental risks, as they are in other industrialized nations.

Before focusing on the French context, the first section reviews the emergence of environmental justice as a concept, movement and area of scholarship and debate in the US, as well as recent developments in Western Europe. The next section briefly presents hazardous sites management policies in Europe and France, as well as recently available sources of data about the location of point-sources of pollution: old and operational industrial sites, nuclear sites, incinerators, waste management facilities etc. The following section presents the methodology used to assess whether some social groups are more likely than others to live in towns where these sites are located. It relies on descriptive and multivariate regression analysis, both simple and spatial. The next section presents the results of the analysis. Finally, the conclusions discuss their limitations and implications.

Environmental Injustice: Evidence from North America and Western Europe

Emergence of the Concept in the US

Social inequities in exposure to pollution and environmental risks or environmental injustices were first described in the American context in the 1970s (Freeman, 1972; Berry, 1977; Asch & Seneca, 1978). They were further investigated throughout the 1980s following the keystone reports of the General Accounting Office and United Church of Christ on race, toxic waste and hazardous landfills (US GAO, 1983;

UCCCRJ, 1987). Despite the limited evidence, they showed that the most disadvantaged populations, poor and African Americans, are more likely to bear environmental risks than their better off and white counterparts, and that race matters even after controlling for income. Environmental justice also emerged as a civil rights-type political movement in the early 1980s, triggered in part by the siting of a PCB landfill in the predominantly African American Warren County in North Carolina in 1982. The movement expanded to the national scale throughout the 1980s and 1990s.

Scholarly research on environmental injustice is ongoing in the US and became more methodologically sophisticated in the 1990s and early 2000s. Many studies focus on air pollution from industrial and transportation sources and on the location of industrial and toxic waste sites, and reveal consistent patterns. African Americans, Latinos and Native Americans are disproportionately exposed to environmental risks, and the relationship between race and toxic exposure cannot be explained by income differentials (Bryant & Mohai, 1992; Zimmerman, 1993; Bullard, 1990, 1993, 1994, 1996; Cutter, 1995; Pollock & Elliot Vittes, 1995; Arora & Cason, 1996; Cutter & Solecki, 1996; Heiman, 1996; Morello-Frosh *et al.*, 2001).

As a result of these findings and political pressures, American federal agencies, starting with the Environmental Protection Agency (EPA), adopted policies and programs to address environmental injustice. The EPA created the Office of Environmental Justice in 1992 and the National Environmental Justice Advisory Council in 1993. President Clinton's 1994 order #12898 "Federal actions to address environmental justice in minority populations and low-income populations" mandates that federal agencies promote environmental justice and avoid worsening existing inequities.

To this day, no other country has devoted research efforts and political organizing to explain and alleviate environmental injustices as extensively as the US. However, similar inequalities have recently been observed in other industrialized nations. In Canada, a few studies have shown that air quality in poor and working-class areas is worse than in better-off communities (Jerrett *et al.*, 2001; Buzzelli *et al.*, 2003). The last few years have also seen the publication of environmental justice studies in Australia and New Zealand (Lloyd-Smith & Bell, 2003; Arcioni & Mitchell, 2005; Pearce *et al.*, 2006).

Evidence from Europe

In 1996, the Expert Group on the Urban Environment of the European Commission titled a section of its *European Sustainable Cities Report* 'Environmental quality in cities is unequally distributed'. It states:

> ... high density ... accentuates negative social and welfare effects of economic activities, such as pollution from production and transport. The poorest and most disadvantaged residents of cities often also live in the worst local environmental conditions, while those who can afford to will buy a better local environment elsewhere. (Chapter 5, Section 20).

In 1996 this statement was not based on systematic observations. Empirical studies on the topic were first conducted in Europe in the UK in the late 1990s (Dobson, 1998; Walker & Bickerstaff, 2000; Agyeman, 2002). In 1998, Stevenson *et al.* observed a positive correlation between poverty, exposure to nitrogen dioxide and respiratory illnesses in the London region. In 1999, Friends of the Earth published the first national study of the location of the 662 most polluting factories and household income. It showed that: British households with incomes below £5000 are exposed to twice the risk of living near a polluting factory than households with incomes above £60 000; that 99% of the most polluting factories in London are in communities with average incomes below the national level; and that 82% of carcinogenic emissions of the largest factories occur in the 20% most disadvantaged areas. This report was followed by a series of studies also showing that the poorest households and ethnic minorities (even controlling for income) are the most affected by air pollution (McLeod *et al.*, 2000; Pennycook *et al.*, 2001; Brainard *et al.*, 2002; Mitchell & Dorling, 2003).

These observations gave birth in the UK to the 'Pollution Injustice' concept. Despite these landmark studies and strong interest by groups such as Friends of the Earth and the Black Environmental Network, no broad grassroots political movement focusing specifically on Pollution Injustice has emerged in the UK (Agyeman, 2002; Agyeman & Evans, 2004). Nonetheless, the political elites, including the Prime Ministers of Great Britain and Wales and the Minister for the Environment publicly recognized these inequalities and highlighted the importance of integrating social justice in sustainable development policies (Mitchell & Dorling, 2003).

The literature on the topic in Germany and the Netherlands is less developed but reveals similar patterns. In Germany, two case studies in Hamburg and Kassel (Köckler, 2005) showed that environmental pollution is negatively correlated to households' socio-economic characteristics—these results were only significant in some neighborhoods in Kassel. In the Netherlands, a study in the Rotterdam region (Rijnmond) showed that the most disadvantaged social classes live in areas with the poorest air quality and least access to environmental amenities (Kruize & Bouwman, 2004). Another case study in Enschede found that polluted sites in high income and education areas are cleaned up faster than those in poorer areas (Coenen & Halfacre, 2003). It is thought that there is no similar study in France.

Ongoing Debates

Despite these findings, some studies of the social distribution of environmental pollution reach different conclusions (Anderton *et al.*, 1994; Been & Gupta, 1997). Some find no significant differences between ethnic groups in environmental quality. Others find that better off populations live in more polluted environments in large urban centers with high air pollution levels and in highly industrialized zones with high employment levels (Perlin *et al.*, 1995 in the US; Jerrett *et al.*, 1996 in Canada).

The debate on the methodological validity of some studies is ongoing. Concerns focus mainly on their geographical level of analysis, the generalizability of case studies, and the analytical methods used (e.g. Anderton *et al.*, 1994; Bowen, 2002). Results are particularly sensitive to the geographical level of analysis: while inequities are consistently observed at the local level, they are rarely observed for large levels of spatial aggregation (Szasz & Meuser, 1997).

Other critiques focus on the lack of methodological rigor of some studies (Bowen, 2002). Some rely on comparisons or simple statistical tests without controlling for the multiple factors that may explain pollution levels, e.g. industrialization or transportation networks when focusing on air pollution. The most sophisticated use multiple regressions, sometimes structural equation modeling, but very rarely spatial analysis (e.g. Buzzelli *et al.*, 2003). Perhaps as a result, many studies explain only a small fraction of the variance in environmental differences (Mohai & Bunyan, 1992).

More fundamentally, the possible *causes* of these inequalities have not been established. The concentration of industrial and toxic sites can be explained by industries' needs to locate near transportation networks. Their concentration in poor and minority communities may also be caused by the historical context of industrial and urban development over the past decades and centuries (Graham *et al.*, 1999). Social or racial discrimination may also take place when selecting sites for polluting facilities. That is, industries and governments may target poor and minority communities where the local capacity to mobilize politically and successfully oppose the siting is limited (Bullard, 1993; Pinderhughes, 1996; Laurian, 2003, 2004). The implementation of existing laws may also be socially inequitable. Wealthier communities may be better able to demand the enforcement of environmental standards, or public agencies may be more inclined to enforce the law in wealthier and white communities (a phenomenon shown in the US, in Lavelle & Coyle, 1992).

Land market dynamics may also explain existing inequalities (Been, 1994). Industries and agencies seek cheap land for polluting facilities, which is usually located in the most disadvantaged communities. A process of selective mobility may also occur *after* the siting. The most well-off and mobile households may move away from polluted areas or avoid them when searching for housing, while the most disadvantaged and least mobile households may be forced to stay in polluted areas or to trade-off low-cost housing for lower environmental quality. Each of these processes may increase environmental inequalities over time, independent of discriminatory practices in siting decisions.

In addition, distinguishing between social class and ethnic makeup is not always straightforward. In countries with strong spatial segregation, as the US, these distinctions are feasible (e.g. by comparing poor white and poor black neighborhoods). In Europe, on the other hand, majority working classes and minority populations (Indian, Pakistani, North or Sub-Saharan African) are more integrated throughout urban landscapes and it can be more difficult to assess the independent impact of ethnicity on exposure to environmental risks. In France, where the concepts of minority or race are not official and not recorded in socio-demographic data, it is even more difficult to quantify these differences.

Hazardous Sites in Europe and France: Public Information and Protection

European and National Policies

Overall, European countries, as with the US, are orienting their environmental policies toward stricter environmental regulations, increased citizens' rights to a safe environment and increased public access to environmental information and decision making. For example, the Portuguese and Spanish Constitutions (Articles 66 and 45, respectively) protect citizens' rights to a safe environment. Similarly, 12 of the 17 countries of Central and Eastern Europe protect the right to a safe environment (Stec, 1998). In France, the 2005 Charter on the Environment states that "all have the right to live in a balanced environment that protects health" (MEDD 2005, Article 1, author's translation). At the European level, the right to a safe environment is considered by the European Court of Human Rights as part of the right to respect for private and family life (Article 8), as evidenced by its judgments on pollution in Guera vs. Italy and Lopez Ostra vs. Spain (Stec, 1998).

In addition to the right to a safe environment, the 1998 Aarhus Convention (UNECE, 1999), adopted in French law in October 2002, protects citizens' rights to environmental information, public participation in environmental decisions and justice in environmental matters. The Convention mandates that signatories develop public access to environmental information, usually through the creation of publicly accessible databases. The right to justice in environmental matters is usually handled through citizens' and associations' rights to legal action and reparations in case of environmental degradation or harm (Bélier, 2002). Yet, in practice legal recourse to enforce environmental legislation and obtain reparations are still very limited in most European countries.

This recent attention to public rights to a safe environment and access to environmental information allows increasingly refined analyses on the relationships between pollution and population, as conducted in this paper, and may open new avenues for public claims to redress disproportionate exposure to environmental risks, nuisances or negative health effects.

The French Context

In France, previously disconnected environmental laws were grouped in the Code for the Environment in September 2000 (ordinance 2000-94). With regard to hazardous facilities, the French government identifies installations presenting significant threats for the public or the environment and regulates them as classified facilities ('installations classées'). Law 76.663 of July 1976 on classified facilities, implemented by the decree 77.1133 of September 1977, gives prefects[1] and local governments authority over classified installations. These include industrial sites, confined animal facilities and waste management facilities that present risks of toxic releases and exposures, explosions, and air and water pollution.

Each classified facility requires a permit, which specifies the type and amount of emissions and the technologies used to avoid or mitigate pollution. The law also applies the polluter-pays principle and mandates that site owners restore the site to safe conditions when the activities cease (Article 34-1). There are approximately 500 000 classified facilities and 63 000 of these require special authorizations, i.e. more stringent permitting processes with impact assessments. A majority of the facilities with special authorizations are in the sectors of chemical manufacturing, petroleum refineries, animal feedlots and slaughterhouses, as well as quarries and incinerators. The 24 December 2002 decree about "the annual reporting of polluting emissions of classified facilities requiring authorization" mandates that owners report the emissions of a series of pollutants to waterbodies (100 pollutants), air

(50 pollutants) and soil (400 types of hazardous waste) if they are emitted above established thresholds (Bélier, 2002; iREP, 2006).

Public access to data on polluting emissions is very recent in France. Implementing rights to public information set by the Aarhus Convention, and given the mandatory reporting of hazardous emissions of classified facilities, the French government has recently begun to provide public access to data on emissions from point-sources. The Directorate on the Prevention of Pollution and Risks of the French Ministry of Ecology and Sustainable Development (MEDD) reports all emissions of classified facilities in the Register of Polluting Emissions (iREP) since 2003, and provides public access to this register since February 2004. The data are integrated into the European Polluting Emissions Register created in 2003. (In contrast, the American Toxic Release Inventory was created in 1988.)[2]

Beyond tracking ongoing emissions, French law also addresses already polluted sites. The Basol registry lists sites where: (1) the soil and/or groundwater are either known to be polluted or potentially polluted; (2) pose or can pose risks to persons or the environment; and (3) are the object of public intervention[3] (MEDD, 1994, 2006). These sites include old industrial sites (e.g. gas production, dry cleaners, gas stations, garages, chemical and pharmaceutical factories), landfills and sites polluted by accidental releases, leaks or spills in the management and storage of toxic substances (CCIP, 2006).

Public safety in the case of industrial accidental releases from operational facilities is managed through the European Seveso directive. Seveso 1 of 1982 and Seveso 2 of 1996, adopted in French law in May 2000, address the "prevention of major accidents involving dangerous substances... in selected categories of facilities classified for environmental protection purposes and requiring special authorizations" (author's translation). Seveso applies to sites where dangerous, toxic or flammable materials are stored permanently or temporarily. These sites include chemical, petrochemical, explosives and gas industries, but exclude military sites, mines, quarries, landfills and incinerators, radioactive materials and transportation devices such as pipelines. Seveso mandates that an Internal Plan of Operation be adopted to specify the course of action if an accident occurs on site, and a Specific Plan of Intervention in the case of off-site accidental releases. The latter needs to be approved by local authorities and is implemented by order of the prefect.

Combined, these new public registers of classified installations, Basol and Seveso sites and recent government policies that provide public access to this information, permit the study of the geographical distribution of, and potential inequities created by, these hazardous sites.

Research Questions, Methodology and Data

The objective of this study is to determine whether environmental injustice occurs in France as it does in other Western industrialized nations. The analysis focuses on the distributional dimension of environmental injustice, i.e. on environmental inequity. It does not seek to identify the mechanisms that may lead to inequities, but rather to constitute a first step toward environmental justice investigations in France. It determines whether various socio-economic groups are evenly or disproportionately affected by the (real or potential) impacts of hazardous sites.

Previous methodological studies have shown that analyses of this type should be conducted at the local level (McLeod *et al.*, 2000; Mitchell & Dorling, 2003; Bowen, 2002). The geographic level of analysis selected for this research is thus the town, or 'commune', i.e. the smallest unit of government in France.

In 1999, year of the last decennial census, there were 35 656 towns in metropolitan France, which is about the size of Texas. The totality of the French territory is divided into communes, i.e. there is no unincorporated land. Urban, rural and suburban areas are all divided into communes. They are political units, headed by a mayor, that range in size from a dozen to hundreds of thousands of residents. French towns are thus numerous and very small in size, with an average area of 14.9 km^2 and a median of 10.7 km^2. Among other European countries, this is an exceptionally small unit of government. For example, the majority of German, Italian, Spanish and Belgian towns are larger than 15 km^2, 22 km^2, 35 km^2, and 40 km^2, respectively. In France, the town-level thus provides a very detailed, or fine, level of analysis.

Data on a variety of polluted sites and the socio-economic characteristics of local populations are linked through a Geographic Information System (GIS) using ArcGIS. The analysis is both descriptive and explanatory. The descriptive analysis involves: (1) a count of the number of hazardous sites by town and region; (2) mapping the sites across metropolitan France; (3) analyzing the level of agglomeration of sites using Moran's I; and, (4) a statistical comparison of the characteristics of towns with and without sites and of the presence of sites in the most and least well-off towns. This descriptive analytical step provides a general overview of the spatial and social distribution of polluted sites in France. But without statistical controls, it does not disentangle which factors explain the location of toxic sites.

The second analytical step involves multivariate regression analyses to isolate these effects. The dependent variables of these models are the presence and number of hazardous sites in a town. Explanatory factors are: the size of the population, household income (strongly correlated with unemployment rates, which are therefore not included in the models), the degree of industrialization of the town, which is potentially an important factor explaining the location of polluted sites (Anderson *et al.*, 1994) and the proportion of persons born abroad (the choice of variables and calculations are explained below). Simple multivariate regressions are run using SAS (using Ordinary Least Square estimations for continuous dependent variables and Logit regression for models predicting the presence or absence of sites).

However, the data are spatial in nature. Neighboring towns are not independent units, but participate in a common regional economy. Therefore, it is possible that toxic sites are clustered, i.e. the probability that a town has one or more sites is not independent from the probability that the neighboring town has some too. Residuals are thus not expected to be evenly dispersed or geographically independent, introducing spatial errors and potential heteroskedasticity in the estimation. The spatial error in a regression can be described as:

$$Y = X\beta + \varepsilon,$$
$$\text{with } \varepsilon = \lambda W + \mu$$

where λ is the spatial auto-regressive coefficient, W is the contiguity matrix which describes the spatial proximity between observations (i.e. the towns) and μ is the non-correlated error term. W was built here by defining neighboring towns as adjacent with a common border or vertex (*queen criterion*, or first-order contiguity). The Moran's I is used to test the hypothesis of no spatial correlation H_0: $\lambda = 0$.

Spatial auto-correlation is often ignored in statistical studies of environmental equity, yet it can bias estimations using standard analytical tools (Anselin, 1992). If spatial effects are limited, standard analytical methods provide a good estimate of regression coefficients. Otherwise, it is necessary to correct these effects using spatial analysis tools (Anselin & Griffith, 1988). Moran's I and the Lagrange Multiplier are used to provide auto-correlation diagnostics, i.e. to indicate the degree of agglomeration of towns with polluted sites. They are first calculated using the residuals of the model without spatial corrections (using the Ordinary Least Squares method). Heteroskedasticity and spatial auto-correlation are jointly tested using the Breusch-Pagan test for the former and the Moran's I and Lagrange Multiplier for the latter (Anselin, 1992). If the spatial correlation is significant, the analysis then uses a spatial regression model that integrates λ among the exogenous variables in a Spatial Auto Regressive model (SAR)—here a 'spatial error model' estimated using the Maximum Likelihood method. On the other hand, heteroskedasticity cannot be corrected, but it affects the robustness of results without biasing them. Spatial analyses were conducted using GeoDa 0.9.5-i. This last version, produced in 2003 by Anselin (University of Illinois) is the first to allow spatial regressions on large datasets.

The data on toxic sites include eight types of sites, shown in Table 1. They include nuclear sites, incinerators, landfills, illegal dumps, sites known to be polluted (Basol),

Table 1. Types of sites and data sources

Sites	Date	Data source
Nuclear sites (reactors and nuclear waste treatment)	January 2006	Electricité de France
Municipal incinerators in operation 'Usines d'incinération d'ordures ménagères en fonctionnement'	January 2005	Ministry of Ecology and Sustainable Development (MEDD, Ministère de l'Ecologie et du Développement Durable)
Legal landfills 'Installations de stockage des déchets ménagers et assimilés'	September 2004	MEDD
Illegal dumps in operation 'Décharges non autorisées toujours en exploitation'	June 2005	MEDD
Seveso sites posing risks in case of accidents	January 2003	MEDD
Basol sites, polluted or potentially polluted with public intervention	October 2005	MEDD
Waste transfer sites 'Déchetteries'	August 2005	Agency for the Environment and Energy ADEME (Agence de l'Environnement et de la Maîtrise de l'Énergie)
Composting sites	February 2005	ADEME

industrial sites presenting hazards in case of accidents (Seveso), and composting and waste transfer facilities. All classified facilities (there are almost 500 000) are not included because many, although required to obtain permits, do not cause substantial risks. On the other hand, most Seveso sites presenting risks in case of accidents (900 of 1100) are classified facilities.

Given the environmental injustice hypothesis, the social variables of interest are income (here measured as a town's average household taxable income) and ethnic minority status. Although racial tensions clearly persist in French society, the concepts of race or ethnicity are not officially recognized, nor are they measured. Only nationality and country of birth are available as proxy for minority status. Foreigners or recent immigrants not yet naturalized cluster in very large cities, and the quasi-perfect correlation between the proportion of foreigners and city size is such that this variable is not used in the analysis. Persons born abroad (foreigners as well as naturalized immigrants) include mainly migrants from North and Sub-Saharan Africa, but also a less visible minority from Eastern Europe. However, they do not include second and third generation migrants and thus do not capture the entire population who experiences life as part of a minority group.

The average household income of towns was provided to the Institut National de la Statistique et des Etudes Economiques (INSEE) by the General Direction of Taxes (Direction Générale des Impôts) of the Ministry of Finance. The proportion of persons born abroad and other control variables, i.e. population size, unemployment rates and levels of industrialization (the proportion of jobs in industrial sectors), were collected through the 1999 decennial census and provided by the INSEE. Table 2 presents the definitions and data sources.

Environmental Injustice in France? Analysis and Findings

The number of polluted and polluting sites in France and the number of towns hosting them are presented in Table 3. The 3700 Basol sites are recognized as polluted and the 1100 Seveso sites present serious risks in the eventuality of an accident. The 24 nuclear sites present low-probability but very high risks in case of radioactive releases. The 130 incinerators are heavily regulated but some studies have shown that they release dioxin, which negatively affects public health. The emissions

Table 2. Town-level socio-demographic characteristics

Population characteristics	Definition and data source
Population size	Population of the town (commune) at the 1999 census, INSEE
Household income	Average household taxable income for town residents in 1999, provided by the Ministry of Finance to the INSEE
Unemployment rate	Percentage unemployed of all active residents for the population over 15 years of age at the 1999 census, INSEE
Industrialization level	Proportion of jobs in light, heavy, chemical and extractive industries (versus agriculture, construction, transportation, commerce and services) at the 1999 census, INSEE
Proportion of persons born abroad	Proportion of persons born abroad, regardless of nationality, in the town at the 1999 census, INSEE

Table 3. Numbers of sites and numbers of towns with sites

	Number of sites	Number of towns with at least one
Incinerators	130	128
Nuclear sites	24	24
Landfills	350	345
Illegal dumps	880	799
Composting sites	450	427
Seveso sites	1100	737
Basol sites	3700	1990
Waste transfer stations	3555	3408

of the 350 landfills and 880 illegal dumps vary with the types of products disposed and the technologies used to prevent releases, i.e. with the age of the landfill. Finally the 450 composting sites and the 3500 waste transfer stations probably have only minor impacts, but nonetheless require the transportation of waste through the towns.

Spatial Distribution of Hazardous Sites in France

The sites considered are dispersed across the French territory. The 1100 Seveso sites are spread over 737 towns and the 3700 Basol sites over 1990 towns, indicating that some towns host multiple sites. Of all metropolitan French towns, 39% (14 118) host at least one of these sites. One fourth host one exactly (9324), 8% host two (2993), and 5% host three or more (1801). Four towns have more than 30 sites: Toulouse, the fourth largest French city with key military and aerospace industries, Roubaix in the industrial and mining northern region near the Belgian border, Strasbourg, a large industrial city in the east of France with a port on the Rhine river, and Gennevilliers in the northern suburbs of Paris, with the largest river port of Paris on the Seine (with 42 sites, the maximum for all towns).[4]

The 22 French regions are not all equally affected by these sites (Table 4). For example, the Rhône-Alpes region in the south-east around Lyon hosts five nuclear sites, the Centre region four, and the Champagne-Ardenne region in the north-east hosts three on the rivers Seine, Marne and Aisne. Approximately 5% of the towns in the Paris region (Ile-de-France) host a Seveso site (64 towns) and 4% of towns in Provence-Alpes-Côte d'Azur in the south-east around Marseille, Nice and Toulon (38 towns) host a Sevseo site. Basol sites are also concentrated in the most industrialized regions, affecting 15% of towns in Ile-de-France (192 towns), 14% in the north industrial and mining region Nord-Pas-de-Calais (216 towns), 13% in Alsace (116 towns) and 6 to 9% in Lorraine (also in the east), Haute Normandie, Provence-Alpes-Côte d'Azur and Rhône-Alpes (248 towns).

The map of the distribution of the sites in France (Figure 1) presents the total number of sites for the 36 565 towns, indicated only for towns that have more than four sites for the sake of clarity. It shows the concentration of the sites in the Paris region and in towns in the north-east and south of Paris, along the Seine river (from Paris to Normandy), the Marseille region and around the Mediterranean coast, the

Table 4. Regional distribution of sites

Region	No. of towns	Number of nuclear sites	Towns with Seveso sites (%)	Towns with Basol sites (%)	Towns with illegal dumps (%)
Alsace	903	1	2.9	12.9	0.2
Aquitaine	2292	1	1.7	4.8	3.1
Auvergne	1310	0	1.2	3.0	9.4
Bourgogne	2045	0	1.3	2.5	0.2
Bretagne	1268	1	2.2	3.2	0.8
Centre	1842	4	2.8	4.8	1.2
Champagne-Ardenne	1945	3	1.5	4.9	0.7
Corsica	360	0	0.8	1.4	15.3
Franche-Comté	1786	0	0.8	3.4	0.6
Ile-de-France (Paris region)	1281	0	5.0	15.0	1.3
Languedoc-Roussillon	1545	1	1.1	3.6	6.3
Limousin	747	0	0.9	3.1	0.7
Lorraine	2337	1	1.2	6.5	1.0
Midi-Pyrénées	3020	1	1.1	3.2	4.9
Nord-Pas-de-Calais	1547	1	3.8	14.0	1.1
Normandy (Basse)	1814	2	1.2	2.5	0.0
Normandy (Haute)	1420	2	2.7	6.0	0.9
Pays de la Loire	1504	0	2.5	4.1	0.7
Picardie	2292	0	1.6	4.6	0.7
Poitou-Charente	1465	1	2.9	2.6	0.0
Provence-Alpes-Côte d'Azur	963	0	4.0	6.9	10.5
Rhône-Alpes	2879	5	3.0	8.6	1.4

Rhone valley from Marseille to Lyon, the Bordeaux region, the Loire Valley and the traditionally industrial north.

Overall, Seveso sites are not significantly clustered, with a Moran's I of 0.005, but they are relatively infrequent at the national scale since they affect only 700 of the 36 600 towns. The total number of sites, relevant for many more towns, reveals some clustering with a low but positive Moran's I of 0.18. The Local Indicators of Spatial Association (LISA) map, which maps significant spatial clusters or outliers (not presented here), shows the clustering of towns with polluted sites in the Loire region, Aquitaine, around the Mediterranean coast and in the Rhône-Alpes region.

Social Distribution of Hazardous Sites

To identify the social distribution of sites, the study first compared the social characteristics (income, population size, unemployment rates and percentages of persons born abroad) for towns with and without sites (see Table 5). The results show that household income is significantly lower in towns with illegal dumps and higher in towns with Seveso and Basol sites, and waste transfer stations. However, these results do not control for population size, and towns with sites are significantly larger than those without sites (except for illegal dumps located in rural areas). Unemployment rates in towns with sites are significantly higher than in towns

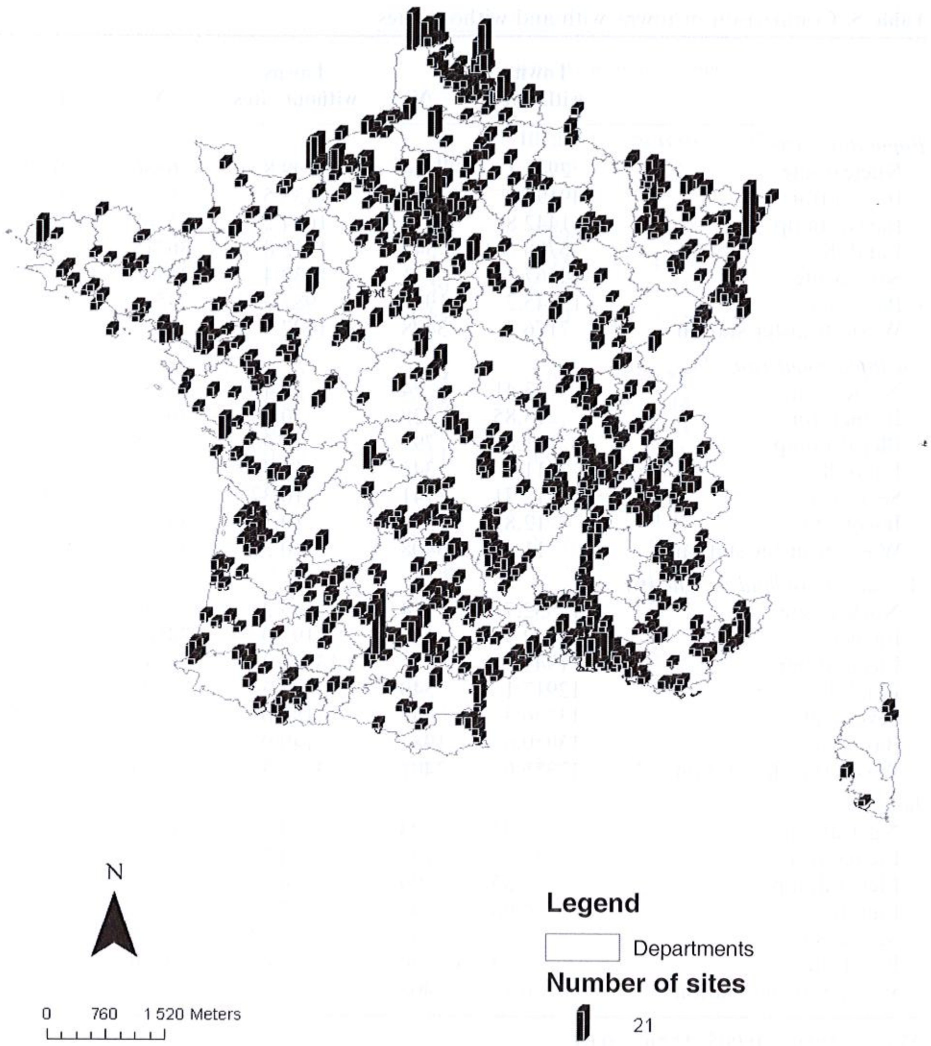

Figure 1. Total number of sites (indicated only for towns with more than four sites).

without sites, perhaps because of their traditional industrial base. Finally, the percentage of persons born abroad is significantly higher in towns with sites than without sites, providing a first indication of potential social inequalities in the distribution of hazardous sites. Nevertheless, these findings do not control for population size, and large cities also host more immigrants and persons born abroad than small towns.

Table 6 distinguishes between towns in the lowest and highest quartiles and deciles for population size, unemployment, income and proportion of those born abroad. It shows that the largest towns host most polluted and polluting sites. Among the 10% most populated towns (highest decile), about 12% have Seveso sites, 35% have Basol

Table 5. Comparison of towns with and without sites

	Towns with sites	N	Towns without sites	N	Test (t)
Population size					
Nuclear site	2942.1	24	1599.8	36536	0.47****
Incinerator	49195.2	128	1433.5	36432	39.51
Illegal dump	1442.8	799	1604.2	35761	−0.32
Landfill	6706.5	345	1552.0	36215	6.84****
Seveso site	14667.7	741	1330.4	35819	26.02****
Basol site	12245.2	1990	987.9	34570	35.65****
Waste transfer station	7176.3	3408	1027.5	33152	24.73****
Unemployment rate (%)					
Nuclear site	13.41	24	10.41	36533	2.80****
Incinerator	13.85	128	10.4	36429	7.45****
Illegal dump	11.81	799	10.38	35758	7.64****
Landfill	11.53	345	10.41	36212	3.95****
Seveso site	12.71	741	10.37	35816	12.07****
Basol site	12.85	1990	10.28	34567	21.42****
Waste transfer station	11.47	3408	10.31	33149	12.35****
Average household income (€)					
Nuclear site	12532.7	24	13195.2	34711	−0.78
Incinerator	13652.9	127	13193.0	34608	1.24
Illegal dump	11944.9	722	13221.2	34013	−8.15****
Landfill	12917.1	340	13197.5	34395	−1.23
Seveso site	13736.3	737	13183.0	33998	3.57****
Basol site	13950.6	1983	13149.0	32752	8.33***
Waste transfer station	13355.6	3401	13177.3	31334	2.37****
Born abroad (%)					
Nuclear site	5.93	24	4.79	36535	1.25****
Incinerator	10.56	128	4.77	36431	14.63****
Illegal dump	6.85	799	4.75	35760	13.12****
Landfill	6.06	345	4.78	36214	5.27****
Seveso site	7.81	741	4.73	35818	18.59****
Basol site	8.13	1990	4.6	34569	34.71****
Waste transfer station	6.15	3408	4.65	33151	18.69****

Notes: ****$p < 0.005$; ***$p < 0.01$.

and 43% have waste transfer stations, in contrast to less than 1% for the 10% least populated towns. Similarly, the 25% of towns with the highest unemployment level (more than 13.1%) are twice as likely to have landfills and illegal dumps and four times as likely to have Basol and Seveso sites than the quarter of the towns with lowest unemployment rates (under 7%).

Furthermore, towns with the highest proportions of residents born abroad are much more likely to have polluted sites than those with low proportions of persons born abroad. The quarter of towns with the highest proportion of persons born abroad (more than 6.3%) are, for example, three times more likely to have illegal dumps, five times more likely to have Seveso sites and seven times more likely to have Basol sites than the quarter of towns with the lowest proportion of persons born abroad (less than 1.8%). These differences are even greater if we compare the

Table 6. Percentage of towns with sites by socio-economic groups[a]

Quartiles/deciles and threshold values	% of towns with at least one					
	Incinerator	Landfill	Illegal dump	Seveso site	Basol site	Waste transfer station
Percent born abroad (%)						
Q1 (<1.85%)	0.07	0.67	1.29	0.81	1.74	6.56
Q3 (>6.34)	0.95	1.4	3.93	4.03	11.77	13.98
D10 (<0.94)	0.05	0.49	1.10	0.33	1.07	3.78
D90 (>10.5)	1.56	1.59	5.20	5.58	14.4	16.48
Unemployment rate (%)						
Q1 (<7.0%)	0.12	0.54	1.64	0.86	2.29	5.47
Q3 (>13.1)	0.80	1.15	3.17	3.44	9.67	11.89
D10 (<4.8)	0.08	0.35	1.71	0.33	1.20	2.91
D90 (>16.8)	0.79	1.11	4.09	3.77	10.98	11.63
Population size						
Q1 (<175 hab.)	0.01	0.24	1.68	0.08	0.23	0.83
Q3 (>927)	1.24	2.17	2.87	6.65	18.41	28.7
D10 (<93)	0	0.14	1.52	0.06	0.08	0.39
D90 (>2483)	2.63	3.31	2.63	12.34	35.5	43.10
Average household income (€)						
Q1 (<€10 642)	0.14	0.77	3.02	0.73	2.40	5.42
Q3 (>€14 821)	0.30	0.81	1.07	2.25	6.52	9.20
D10 (<€9276)	0.06	0.55	3.71	0.29	1.01	3.05
D90 (>€17 868)	0.32	0.63	1.21	1.93	6.51	8.09

Notes: [a]Nuclear sites are not included because there are too few to observe significant differences.
Q1 = 1st quartile, lowest 25% towns; Q3 = 4th quartile, highest 25% towns.
D10 = 1st decile, lowest 10% towns; D90 = 10th decile, highest 10% towns.
1st and 4th quartiles: $N \approx 9100$, depending on available data.
1st and 10th deciles: $N \approx 3650$, depending on available data.

maximum and minimum deciles. For example, 5% and 14% of towns in the lowest decile have Seveso and Basol sites, versus 0.3% and 1% in the towns in the lowest decile, respectively. Again, despite the absence of statistical controls for income, population size or industrialization, this finding points to some degree of environmental injustice.

However, this comparison also shows that towns with high household incomes also have more hazardous sites than the poorer towns (except for illegal dumps). Among the towns with average household income above €14 800, 2% and 6% have Seveso and Basol sites, vs. only 0.7% and 2%, or 0.3% and 1% of the poorest towns, depending on whether the lowest quartile is considered (under €9 300) or decile (under €10 600). It is possible that incomes are higher in larger cities that also have numerous sites and/or previously industrialized towns that have been able to convert their economic bases and maintain their income levels (such as Toulouse). This highlights the necessity of distinguishing the independent effects of these variables when explaining the presence of hazardous sites.

The multiple regression models include towns with populations between 100 and 400 000 residents. They exclude Paris, Lyon and Marseille and towns with fewer than 100 residents. These three cities and small towns are extreme outliers which bias all parameters, in terms of population size for the large cities and for all other exogenous variables for the very small towns.[5]

The models include, among the exogenous variables, average household income but not unemployment rates because these two variables are correlated (with a Pearson correlation coefficient of 0.28). Household income is very weakly correlated with population size (Pearson correlation coefficient of 0.07). The proportion of foreigners, i.e. recent immigrants, is very strongly correlated with population size (with a correlation coefficient of 0.82), and was not included in the models. On the other hand, the proportion of persons born abroad, which include recent as well as naturalized immigrants, is only weakly correlated with population size (correlation of 0.13) and does not pose major collinearity problems for the multiple regression models. The correlation between the proportion of persons born abroad and average household income for the town is only 0.12 and does not pose significant problems for the models either. Excluding Paris, Lyon and Marseille further reduces problems of collinearity between the proportion of persons born abroad and population size, with a correlation that drops from 0.22 to 0.13 when these three largest cities are excluded.

The simple linear and logistic regressions, presented in Table 7, produce very consistent results. For the total number of sites and most types of sites considered separately, everything else held constant, towns with higher income levels tend to have fewer hazardous sites and larger towns, those with most industrial jobs and those with higher proportions of persons born abroad tend to have more hazardous sites. Only one type of site deviates from this trend: illegal dumps, mainly located in rural areas, tend to be in small towns with low levels of industrialization.

The model that predicts the total number of sites explains about 34% of the variance in number of sites. This R^2 is higher than that observed in most studies on the location of toxic sites, and suggests that these regression models are well specified. When only one type of site is considered, such as Seveso sites only, the proportion of the variance explained drops to only 9% because there are fewer sites and their location is more directly affected by historical development patterns, not accounted here.

For all types of sites and the total number of sites in a town, towns with higher average household income have fewer sites. This finding does not imply a causal relationship since wealthy households may have moved away from polluted towns, or poorer households may have settled in polluted towns when looking for affordable housing or proximity to industrial jobs. However, poorer towns are more likely to host hazardous sites than wealthier towns, even after controlling for their level of industrialization.

Another, and perhaps more disturbing, observation is that towns with higher proportions of persons born abroad have significantly more sites (of all types) than towns with fewer persons born abroad. The only exception to this finding is for nuclear sites, where this relationship is not significant. (Nuclear sites are dispersed across the territory and located in the least populated areas with abundant fresh water supplies.) This observation about the impact of the proportion of people born abroad is independent of population size, income and industrialization levels that are

Table 7. Simple linear ($^{+}$) and logit ($^{++}$) regressions predicting the total number of sites and presence of each type of sites at the town level

	Total number of sites^{+}		Number of Seveso sites^{+}	
	Coeff	**t (sig)**	**Coeff**	**t (sig)**
Total population (in 10 000s)	0.96	119.7***	0.09	45.7***
Income (in 1000)	−0.024	−15.9***	−0.0015	−4.1***
Percent industrial jobs	0.011	30.2***	0.0018	19.6***
Percent born abroad	0.029	19.9***	0.0033	8.9***
Intercept	0.586	28.0***	0.0001	0.03
F	4162.1***		751.1***	
R^2	0.341		0.085	
Adjusted R^2	0.341		0.085	

	Presence of an incinerator^{++}		Presence of a nuclear site^{++}	
	Coeff	**Wald ChiSq**	**Coeff**	**Wald ChiSq**
Total population (in 10 000s)	0.49	209.6***	0.11	1
Income (in 1000)	−0.01	0.38	−0.11	2.2
Percent industrial jobs	0.013	5.68**	0.065	84.4***
Percent born abroad	0.094	50.5***	0.054	1.74
Intercept	−6.57	342.7***	−7.87	60.1***
−2Log L	1240.7		316.8	
Likelihood ratio	407.3***		76.8***	

	Presence of a landfill^{++}		Presence of an illegal dump^{++}	
	Coeff	**Wald ChiSq**	**Coeff**	**Wald ChiSq**
Total population (in 10 000s)	0.16	433.6***	−0.2	5.22**
Income (in 1000)	−0.04	6.09**	−0.12	82.9***
Percent industrial jobs	0.011	14.7***	−0.007	7.23***
Percent born abroad	0.039	13.11***	0.087	165.0***
Intercept	4.45	433.6***	−2.71	291.1***
−2Log L	3646		6480.1	
Likelihood ratio	69.1***		231.6***	

	Presence of a Seveso site^{++}		Presence of a Basol site^{++}	
	Coeff	**Wald ChiSq**	**Coeff**	**Wald ChiSq**
Total population (in 10 000s)	0.46	217.4***	2.09	1119.3***
Income (in 1000)	−0.0034	0.134	−0.01	4.27**
Percent industrial jobs	0.0375	537.0***	0.041	1178.0***
Percent born abroad	0.074	116.8***	0.053	88.1***
Intercept	−4.99	1209.2***	−4.149	1614.8***
−2Log L	5993.6		10706.2	
Likelihood ratio	1005.7***		4155.1***	

Notes: Towns of more than 100 residents, except for Paris, Lyon and Marseille ($N = 32\,465$).
***$p < 0.01$; **$p < 0.05$.

controlled for in these models. It is also significant when regions are included among the exogenous variables (models not presented here). This result thus reveals that, independent of economic factors (income and industrial employment base), the social makeup of the town in terms of the proportion of immigrants is an important predictor of the location of hazardous sites.[6]

These models were also run with binary variables for each of the 12 regions which have the most sites (results not presented here). In the model predicting the total number of sites, the proportion of the variance that is explained increases from 33% to 35%, but the regression coefficients for the exogenous variables do not change in direction, scale or significance. However, it reveals that towns in the regions Provence-Côte d'Azur (Marseille, Nice) and Rhône-Alpes (Lyon) tend to have more sites than towns in other regions, everything else being equal.

As explained above, because the data are spatial in nature, spatial auto-correlation may bias these results. Diagnostics of spatial auto-correlations were therefore conducted using Moran's I and the Lagrange Multiplier for the total number of sites (for which positive clustering was observed). In regressions using ordinary least squares, significant Moran's I and Lagrange Multiplier (Moran's I, error: 46.2***, Lagrange Multiplier, robust error: 501.1***) are observed. The Breusch Pagan tests also reveal, as expected, some heteroskedasticity.

The spatial regression model, estimated using a Spatial Error Model, is presented in Table 8. It explains, as before, about 30% of the variance and reveals a positive and significant spatial auto-regressive coefficient ($\lambda = 0.27$). This model, which takes into account spatial auto-correlation, still indicates that population size and the proportion of industrial jobs are significant predictors of the number of sites in a town and that, again, the higher the proportion of persons born abroad, the higher the number of hazardous sites in the town. In contrast, the negative relationship between household income and the number of sites is not significant anymore. The effect of income disappears when spatial auto-correlation is taken into account, suggesting that the effects of income previously observed in OLS estimations were misleading and indirect effects of spatial auto-correlations. Heteroskedasticity remains significant but is diminished and does not bias the results.

In sum, although the effect of household income is not significant in this spatial regression model, the proportion of persons born abroad is still a significant

Table 8. Spatial Auto-regressive Regression

	Total number of sites^{+}	
	Coeff	**z (sig)**
Total population (in 10 000s)	0.696	100.4***
Income (in 1000)	−0.0017	−1.32
Percent industrial jobs	0.00055	1.59*
Percent born abroad	0.033	22.19***
Intercept	0.367	18.8***
Lambda	0.275	35.36***
R^2		0.29

Notes: *$p < 0.1$; ***$p < 0.01$.

predictor of the total number of sites, highlighting robustness of this variable in explaining the number of hazardous sites in a town. The results of these models are very consistent across a range of types of sites and accounting for spatial effects. Combined, they indicate that towns with high proportions of persons born abroad are the most likely to host hazardous sites. The hypothesis that environmental inequities in the distribution of environmental burden exist in France, as in other Western industrialized nations, is therefore supported by the analysis.

Conclusions

This paper presents the first environmental equity analysis of the distribution of hazardous sites in France. It tests the hypothesis that the populations of all French communes, or towns, are not equally affected by the presence of toxic sites, and that towns with lower income and higher proportions of immigrants (persons born abroad) host more toxic sites than their better off counterparts. This hypothesis is based on the environmental inequities observed in other Western industrialized nations, in North America and Europe. To test this hypothesis, links were made for all 36 565 towns of metropolitan France: (1) the socio-demographic characteristics of the population and (2) data about the presence and number of hazardous sites, including nuclear sites, landfills and illegal dumps, industrial sites posing environmental risks in case of accidents (Seveso sites) and Basol sites that are known to be or are likely to be polluted, as well as composting sites and waste transfer stations. The analysis is both descriptive and explanatory, univariate and multivariate, and includes, among other techniques, the use of diagnostics for spatial clustering and linear, logit and spatial multiple regressions.

It is important to note that this analysis was made possible by recently available data on the location of a wide range of hazardous sites. This is in part due to European mandates on public access to information and, in particular, to the Aarhus Convention.

The results of this analysis are consistent across different types of sites within this study, and with observations made in many other countries. They show that towns with the lowest income levels are more likely to host hazardous sites, even when controlling for population size and the level of industrialization of the town. Yet, the analysis found that this result is partly due to spatial agglomeration effects. More importantly, the analysis shows that towns with higher proportions of immigrants are more likely to have a variety of hazardous sites and to host greater numbers of sites, even after controlling for income, town size, level of industrialization and region. This finding is very robust and persists when spatial auto-correlations are taken into account.

The limitations of this research stem from its strict focus on the distributional aspect of environmental justice and from the data used. First, it establishes that there are social disparities between towns that host and do not host polluting facilities. However, it does not seek to establish causal relationships between population characteristics and the location of hazardous sites, or to identify the mechanisms that lead some towns to host more hazardous sites than others. In other words, it does not reveal any procedural injustice. Discriminatory attitudes and decisions may have shaped the siting of these sites or the application, monitoring or enforcement of environmental regulations. The populations of some towns may have had sufficient clout to successfully oppose the location of noxious facilities, while others may have sought jobs and revenue-generating industries. These inequities may also be explained by historical urban (industrial and residential) development patterns, market forces that shaped siting decisions, or socio-demographic changes after sitings took place. Further research on environmental justice in France will need to focus on the causes of the inequalities observed here (for examples of causal analyses, see for instance Krieg 1995; Kuehn, 1996; Wigley & Shrader-Frechette, 1996; Weinberg, 1998; Helfand & Peyton, 1999; Bullard, 2000).

Second, the study is limited by the data used. It is probable that the official databases of polluted and polluting sites are incomplete. In France there are probably many sites not identified in these databases, either because they are not known or because they are known but yet undeclared (Ogé & Simon, 2004). The fact that the findings are consistent across types of sites points to the robustness of the results but, clearly, risks related to nuclear sites are not of the same nature as risks associated with waste transfer stations or composting sites. The study did not compute relative health risks for the sites, and thus provides only a rough approximation of existing hazards.

Third, the town level of analysis is very fine given the very small average size of French towns and is more precise than the level used in other environmental justice studies (e.g. UCCCRJ, 1987; GAO, 1983; Perlin *et al.*, 1995). It is also the smallest level of geography at which some data on the location of sites are available. However, the town level does not approximate actual exposure of populations to local environmental risks since air and water pollution can affect only some of the residents and migrate to adjacent towns. In addition, towns are not homogenous and the town-level analysis can hide socio-demographic variations between neighborhoods in a town. Although the largest cities, Paris, Lyon and Marseille, were excluded from the multivariate analyses, intra-town variations may remain significant for other cities. Only more localized analyses at the neighborhood or block level can examine the linkages between hazardous sites and the populations exposed to environmental risks.

However, even if it were possible to estimate the characteristics of the populations living within 100 or 500 m of hazardous sites, or better downstream or downwind of pollution sources, actual exposure levels would remain extremely difficult to assess. Populations are exposed to pollutants outdoors, in their homes, at work and in schools, and exposure is affected by individual behaviors. These factors make local exposure to hazardous substances and their health effects very difficult to measure.

Other studies will also need to focus on exposure to non-point pollution sources (e.g. air pollution from transportation sources), and it will be important to conduct epidemiological studies about the health impacts of hazardous sites and exposures to pollution, especially for the most vulnerable populations, i.e. children and the elderly. The sensitivity of findings to spatial auto-correlation suggests that future studies should also correct for spatial effects.

Despite these limitations, this first national study on environmental inequalities in France raises important public policy questions about distributive and procedural social justice. Concerns for distributive justice raise the questions: who benefits from a clean environment? Who is most exposed to environmental risks? Concerns for procedural justice raise the questions: are citizens' rights respected? Is the implementation and enforcement of environmental laws fair? While this study demonstrates a social injustice in the distribution of a social good (access to a safe environment), it did not establish the presence of procedural inequalities, which may be revealed when the causes of environmental injustice are investigated further.

Nonetheless, public policies can focus on correcting existing distributive inequalities. For instance, policies that seek to reduce pollution levels across the territory (e.g. reducing auto emissions) may improve environmental quality but not diminish existing inequalities. In contrast, policies seeking to mitigate the impacts of polluted sites or focus on areas where environmental risks are the greatest will improve environmental conditions in the most affected towns and may reduce inequalities (on this, see Todd & Zografos, 2005 in the Scottish context).

Improving procedural justice would require improving direct and participatory democratic processes and public participation in environmental decisions (Lake, 1996; Hunold & Young, 1998; Schlosberg, 1999, 2003). Involving local communities in deliberations about local environmental issues is essential for local democracy (Dobson, 1998; Agyeman & Evans, 2004; Watson & Bulkeley, 2005). More participatory and democratic decision making may correct existing inequalities if the most affected populations are able to oppose the siting of hazardous sites in their locality, receive compensations for negative impacts, or obtain the clean-up of toxic sites. However, better-off populations tend to benefit from the best access to political and judicial systems and are more likely to prevail in these local struggles than the most disadvantaged populations.

In addition to supporting local communities, national mandates could require that national, regional or local policies should not increase environmental inequalities. These mandates could be included, as in the UK, in policies on environmental protection and fights against social exclusion. They could, for example, shape the conditions required to obtain a permit for polluting emissions. Decisions on the siting of new polluting facilities could take into account the socio-economic makeup of the local population (age, income, health levels or other vulnerabilities) to avoid worsening environmental quality in already impacted areas. However, it is difficult to imagine how policies that would result in siting new pollution sources in better-off communities would be politically implemented in practice. More realistic solutions may consist of more stringent and fairer enforcement of existing regulations about the adoption of emergency plans, emission controls or by imposing higher fines where emissions exceed authorized levels.

Alternative and innovative policies to reduce environmental inequalities could promote the mobility of the most disadvantaged or vulnerable populations who may want to leave polluted areas for health reasons (families with children, elderly or pregnant women). Voluntary agreements between local populations and managers of polluting facilities are another model whereby industries agree to minimize the negative effects of their operations, sometimes going beyond environmental regulations (see Illsley, 2002, about the implementation of these 'good neighbor agreements' in the UK).

The adoption of national policies for the clean-up and control of hazardous sites, to facilitate agreement between private and public entities, or to support citizens' groups to address environmental inequalities will require fundamental social changes over time. Although the French national policy agenda does not yet focus on these issues, socio-demographic and epidemiological research should investigate not only human exposure to air and water pollution, but also the impacts of public policies on the distribution of environmental risks.

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Notes

1 Prefects are the heads of departments. Metropolitan France is administratively divided into 35 600 communes in 95 departments and 22 regions.

2 Data are also available on air quality (only for cities with more than 100 000 residents) and on drinking and swimming waters (ADEME, IFEN).

3 In French: Sites et sols pollués ou potentiellement pollués appelant une action des pouvoirs publics, à titre préventif ou curatif.

4 The average per capita number of sites for all towns is 10.6% with a high standard deviation of 33.1%. This per capita rate is not used in the analysis because it is much more affected by the size of the town (denominator) than by the number of sites (numerator). It is high only for small towns with many sites, but remains equally low for towns with few sites and large towns with numerous sites.

5 Four additional towns were excluded: three with approximately 300 residents and average incomes about 15 times the standard deviation, and one with 160 residents and a proportion of residents born abroad above 50%.

6 When the proportion of those born abroad is excluded from these models, the regression coefficients for all other exogenous variables keep the same direction and significance level. The proportion of variance that is explained decreases to $R^2 = 0.33$ for the model predicting the total number of sites. That is, the proportion of persons born abroad contributes to 1% of the total variance, or 3% of the explained variance in the total number of sites.

References

Agyeman, J. (2002) Constructing environmental (in)justice: transatlantic tales, *Environmental Politics*, 11(3), pp. 31–53.

Agyeman, J. (2005) *Sustainable Communities and the Challenge of Environmental Justice* (New York: New York University Press).

Agyeman, J. & Evans, B. (2004) 'Just sustainability': the emerging discourse of environmental injustice in Britain? *The Geographic Journal*, 170(2), pp. 155–164.

Agyeman, J., Bullard, R. D. & Evans, B. (Eds) (2003) *Just Sustainabilities: Development in an Unequal World* (Cambridge, MA: MIT Press).

Anderson, D. L., Anderson, A. B., Oakes, J. M. & Fraser, M. R. (1994) Environmental equity: the demographics of dumping, *Demography*, 31, pp. 229–248.

Anselin, L. (1992) Space and applied econometrics: introduction, *Regional Science and Urban Economics*, 22(3), pp. 307–316.

Anselin, L. & Griffith, D. A. (1988) Do spatial effects really matter in regression analysis? *Papers of the Regional Science Association*, 65, pp. 11–34.

Arcioni, E. & Mitchell, G. (2005) Environmental justice in Australia: when the RATS become IRATE, *Environmental Politics*, 14(3), pp. 363–379.

Arora, S. & Cason, T. (1996) Do community characteristics determine environmental outcomes? Evidence from the Toxics Release Inventory Working paper 97-12 (Washington, DC: Resources for the Future).

Asch, P. & Seneca, J. J. (1978) Some evidence on the distribution of air quality, *Land Economics*, 54(3), pp. 278–297.

Been, V. (1994) Locally undesirable land uses in minority neighborhoods: disproportionate siting or market dynamics? *The Yale Law Journal*, 103(6), pp. 1383–1422.

Been, V. & Gupta, F. (1997) Coming to the nuisance or going to the barrios? A longitudinal analysis of environmental justice claims, *Ecology Law Quarterly*, 24, pp. 1–56.

Bélier, S. (2002) France Country report, in: N. de Sadeleer, G. Roller & M. Dross *Access to Justice in Environmental Matters*. ENV.A.3/ETU/2002/0030 Final Report. Available at http://www.ucastverejnosti.cz/dokumenty/studie-aarhus-zeme-eu.pdf

Berry, B. (1977) *Social Burdens of Environmental Pollution* (Cambridge, MA: Ballinger).

Bowen, W. (2002) An analytical review of environmental justice research: what do we really know? *Environmental Management*, 29(1), pp. 3–15.

Brainard, J. S., Jones, A. P., Bateman, I. J., Lovett, A. A. & Fallon, P. J. (2002) Modelling environmental equity: access to air quality in Birmingham, England, *Environment and Planning A*, 34, pp. 695–716.

Bryant, B. & Mohai, P. (Eds) (1992) *Race and the Incidence of Environmental Hazards* (Boulder, CO: Westview Press).

Bullard, R. D. (1990) *Dumping in Dixie: Race, Class, and Environmental Quality* (Boulder, CO: Westview Press).

Bullard, R. D. (1993) *Confronting Environmental Racism: Voices from the Grassroots* (Boston: Southern Press).

Bullard, R. D. (Ed.) (1994) *Unequal Protection: Environmental Justice and Communities of Color* (San Francisco: Sierra Club Books).

Bullard, R. D. (1996) Environmental justice: more than waste facility siting, *Social Science Quarterly*, 77, pp. 493–499.

Bullard, R. D. (2000) *Dumping in Dixie: Race, Class, and Environmental Quality* (Boulder, CO: Westview Press).

Bullard, R. D. & Johnson, G. S. (2000) Environmental justice: grassroots activism and its impact on public policy decision making, *Journal of Social Issues*, 56, pp. 555–578.

Buzzelli, M., Jerrett, M., Burnett, R. & Finklestein, N. (2003) Spatiotemporal perspectives on air pollution and environmental justice in Hamilton, Canada, 1985–1996, *Annals of the Association of American Geographers*, 93(3), pp. 557–573.

Chambre de Commerce et d'Industrie de Paris (2006) *La pollution des sols et leur traitement*. Available at http://www.environnement.ccip.fr/icpe-sites/sites-sols/definition.htm

Coenen, F. & Halfacre, A. C. (2003) Local autonomy and environmental justice: Implementing distributional equity across national scales, in: H. T. A. Bressers & W. A. Rosenbaum (Eds) *Achieving Sustainable Development: The Challenge of Governance Across Social Scales* (Westport, CT and London: Praeger).

Cutter, S. L. (1995) Race, class and environmental justice, *Progress in Human Geography*, 19, pp. 111–122.

Cutter, S. & Solecki, W. D. (1996) Setting environmental justice in space and place: acute and chronic airborne toxic releases in the southeastern United States, *Urban Geography*, 17(5), pp. 380–399.

Dobson, A. (1998) *Justice and the Environment* (Oxford: Oxford University Press).

Environmental Protection Agency (2001) Office of Environmental Justice, Guidance to Assessing and Addressing Allegations of Environmental Justice, Working Draft, 7 (January 10, 2001).

European Commission Expert Group on the Urban Environment (1996) *European Sustainable Cities: Report* (Directorate General XI, Environment, Nuclear Safety and Civil Protection, Brussels, March 1996).

Freeman, A. M. (1972) Distribution of environmental quality, in: A. V. Kneese & B. T. Bower (Eds) *Environmental Quality Analysis: Theory and Method in the Social Sciences*, pp. 243–278 (Baltimore, MD: The Johns Hopkins Press).

Friends of the Earth (1999) *The Geographic Relation Between Household Income and Polluting Factories*. A report for Friends of the Earth, D. McLaren, O. Cottray, M. Taylor, S. Pipes & S. Bullock (London: FOE).

Graham, J. D., Beulieu, D. N., Sussman, D., Sadowitz, M. & Li, Y.-C. (1999) Who lives near coke plants and oil refineries? An exploration of the environmental inequity hypothesis, *Risk Analysis*, 19, pp. 171–186.

Heiman, M. K. (1996) Race, waste, and class: new perspectives on environmental justice, *Antipode*, 28(2), pp. 111–121.

Helfand, G. E. & Peyton, L. J. (1999) A conceptual model of environmental justice, *Social Science Quarterly*, 80, pp. 68–83.

Holifield, R. (2001) Defining environmental justice and environmental racism, *Urban Geography*, 22(1), pp. 78–90.

Hunold, C. & Young, I. (1998) Justice, democracy, and hazardous siting, *Political Studies*, 46(1), pp. 82–95.

Illsley, B. M. (2002) Good neighbour agreements: the first step to environmental justice? *Local Environment*, 7(1), pp. 69–79.

Jerrett, M., Eyles, J., Cole, D. & Reader, D. (1996) *Environmental Equity in Canada: An Empirical Investigation into the Income Distribution of Pollution in Ontario* (Hamilton, ON: McMaster University).

Jerrett, M., Burnett, R., Kanaroglou, P., Eyles, J., Finkelstein, N., Giovis, C. & Brooks, J. (2001) A GIS-environmental justice analysis of particulate air-pollution in Hamilton, Canada, *Environment and Planning A*, 33, pp. 955–973.

Köckler, H. (2005) Coping strategies of households exposed to unequal environmental quality in Germany. Paper presented at the 4th Global Conference Environmental Justice and Global Citizenship: Environments, Sustainability and Technologies, Center for Environmental Systems Research (CESR), University of Kassel, Germany. Available at http://www.inter-disciplinary.net/ptb/ejgc/ejgc4/paper_koeckler1.pdf

Krieg, E. J. (1995) A socio-historical interpretation of toxic waste sites: the case of Greater Boston, *Journal of Economics and Sociology*, 54(1), pp. 1–14.

Kruize, H. & Bouwman, A. A. (2004) *Environmental (In)equity in the Netherlands: A Case Study on the Distribution of Environmental Quality in the Rijnmond Region*. RIVM Report 550012003/2004. Ministry of Public Housing. Available at http://www.rivm.nl/bibliotheek/rapporten/550012003.pdf

Kuehn, R. R. (1996) The environmental justice implications of quantitative risk assessment, *University of Illinois Law Review*, 13(1), pp. 103–172.

Lake, R. (1996) Volunteers, NIMBY and environmental justice: dilemmas of democratic practice, *Antipode*, 28(2), pp. 175–192.

Laurian, L. (2003) A prerequisite for participation: environmental knowledge and what residents know about local toxic sites, *Journal of Planning Education and Research*, 22(3), pp. 257–269.

Laurian, L. (2004) Participation and non-participation in environmental decision-making, *Journal of the American Planning Association*, 70(1), pp. 53–65.

Lavelle, M. & Coyle, M. (1992) Unequal protection: racial divide in environmental law, *The National Law Journal*, 15, pp. S1–S12.

Lloyd-Smith, M. E. & Bell, L. (2003) Toxic disputes and the rise of environmental justice in Australia, *International Journal of Occupational Health*, 9(1), pp. 14–23.

McLeod, H., Langford, I. H., Jones, A. P., Stedman, J. R., Day, J. R., Lorenzoni, I. & Bateman, I. J. (2000) The relationship between socio-economic indicators and air pollution in England and Wales: implications for environmental justice, *Regional Environmental Change*, 1(2), pp. 78–85.

Miller, D. (2004) Measuring environmental justice—the third dimension of sustainable development. Paper presented at the 6th symposium of the International Urban Planning and Environment Association, 5 September, Louisville, Kentucky.

Ministère de l'Ecologie et du Développement Durable (1994). Arrêté du 17 octobre 1994 relatif à l'informatisation de l'inventaire national des sites et sols pollués au ministère de l'Environnement (Journal Officiel du ler novembre 1994). Available at: http://aida.ineris.fr/textes/arretes/text0340.htm

Ministère de l'Ecologie et du Développement Durable (2005) Charte de l'environnement, adopted February 28 2005. Available at http://www.ecologie.gouv.fr/IMG/pdf/charte_environnement.pdf

Ministère de l'Ecologie et du Développement Durable (2006) *Pollution des sols*. Available at http://basol.environnement.gouv.fr/

Mitchell, G. & Dorling, D. (2003) An environmental justice analysis of British air quality, *Environment and Planning A*, 35, pp. 909–929.

Mohai, P. & Bunyan, B. (1992) Environmental racism, in: P. Mohai & B. Bunyan (Eds) *Race and the Incidence of Environmental Hazards: A Time for Discourse*, pp. 163–176 (Boulder, CO: Westview Press).

Morello-Frosch, R., Pastor, M. & Sadd, J. (2001) Environmental justice and Southern California's Riskscape: the distribution of air toxics exposures and health risks among diverse communities, *Urban Affairs Review*, 36(4), pp. 551–578.

Ogé, F. & Simon, P. (2004) *Sites pollués en France, enquête sur un scandale sanitaire* (Paris: J'ai Lu Editions, Librio Santé).

Pearce, J., Kingham, S. & Zawar-Reza, P. (2006) Every breath you take? Environmental justice and air pollution in Christchurch, New Zealand, *Environment and Planning A*, 38(5), pp. 919–938.

Pellow, D. & Brulle, R. (2005) The future of environmental justice movements, in: D. Pellow & R. Brulle (Eds) *Power, Justice and the Environment*, pp. 293–300 (Cambridge, MA: MIT Press).

Pennycook, F., Barrington-Craggs, R., Smith, D. & Bullock, S. (2001) *Environmental Justice. Mapping Transport and Social Exclusion in Bradford* (London: Friends of the Earth).

Perlin, S. A., Setzer, R. W., Creason, J., Sexton, K. (1995) Distribution of industrial air emissions by income and race in the United States: an approach using the Toxic Release Inventory, *Environmental Science and Technology*, 29(1), pp. 69–80.

Pinderhughes, R. (1996) The impact of race on environmental quality: an empirical and theoretical discussion, *Sociological Perspectives*, 39(2), pp. 231–248.

Pollock, III, P. H. & Elliot Vittes, M. (1995) Who bears the burdens of environmental pollution? Race, ethnicity, and environmental equity in Florida, *Social Science Quarterly*, 76, pp. 294–310.

Registre Français des Emissions Polluantes sur Internet, iREP (2006) Direction de la Prévention des Pollutions et des Risques du Ministère de l'Ecologie et du Développement Durable. Available at http://www.irep.ecologie.gouv.fr/IREP/index.php

Schlosberg, D. (1999) *Environmental Justice and the New Pluralism: The Challenge of Difference for Environmentalism* (Oxford: Oxford University Press).

Schlosberg, D. (2003) The justice of environmental justice: reconciling equity, recognition, and participation in a political movement, in: A. Light & A. deShalit (Eds) *Moral and Political Reasoning In Environmental Practice* (Cambridge, MA: MIT Press).

Stec, S. (1998) Access to justice in environmental matters, chapter 3 in: *A Pan-European Assessment of Current Trends and Practices in Public Participation in Environmental Matters* (Szentendre: The Regional Environmental Center for Central and Eastern Europe, Hungary, ProTertia).

Stevenson, S., Stephens, C., Landon, M., Pattendon, S., Wilkinson, P. & Fletcher, T. (1998) Examining the inequality and inequity of car ownership and the effects of pollution and health outcomes such as respiratory disease, *Epidemiology*, 9(4), pp. S29. Summary of a presentation at the 10th Conference of the International Society for Environmental Epidemiology, Boston.

Szasz, A. & Meuser, M. (1997) Environmental inequalities: literature review and proposals for new directions in research and theory, *Current Sociology*, 45(3), pp. 100–120.

Todd, H. & Zografos, C. (2005) Justice for the environment: developing a set of indicators of environmental justice for Scotland, *Environmental Values*, 14, pp. 483–501.

US General Accounting Office (1983) *Siting of Hazardous Waste Landfills and their Correlation with Racial and Economic Status of Surrounding Communities* (Washington, DC: United States General Accounting Office).

UNECE (1999) *Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters* (Geneva: United Nations Economic Commission for Europe).

United Church of Christ Commission for Racial Justice (1987) *Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities Surrounding Hazardous Waste Sites* (New York: United Church of Christ).

Walker, G. & Bickerstaff, K. (2000) Polluting the poor: an emerging environmental justice agenda for the UK? Paper presented at the conference Environmental Justice in a Divided Society, University of London. Available at http://www.goldsmiths.ac.uk/cucr/pdf/walker.pdf

Watson, M. & Bulkeley, H. (2005) Just waste? Municipal waste management and the politics of environmental justice, *Local Environment*, 10(4), pp. 411–426.

Weinberg, A. (1998) The environmental justice debate: a commentary on methodological issues and practical concerns, *Sociological Forum*, 13, pp. 25–32.

Wigley, D. C. & Shrader-Frechette, K. S. (1996) Environmental racism and biased methods of risk assessment, *Risk: Health Safety & Environment*, 7, pp. 55–88.

Zimmerman, R. (1993) Social equity and environmental risk, *Risk Analysis*, 13(6), pp. 649–666.