



Environmental justice in a French industrial region: Are polluting industrial facilities equally distributed?

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ABSTRACT

Recent studies have suggested that minority or deprived groups are subject to the additional burden of a polluted living environment. Our goal is to determine whether such environmental inequalities occur in France's leading industrial region, using detailed socio-economic data and advanced Bayesian methods. Associations between proximity to hazardous facilities (i.e., within a 2 km radius) and the socio-economic characteristics of populations are analyzed at fine geographical scales. Noxious facilities are disproportionately located in higher foreign-born communities after controlling for deprivation (Townsend score), population density and rural/urban status. High deprivation also appears as a predictive factor, although less strongly and less consistently.

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1. Introduction

The concept of environmental justice originated in the United States in the 1980s and is currently defined by the US Environmental Protection Agency as the “fair 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” (Environmental Protection Agency, 2010). The distributional dimension of environmental justice, referred to as environmental equality, focuses on the disproportionate burden of environmental risks that some social, racial, economic and ethnic groups bear. First demonstrated in the US (Lee 2002), environmental inequalities have been also observed in Western Europe (UK, Germany, The Netherlands; Laurian, 2008). Studies focusing on air pollutants (stationary and mobile sources) dominate the literature. Research has initially focused on residential proximity to noxious facilities, municipal landfills, incinerators and abandoned toxic waste sites (for reviews, see Bowen, 2002; Downey and Hawkins, 2008; Briggs et al., 2008). A number of recent studies have examined the implications of exposure to transportation-related emissions, and most consistently indicated disproportionate burdens (Apelberg et al., 2005; Pastor et al., 2005; Chaix et al., 2006; Fisher et al. 2006; Maantay, 2007; Chakraborty, 2009).

The association between deprivation and increased mortality or morbidity is well established, across a wide range of diseases and areas (Davey Smith et al., 1998; Carstairs, 2000; Benach et al., 2001). Equally, living near industrial facilities has long been known to represent a risk factor for a number of health outcomes (Elliott et al., 1996; Benedetti et al., 2001; Franchini, et al., 2004; Knox, 2005; Loyo-Berrios et al., 2007; Kaatsch et al., 2008; Viel et al., 2008; De Roos et al., 2010).

The unequal distribution of hazardous sites is driven by different forces: the historical contexts of industrial and urban development, industries' needs (such as location near a transportation network), heterogeneous community clout (poor communities are less inclined to mobilize and less likely to be successful in their political or legal actions), land market dynamism (cheap land for polluting facilities is usually located in disenfranchised neighborhoods), selective residential mobility (deprived households may be forced to trade off low-cost housing for lower environmental quality) and so forth (Laurian, 2008). None of these mechanisms is inherently specific to any nation or culture and each may increase environmental inequalities over time independent of discriminatory practices in siting decisions.

Very little research on this issue has been conducted in France. Recently, Laurian carried out the first nationwide study on environmental inequalities in France showing that poor and immigrant communities are disproportionately exposed to environmental risks (Laurian, 2008).

Franche-Comté is France's leading industrial region (in terms of relative share of jobs), employing 25.5% of its working population in

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industry (mainly automotive and metal industries). It thus provides a unique opportunity to address the environmental justice issue. Our goal was therefore to expand upon Laurian's research using more detailed data (i.e., on a finer geographical scale and with accurate geocoding of facilities' locations) to determine whether minority or deprived groups are disproportionately affected by the (real or potential) impacts of hazardous sites in the Franche-Comté region.

2. Methods

2.1. Study area

The Franche-Comté region (16,202.34 km²; 1,117,059 inhabitants in 1999) is located in eastern France along the Swiss border. To assess as accurately as possible the level of environmental exposure to hazardous substances, the smallest geographical census units available in France were considered. These so-called "IRISes", defined by the National Institute for Statistics and Economic Studies (INSEE), are equivalent to the US census block groups or the British lower super output areas. The regional capital and towns with more than 5000 inhabitants are divided into several IRISes (for a total of 214 IRISes), while smaller towns form one IRIS each (corresponding to 1758 IRISes). The study area therefore comprises a total of 1962 IRISes with a mean population of 569, and a mean area of 8.31 km².

2.2. Industrial sites

In response to rights to public information set forth by the Aarhus Convention and given the mandatory reporting of hazardous emissions from polluting facilities, the French government has recently begun to provide public access to data on emissions from point sources. Since 2003, the Register of Polluting Emissions (iREP) has covered industrial plants exceeding at least one of the specific emission thresholds for 92 waterborne pollutants, 81 airborne pollutants and 400 types of waste discharged into the soil (French Ministry of Ecology and Sustainable Development, 2010). From this public register, we extracted information on the 181 facilities operating between 2003 and 2006 in the Franche-Comté region. Unfortunately, the types and quantities of pollutants emitted from each industrial facility could not be used because of reporting deficiencies.

Many facilities' addresses were missing from the register. Fortunately, all individual entrepreneurs or corporate bodies are also registered in the Sirene (or "Database for a Register of Companies and their Establishments") register managed by the INSEE. After extracting each facility's address, geocoding of the exact building (and not of the site gateway) was achieved with an accuracy of about 10 m using complementary tools: the electronic database of cadastral plans maintained by the French Tax Department, Microsoft Bing Maps®, Google Earth® and the Geoportail® project (a French public service gateway with online access to geographical data, including cartographic displays).

2.3. Exposure assessment

Considering the diverse types of industrial activities in the region, the lack of precise data on the pollutants being emitted and the different pathways of dispersion, reliable environmental concentrations could not be estimated with sophisticated models to define exposed and unexposed areas. Exposure was therefore defined as proximity to the source of pollution. Without real knowledge about the spatial variation in exposures, a simple threshold distance was used. Using buffering techniques in a

GIS, circles with a radius of 2 km were drawn around each of the industrial sites (following Elliott et al., 2001), to represent the likely limit of any detectable increase in pollutant concentrations. IRISes whose borders intersected with these circles were included in the impact zone. A 500 m distance was used in sensitivity analysis.

Two routes of exposure for nearby residents (air and water) and four types of sites (mechanical engineering and surface finishing, chemical manufacturing, waste management, and metallurgy and steel industry) were considered in sub-group analyses using a uniform buffer radius for comparison purposes.

2.4. Socio-economic characteristics

Given the environmental inequality hypothesis, the social variables of interest are income and ethnic minority status. For confidentiality reasons, French household poverty status was not available for the 1355 IRISes comprising less than 50 households. We therefore relied upon the Townsend index to assess the economic level of each IRIS. Four variables (unemployed residents as a percentage of all economically active residents; households that do not own a car as a percentage of all households; households that do not own a home as a percentage of all households; and household overcrowding, i.e., more than one person per room) were extracted from the 1999 population census and combined to form an overall score for each IRIS. The higher the Townsend index score, the more deprived and disadvantaged an IRIS is thought to be.

In France, the concepts of minority and race are unofficial and are not recorded in census data. On the other hand, each respondent's country of birth (regardless of nationality) is available. The proportion of persons born abroad (i.e., foreigners and naturalized immigrants) was therefore used as a proxy for minority status.

Foreigners and recent immigrants who have not yet become naturalized cluster in large cities. Moreover, towns with industrial sites are usually larger and more populated (because of their traditional industrial base) than are those without sites (except in rural areas). Population density and urban/rural status (according to the INSEE classification scheme) were therefore considered as confounding factors when determining which effects explain the location of industrial sources of pollution.

2.5. Statistical analysis

We studied associations between proximity to industrial sites and socio-economic characteristics by Bayesian hierarchical logistic regressions using the Markov chain Monte Carlo methods with the IRIS as the statistical unit (Besag et al., 1991; Lawson et al., 2003). The dependent variable was coded as a binary variable to indicate whether each IRIS was within 2 km (or 500 m) of at least one noxious facility. Among the independent variables, Townsend score and population density were entered as categorical variables (tertiles) in the models to reach convergence in Bayesian data analysis. The proportion of persons born abroad was also split into three classes, but because of its very unbalanced distribution, the first class corresponded to no foreign people and the next two classes were separated by the median of the non-zero values. Urban status was entered as a binary variable (rural/urban).

To account for spatial autocorrelation, a spatially unstructured random effect (also called heterogeneity) and a spatial random effect (also called clustering) were introduced. We used a conditional autoregressive structure to describe the distribution of the spatial random effects; the distribution of each spatial effect was centered around the mean of its neighbors. With no prior knowledge about the spatial processes in question, neighborhood definitions were adjacency-based: all IRISes sharing a border with the

IRIS of interest were considered neighbors. A burn-in of 1000 iterations was allowed, followed by 10,000 iterations for which parameter values were stored. Odds ratios (OR) and their 95% credibility intervals (CI) were calculated.

To allow for comparisons, the four independent variables were considered simultaneously in all models. All analyses were performed using WinBUGS software (Lunn et al., 2002).

3. Results

3.1. Socio-economic characteristics of the study area

Among the 1962 IRISes composing the region, 1459 are inhabited by at least one person born abroad (Table 1). The Townsend score ranges from –6.67 to 18.47 and population density from 0.4 to 27864.4 inhabitants per km². Of all IRISes, 837 are rural (42.7%).

3.2. Spatial distribution of polluting facilities

Industrial sites are relatively infrequent at the regional scale (Fig. 1). They are spread over 137 IRISes, of which 24 each host 2 to 7 sites. Regarding emissions, 71 facilities reported air releases, 44 facilities reported water releases and none reported releases to land. Of all facilities, 142 transferred waste off-site for recovery or disposal. The distribution by type of industrial activity shows that mechanical engineering and surface finishing facilities tend to be somewhat less dispersed (71 sites hosted by 53 IRISes) than the other types of industrial activity (Table 2).

3.3. Social distribution of polluting facilities

When the 181 industrial sites are considered, IRISes with the highest proportions of residents born abroad are more likely to host polluting industries (OR=3.11 and OR=11.37 for the second and third tertiles, respectively; Table 3). Deprivation is moderately associated with proximity to industrial sites, but only for the third tertile of the Townsend score (OR=1.37). Conversely, urban status and population density are strong confounding factors.

Specific types of emissions (to air or water) yield similar patterns with risk estimates of similar magnitudes, with the exception of foreign-born second tertiles (no longer significant)

Table 1
Socio-demographic characteristics of the 1962 IRISes composing the Franche-Comté region (France, 1999).

	Count	%
Persons born abroad		
0%	503	25.6
0.1–1.6%	730	37.4
1.7–53.0%	729	37.0
Townsend score		
–6.67 to –1.24	625	33.3
–1.23–0.41	625	33.3
0.42–18.47	625	33.3
Zone		
Rural	837	42.7
Urban	1125	57.3
Population density^a		
0.4–19.5	625	33.3
19.6–50.8	625	33.3
50.9–27864.4	625	33.3

^a Inhabitants per km².

and the Townsend third tertile, whose risk estimates slightly increase (OR=2.18 and OR=2.10 for air and water, respectively; Table 3).

The analysis by type of industry exhibits contrasting patterns (Table 4). Results from the most numerous sites (mechanical engineering and surface finishing) are consistent with those obtained from the global analysis. The predictive factors for hosting chemical manufacturing plants are a high proportion of people born abroad (OR=3.13), urban status (OR=2.44) and a high population density (OR=10.19). Deprivation does not explain proximity to noxious chemical facilities. The siting of waste management facilities is mainly influenced by confounding factors such as urban status (OR=5.88) and high population density (OR=4.60). Deprivation has a small but significant influence on the siting of waste management facilities (third tertile, OR=1.71). In metallurgy and the steel industry, IRISes with the highest proportion of persons born abroad (OR=2.50) and the highest population densities (OR=6.88 and OR=23.97 for the second and third tertiles, respectively) are more likely to host these facilities. A U-shaped association is observed for deprivation (second tertile: OR=0.46). Urban communities are not disproportionately impacted.

Sensitivity analysis with a 500 m distance yield similar ORs, but with broader credibility intervals due to lower numbers of exposed IRISes (results not shown).

4. Discussion

Noxious facilities are disproportionately located in higher foreign-born communities after controlling for deprivation, population density and rural/urban status. The consistent gradient observed across a range of types of sites adds evidence to the environmental injustice hypothesis. High deprivation also appears as a predictive factor, although less strongly and less consistently.

We used the finest geographical scale to capture the underlying spatial processes involved in exposure to environmental hazards. Data aggregated by small geographical units are generally considered more reliable as indicators of disproportionate burdens and more accurate in identifying the affected populations, than are data aggregated at higher levels (Maantay, 2002).

We carefully cross-checked the locations of hazardous facilities to augment the accuracy of our geocoding. To determine exposure potential, we did not rely on the spatial coincidence method (whereby exposure is defined as whether the population is in the same IRIS as the facility) but on a proximity analysis performed by constructing buffer zones. This yielded a more realistic estimation of actual exposure because IRISes are of unequal areas and many facilities are located on the edges of IRIS boundaries (Maantay, 2002). However, with this technique an IRIS that barely intersects with the 2 km buffer of an industrial facility is assumed equally exposed to industrial hazards as another IRIS that contains or intersects with multiple facilities. The exposure risk was assumed to be equally distributed within a given buffer zone. This assumption may not hold in some cases because the actual exposure may depend on many variables, such as type of facility, substances emitted, quantities released, pollution controls used, atmospheric conditions, topographic factors, aquifer scale and so forth. However, Briggs et al. (2008) showed that buffering could represent a conservative approach as associations tend to be weaker for measures of proximity compared with emissions intensity or concentration.

We included in this study a range of different types of industrial sites and verified the robustness of the analysis by comparing the results for each type of site. Facilities transferring waste off-site were not considered in sub-group analyses because this activity does not entail exposure of populations living in proximity to such

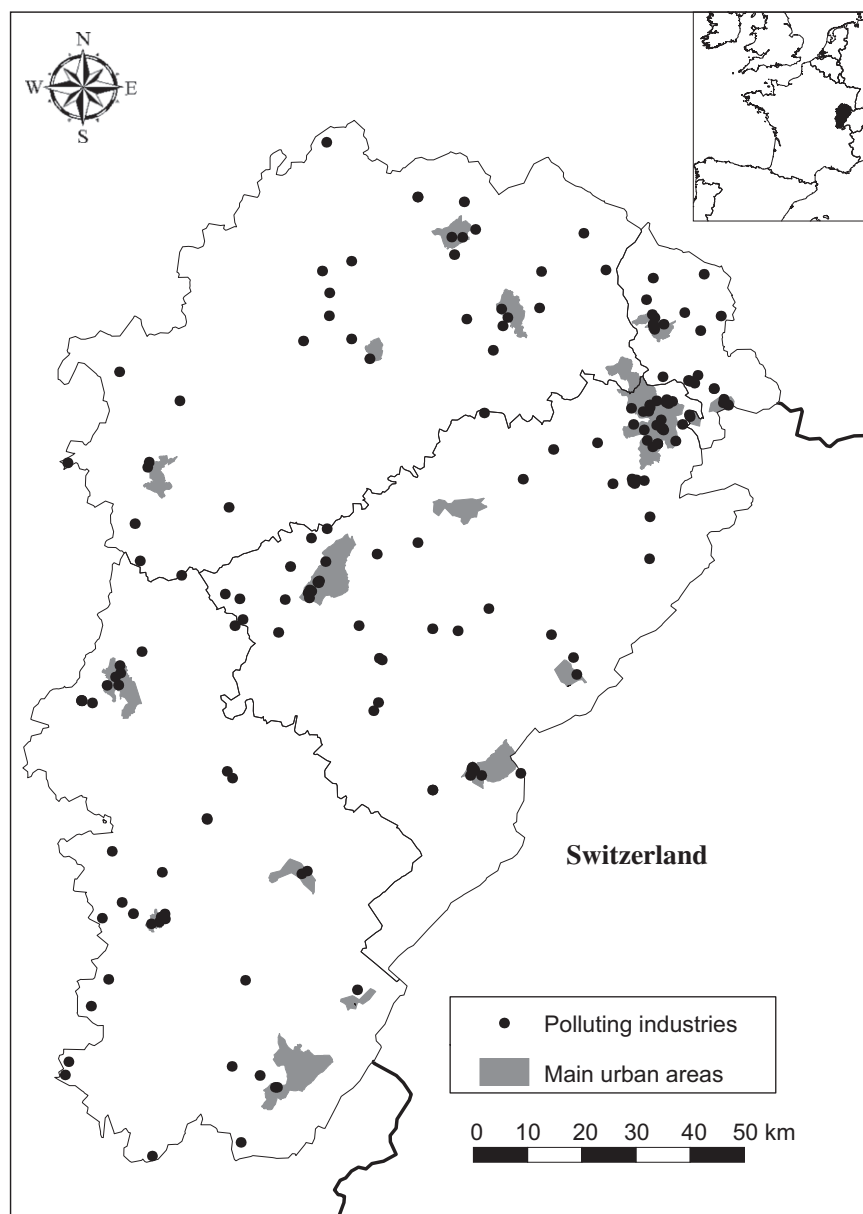


Fig. 1. Locations of polluting industrial sites in the Franche-Comté region (France, 2003–2006).

Table 2

Number of polluting industrial sites and number of IRISes with at least one site (within a 2 km distance) in the Franche-Comté region (France, 2003–2006).

Type	Number of sites	Number of IRISes with at least one site
Mechanical engineering and surface finishing	71	53
Chemical manufacturing	21	17
Waste management	19	18
Metallurgy and steel industry	18	17
Food industry	12	12
Wood processing industry	7	6
Miscellaneous	23	22
Missing	10	10
All types	181	137

facilities. Socio-economic conditions were accounted for using a material deprivation index (the Townsend score) in a multivariate framework. Entirely census-based, the Townsend score is one of the

most widely used deprivation indices, allowing comparisons across studies. We are, however, well aware that environmental inequalities cannot readily be characterized by any single aspect of socio-economic status (SES).

Our results should be interpreted with the following points in mind. In determining the existence of disproportionate environmental burdens, we considered only large and medium-sized hazardous facilities operating in 2003–2006 because these plants are registered and tracked at a national level. This approach merely touches the tip of the iceberg because non-point sources, small emitters (which may cumulatively create more of an environmental burden than one large facility), landfills and facilities shut down before 2003 (which could continue to release pollutants into the environment) were not considered in the present study.

Persons born abroad include mainly migrants from North and Sub-Saharan Africa as well as a less visible minority from Eastern Europe. However, the persons born abroad do not include second- and third-generation migrants and thus do not capture the experiences of the entire minority population.

Table 3

Risk of exposure to industrial sources of pollution (1962 IRISes, Franche-Comté region, France, 2003–2006). 95% CI: credibility interval at 95%.

	All emissions		Emissions to air		Emissions to water	
	Exposed IRISes (%)	Odds ratio (95% CI)	Exposed IRISes (%)	Odds ratio (95% CI)	Exposed IRISes (%)	Odds ratio (95% CI)
Persons born abroad						
0%	49 (9.7)	1	22 (4.4)	1	21 (4.2)	1
0.1–1.6%	229 (31.2)	1.96 (1.32–2.85)	96 (13.1)	1.71 (0.97–2.86)	90 (12.3)	1.41 (0.78–2.44)
1.7–53.0%	309 (42.6)	2.66 (1.80–3.92)	214 (29.5)	3.67 (2.08–6.38)	193 (26.6)	2.57 (1.40–4.39)
Townsend score						
– 6.67 to – 1.24	191 (29.2)	1	83 (12.7)	1	80 (12.2)	1
– 1.23–0.41	140 (21.4)	0.83 (0.60–1.11)	70 (10.7)	1.08 (0.72–1.56)	57 (8.7)	0.92 (0.60–1.35)
0.42–18.47	256 (39.2)	1.37 (1.02–1.83)	179 (27.4)	2.18 (1.52–3.20)	167 (25.6)	2.10 (1.43–3.03)
Zone						
Rural	131 (15.6)	1	60 (7.2)	1	50 (6.0)	1
Urban	456 (40.5)	1.82 (1.39–2.44)	272 (24.2)	2.38 (1.69–3.57)	254 (22.6)	2.38 (1.64–3.57)
Population density^a						
0.4–19.5	49 (7.5)	1	28 (4.3)	1	18 (2.7)	1
19.6–50.8	151 (23.1)	3.11 (2.09–4.63)	66 (10.1)	2.05 (1.22–3.36)	55 (8.4)	2.87 (1.57–4.90)
50.9–27864.4	387 (59.3)	11.37 (7.20–19.25)	238 (36.4)	6.59 (3.79–13.17)	231 (35.4)	10.82 (5.91–18.66)

^a Inhabitants per km².**Table 4**

Risk of exposure to industrial sources of pollution according to the type of industry (1962 IRISes, Franche-Comté region, France, 2003–2006) 95% CI: credibility interval at 95%.

	Mechanical engineering and surface finishing		Chemical manufacturing		Waste management		Metallurgy and steel industry	
	Exposed IRISes (%)	Odds ratio (95% CI)	Exposed IRISes (%)	Odds ratio (95% CI)	Exposed IRISes (%)	Odds ratio (95% CI)	Exposed IRISes (%)	Odds ratio (95% CI)
Persons born abroad								
0%	19 (3.8)	1	7 (1.4)	1	12 (2.4)	1	9 (1.8)	1
0.1–1.6%	92 (12.5)	1.10 (0.80–1.71)	38 (5.2)	1.83 (0.69–4.30)	53 (7.2)	1.49 (0.70–2.93)	34 (4.6)	1.12 (0.48–2.34)
1.7–53.0%	198 (27.3)	2.30 (1.12–3.64)	74 (10.2)	3.13 (1.21–7.19)	79 (10.9)	1.67 (0.78–3.30)	86 (11.9)	2.50 (1.11–5.05)
Townsend score								
– 6.67 to – 1.24	87 (13.3)	1	36 (5.5)	1	41 (6.3)	1	44 (6.7)	1
– 1.23–0.41	63 (9.6)	0.97 (0.69–1.22)	27 (4.1)	1.06 (0.58–1.78)	34 (5.2)	1.22 (0.72–1.95)	18 (2.7)	0.46 (0.24–0.79)
0.42–18.47	159 (24.3)	1.55 (1.01–2.21)	56 (8.6)	1.18 (0.70–1.88)	69 (10.6)	1.71 (1.04–2.64)	67 (10.3)	0.98 (0.61–1.50)
Zone								
Rural	37 (4.4)	1	16 (1.9)	1	11 (1.3)	1	35 (4.2)	1
Urban	272 (24.2)	3.45 (2.13–5.88)	103 (9.2)	2.44 (1.43–4.76)	133 (11.8)	5.88 (3.33–12.5)	94 (8.4)	0.81 (0.53–1.30)
Population density^a								
0.4–19.5	16 (2.4)	1	7 (1.1)	1	13 (2.0)	1	5 (0.8)	1
19.6–50.8	51 (7.8)	2.23 (1.03–4.39)	17 (2.6)	2.23 (0.76–5.68)	21 (3.2)	1.11 (0.50–2.17)	25 (3.8)	6.88 (2.35–17.13)
50.9–27864.4	242 (37.1)	11.24 (5.27–25.23)	95 (14.5)	10.19 (3.68–26.21)	110 (16.8)	4.60 (2.21–8.61)	99 (15.2)	23.97 (8.36–59.56)

^a Inhabitants per km².

An extensive body of research has noted associations between proximity to polluting industrial facilities and the SES of host communities, although some studies produced mixed results (Bowen, 2002). Recently, Briggs et al. (2008) showed in England that these associations varied depending on the spatial scale, the choice of pollutant and the way in which it is characterized. Our study conducted on a local spatial scale found that the communities that are most heavily burdened with environmentally hazardous facilities are higher foreign-born communities, while socio-economic deprivation seems to be of less importance in the location of these facilities, everything else held constant. The effect of deprivation was strongly attenuated when accounting for auto-correlation (results not shown). This finding confirms both the environmental injustice hypothesis and previous results indicating unequal distributions of environmental hazards in France and elsewhere.

The locations of chemical manufacturing facilities are relatively deprivation independent, maybe because their factory workers are generally more qualified, better trained and better paid than

average. Waste management can be considered a proximity industry localized close to the places where people live and produce waste. These facilities are indeed hosted by urban, densely populated and deprived communities. The results pertaining to metallurgy and the steel industry can be explained by historical development patterns. Such facilities' locations used to depend on a range of factors, including closeness to raw materials, energy and water supplies, flat land, transport and a large skilled workforce. The scales of these operations prevented a plant from being moved to another location. These historical factors could at least partly explain the U-shaped association with deprivation now observed, some 19th century deprived areas having turned into affluent areas two centuries later.

If intentional or structural discriminatory practices shaped the siting of these facilities or the monitoring and enforcement of environmental regulations, then environmental inequalities (revealing distributional injustice) should be regarded as environmental inequities (revealing procedural injustice; Laurian, 2008). We made no attempt to argue causal relationships between

population characteristics and the locations of hazardous sites or to identify the mechanisms that lead some areas to host more hazardous sites than others. We can nevertheless propose some possible explanations for observed inequalities based on how different mechanisms might play out in the French context. Discrimination is possible in some charged political contexts, especially in regions struggling with high unemployment such as the North and the Northeast. To our knowledge there is no evidence of explicit discrimination, but towns with more immigrants may be regarded as less worthy of environmental protection and more in need of industrial facilities for the sake of job creation. Similarly, while we are not aware of any evidence of unequal environmental protection, social and political capital is inversely proportional to poverty, unemployment and immigration. If not through legal recourse, which is unusual in France, the ability of upper/middle class and native French communities to mobilize via local media and pressure on elected officials may increase the likelihood that governing bodies disproportionately protect these communities (consciously or not). In terms of the land market factors, the North and Eastern regions of France are historically industrial. Over the last two centuries, urban development patterns may have simultaneously co-located industrial activities and high foreign-born communities in the same urban zones, the very same zones where land and housing values are the lowest. On the other hand, changes in population characteristics after the siting of a new industrial facility are less likely to explain inequalities. The French population has much lower rates of residential mobility than the American one, and it is uncertain whether demographic changes after the siting could be significant enough to account for existing inequalities.

Exposure inequalities can and must be reduced by appropriate measures of mitigation and abatement of emissions from potential sources (Martuzzi et al., 2010). Programs to clean up closed industrial sites (typically with soil and groundwater contamination) should prioritize both the most contaminated sites and those located in communities bearing disproportionate environmental burdens. Inequalities can be further countered by health promotion initiatives that target the most affected populations and by increased citizen participation in the problem-solving and decision-making processes that affect over-burdened communities (Faber and Krieg, 2002).

The French national policy agenda does not yet focus on environmental inequalities. National 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.

Research into social inequalities in exposure to environmental risk is still new in Europe and has hardly begun in France. New epidemiological and socio-demographic 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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