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Social Inequalities Related to Hazardous Incinerator Emissions: An Additional Level of Environmental Injustice

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ABSTRACT

Environmental justice (EJ) research focuses on disproportionate population exposures to multiple point and non-point pollution sources. The hazardous pollutants released by waste incinerators can contribute to uneven (or unjust) spatial and social distributions of environmental risks. The EJ literature has already revealed that the geographical distribution of incinerators generates distinct social inequalities. In the French context, these inequalities are evident when considering the proportion of unemployed people, the proportion of recent immigrants and the proportion of persons born abroad (each increases the likelihood that a town hosts an incinerator). In this article, we seek to determine whether *additional* social injustices occur due to disproportionate quantities of incinerator emissions.

We collected annual nitrogen oxide (NOx) emissions from all incinerators in France for 2009–2010. We found that incinerators in French municipalities with higher unemployment and higher proportions of immigrants and persons born abroad have higher NOx emission levels, even when controlling for population size and broader regional social and environmental deprivation indices. This indicates that incinerators in France generate higher social inequalities than initially thought, both due to their spatial distribution and to the amount of emissions they release. We recommend that unequal social impacts should be considered in waste management planning, facility siting decisions, and decisions affecting emission controls for existing and possible future incinerators in France.

INTRODUCTION

Environmental Justice (EJ) can be defined as ''the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to development, implementation and enforcement of environmental laws, regulations and policies.''[1] The environmental justice movement emerged in the United States in the 1970s. Drawing from both the social justice and environmentalist movements, it challenges the disproportionate exposure of poor, minority and marginalized groups to toxic waste and other polluting facilities and environmental hazards. Environmental justice is often investigated by measuring differences between communities in exposure to air pollution and proximity to toxic waste sites.[2,3,4]

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[1]U.S. EPA, *What is Environmental Justice?* <http://www.epa.gov/oecaerth/environmentaljustice/>, 2015.

[2]Kondo, M. C., Gross-Davis, C. A., May, K., Davis, L. O., Johnson, T., Mallard, M., et al. (2014). ''Place-based Stressors Associated with Industry and Air Pollution.'' *Health and Place* 28: 31–37.

[3]Mitchell, G. and Dorling, D. (2003). ''An Environmental Justice Analysis of British Air Quality.'' *Environment and Planning A*, 35(5): 909–929.

[4]Wilson, S. M., Fraser-Rahim, H., Williams, E., Zhang, H., Rice, L., Svendsen, E., et al. (2012). ''Assessment of the Distribution of Toxic Release Inventory Facilities in Metropolitan Charleston: An Environmental Justice Case Study.'' *American Journal of Public Health* 102(10): 1974–1980.

Among other polluting facilities, the location of incinerators has been used as a measure of social inequalities in the spatial distribution of environmental risks. Several studies have found that incinerators are more likely to be located in areas with high concentrations of disadvantaged groups.[5,6,7] In most nations where EJ studies are conducted, the disadvantaged groups considered are low-income groups and ethnic minorities. In France, where ethnicity or minority status is not recorded in official data collection instruments, concentrations of immigrants serve as a proxy for disadvantaged communities.

Incineration is the chemical reaction of oxygen with combustible waste material.[8] Waste-to-energy incinerators dispose of waste and produce power (steam and/or electricity). Depending on waste types and volume, combustion temperatures, and emissions control technologies, incinerators release various amounts of toxic pollutants such as dioxins, furans, nitrogen oxides, sulfur dioxides, and heavy metals.[9] Research has shown that exposure to these pollutants affect health by impairing the nervous system, endocrine systems, and reproductive functions.[10] A cross-sectional study in the Basque Country of Spain revealed that residential proximity to incinerators is associated with a greater mortality from tracheal, bronchial, and lung cancer for men and a greater mortality from ischaemic heart disease and respiratory illness for women.[11] Additionally, dioxin emissions from incinerators in France have been shown to be associated with increased mortality from various forms of cancers, such as non-Hodgkin's lymphoma and soft-tissue sarcoma.[12,13,14,15,16] Since incinerators are only one among many possible sources of exposure to these toxins, the pollutants released from incinerators add incrementally to baseline exposures.

Furthermore, incinerators emit a significant fraction of the global emissions of dioxins and furans, which are toxic and bio-accumulate in the environment. Dioxins and furans continue to cause harm after their initial emissions because they persist in air, soil, sediments, and food.[17] For example, dairy products from cows raised near incinerators have been found to have high dioxin levels, demonstrating that human health can also be affected through the food chain.[18,19,20] In addition to the negative and long-term health impacts associated with their emissions, incinerators can also generate negative social stigmas, decrease property values in surrounding areas, and cause additional stress for local residents.[21]

The objective of this study is to determine whether social inequalities exist in France due to incinerator emissions. France is the country with greatest number of incinerators and the highest rate of incineration in Europe.[22] ''In 2003, incineration plants [had] treated 12.6 Mt [millions tons] of non-dangerous wastes, including household waste, waste from industry, business, services, sewage sludge, or clinical waste.''[23] The negative environmental and health effects associated with incinerators generate public concerns and opposition to the siting of new incinerators. Following European Union policies, French regulations were passed in 2002 to impose stricter standards to reduce emissions and to close noncomplying incinerators. Pollutant emissions have decreased in recent years as a result of these new policies.[24] Nonetheless, the total amount of waste incinerated has

[5]Bullard, R. D. and Johnson, G. S., 2000. ''Environmentalism and Public Policy: Environmental Justice: Grassroots Activism and its Impact on Public Policy Decision Making.'' *Journal of Social Issues* 56: 555–578.

[6]Laurian, L. and Funderburg, R. 2014. ''Environmental Justice in France? A Spatio-temporal Analysis of Incinerator Location.'' *Journal of Environmental Planning and Management* 57: 424–446.

[7]Martuzzi, M., et al. 2010. ''Inequalities, Inequities, Environmental Justice in Waste Management and Health.'' *European Journal of Public Health* ckp216.

[8]Autret, E., et al. 2007. ''Incineration of Municipal and Assimilated Wastes in France: Assessment of Latest Energy and Material Recovery Performances.'' *Journal of Hazardous Materials* 139: 569–574.

[9]Sharma, R., et al. 2013. ''The Impact of Incinerators on Human Health and Environment.'' *Reviews on Environmental Health* 28: 67–72.

[10]Mattiello, A., et al. 2013. ''Health Effects Associated with the Disposal of Solid Waste in Landfills and Incinerators in Populations Living in Surrounding Areas: A Systematic Review.'' *International Journal of Public Health* 58: 725–735.

[11]Cambra, K., et al. 2010. ''Mortality in Small Geographical Areas and Proximity to Air Polluting Industries in the Basque Country (Spain).'' *Occupational and Environmental Medicine*. 68: 140–147.

[12]De Roos, A., et al. 2010. ''Residential Proximity to Industrial Facilities and Risk of Non-Hodgkin Lymphoma.'' *Environmental Research* 110: 70–78.

[13]Elliott, P., et al. 1996. ''Cancer Incidence Near Municipal Solid Waste Incinerators in Great Britain.'' *British Journal of Cancer* 73: 702.

[14]Franchini, M., et al. 2003. ''Health Effects of Exposure to Waste Incinerator Emissions: A Review of Epidemiological Studies.'' *Annali dell'Istituto superiore di sanità* 40: 101–115.

[15]Kogevinas, M., et al. 1997. ''Cancer Mortality in Workers Exposed to Phenoxy Herbicides, Chlorophenols, and Dioxins: An Expanded and Updated International Cohort Study.'' *American Journal of Epidemiology* 145: 1061–1075.

[16]Viel, J.-F., et al. 2008. ''Risk for Non Hodgkin's Lymphoma in the Vicinity of French Municipal Solid Waste Incinerators.'' *Environ. Health* 7: 51.

[17]U.S. EPA, *What is Environmental Justice?* <http://www.epa.gov/oecaerth/environmentaljustice/>, 2015.

[18]Fierens, S., et al. 2003. ''Dioxin Accumulation in Residents Around Incinerators.'' *Journal of Toxicology and Environmental Health Part A* 66: 1287–1293.

[19]Szarka, J. 2002. *The Shaping of Environmental Policy in France*. Berghahn Books.

[20]Verdura, *Les dioxines des vieux inciné rateurs de dé chets toujours présentes.* Vol. 2015, 2009.<?FNTX>

[21]Gregory, R., et al. 1995. ''Macroscope: Technological Stigma.'' *American Scientist* 83: 220–223.

[22]ADEME. *Explorer la voie des REP pour accroître le taux de recyclage en France*. Vol. 2015, 2008.

[23]Autret, E., et al. 2007. ''Incineration of Municipal and Assimilated Wastes in France: Assessment of Latest Energy and Material Recovery Performances.'' *Journal of Hazardous Materials* 139: 569–574.

[24]Centre National D'Information Indépendante sur les Dechets (cniid). Vol. 2014, <http://www.cniid.org/>, 2009–2010.

increased and incineration continues to be the primary means of waste management in France.[25]

The French Charter on the Environment declares, ''all have the right to live in a balanced environment that protects health.''[26] Several studies have investigated the distributional element of environmental injustice in France. In the first environmental injustice research study completed in France on this topic, Laurian (2008) showed that towns (communes) with low income and high proportions of immigrants are more likely to host hazardous sites, even after controlling for relevant economic and demographic factors.[27] Laurian and Funderburg later showed that incinerators are disproportionately placed in areas with high concentrations of immigrant populations, even after controlling for towns' demographic, economic, and socioeconomic characteristics and for spatial autocorrelation.[28] Although the historical context and land market dynamics must be considered, the underlying causes of these inequalities can also be attributed to discriminatory practices and policies regarding the siting of facilities and the implementation and enforcement of environmental regulations post construction.[29]

Environmental justice studies showing social inequalities in the spatial distribution of incinerators are useful to orient equity-focused urban planning, policies, and regulations to mitigate the unequal probability of incinerator location in socially deprived communities. Although numerous studies in various countries have revealed that spatial injustices exist due to incinerator *locations*,[30,31,32] the magnitude of emissions for each of these incinerators has not been fully quantified with regard to environmental justice. Therefore, it is necessary to assess whether *additional* social inequalities exist due to incinerator emissions. Do incinerators located in the most socio-economically deprived communities pollute disproportionally when taking into account the population?

The purpose of this study is to determine whether social inequalities exist in France due to the *quantity* of emissions released by incinerators. Since environmental injustices due to the location of incinerators has already been demonstrated, this would reveal a double level of injustice. We hypothesize that not only are there inequalities with regard to where incinerators are located in French municipalities, but also with regard to the *quantity of pollutants* released by these incinerators. Results from this study can have an impact on future policies and regulations concerning the development and surveillance/regulation of incinerators in France. In addition, this study may have implications for the future investigation of environmental justice by illustrating the importance of examining this second level of injustice.

METHODS

Study area

The area used for this study is metropolitan France, which has a population of 66.03 million people and a land area of 640,679 square kilometers. There are 36,569 municipalities in France (nested in their respective departments). Municipalities are used as a fine spatial level of analysis. Information was collected for all incinerators in France, and the study population is composed of all 123 municipalities that have one or more incinerators.

Incinerator emissions

Data on French incinerator emissions was collected from the Cniid (centre national d'information indépendante sur les dechets) [Global Alliance for Incinerator Alternative],[33] an independent information center with the objective of sharing information about waste management in France and encouraging the reduction of waste and pollutants associated with incineration. The data is comprised of the annual emissions from all incinerators in France for the 2009–2010 period. Information was obtained from local environmental administrations at the municipality level. Annual emissions levels were calculated using a formula based on annual amount of incinerated waste, exhaust gas volume (dry), and daily recorded emissions by incinerator for different environmental pollutants.[34] The average annual emission per incinerator was calculated for municipalities with more than one incinerator. We use nitrogen oxide (NOx) as an indicator of emissions. Data on carbon dioxide (CO2), cadmium (Cd), mercury (Hg), dioxin, and furan emissions were also collected, but are not used because of their strong correlation with NOx emissions.

In order to investigate the relationship between incinerator emissions and socio-economic characteristics of French municipalities, it is assumed that all residents in a municipality that hosts an incinerator have similar exposure to incinerator emissions. This hypothesis is not

[25]ADEME. *Explorer la voie des REP pour accroître le taux de recyclage en France*. Vol. 2015, 2008.

[26]MEDD, *Charte de l'environnement*. Vol. 2015, 2005, Ministère de l'Ecologie, du Développement Durable et de l'Energie.

[27]Laurian, L. 2008. ''Environmental Injustice in France.'' *Journal of Environmental Planning and Management* 51: 55–79.

[28]Laurian, L. and Funderburg, R. 2014. ''Environmental Justice in France? A Spatio-temporal Analysis of Incinerator Location.'' *Journal of Environmental Planning and Management* 57: 424–446.

[29]Ibid.

[30]Pellow, D. N. and Brulle, R. J. (2014). ''Environmental justice.'' *The Social Movements Reader: Cases and Concepts* 391.

[31]Cotton, M. D. (2014). ''Environmental Justice Challenges in United Kingdom Infrastructure Planning: Lessons from a Welsh Incinerator Project.'' *Environmental Justice* 7: 39–44.

[32]Wilson, S. M., Fraser-Rahim, H., Williams, E., Zhang, H., Rice, L., Svendsen, E., et al. (2012). ''Assessment of the Distribution of Toxic Release Inventory Facilities in Metropolitan Charleston: An Environmental Justice Case Study.'' *American Journal of Public Health* 102(10): 1974–1980.

[33]Centre National D'Information Indépendante sur les Dechets (cniid). Vol. 2014, <http://www.cniid.org/>, 2009–2010.

[34]Bogner, J., et al. 2008. ''Mitigation of Global Greenhouse Gas Emissions from Waste: Conclusions and Strategies From The Intergovernmental Panel On Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). *Waste Management and Research* 26: 11–32.

Table 1. Descriptive Statistics for Emissions and Socio-economic Characteristics of the 123 Municipalities that Host Incinerators

			Quintiles (percentiles)				
Variable	*Mean*	*Standard deviation*	*20th percentile*	*40th percentile*	*60th percentile*	*80th percentile*	*100th percentile*
NOx (kg/year)	140,342	139,337	41,520	86,880	132,000	192,000	876,000
Unemployment (%)	13.80	4.92	9.55	12.76	14.87	17.69	26.78
Immigrants (%)	6.40	4.98	2.00	4.26	6.58	10.09	23.66
Born Abroad (%)	10.48	6.54	4.52	7.6	11.36	16.23	32.81
SED	0.76	1.51	–0.55	0.26	0.91	2.33	4.45
Population	302,227	557,011	1,749	10,772	33,939	83,811	389,700
Social Deprivation Index	0.56	0.12	0.45	0.56	0.60	0.67	0.75

NOx = nitrogen oxide; SED = spatial environmental deprivation index.

very realistic at the micro-level, but it provides a reasonable approximation of exposure given the small size of French municipalities.

Socio-economic characteristics

Three variables were used to represent socio-economic and political power: the proportion of unemployed people, the proportion of immigrants (recent immigrants who are foreigners at the time of the census), and the proportion of persons born abroad (a group that includes immigrants who have become naturalized citizens, e.g., including the many North Africans who migrated to France in the 1960s–1970s). We collected socio-economic data from the 2006 census, and a sensitivity analysis was conducted using data from the 1999 census. Percentage unemployment was used as an indicator of the material deprivation of the municipality; it was used rather than income, because income measures can hide differences in wealth, assets, and cost of living. Minority and race are not officially recorded in French socio-demographic data, so it is challenging to quantify this information. However, the country of birth and nationality status of all residents is recorded in the census, therefore variables measuring the percentage of immigrants and proportion of persons born abroad were used as a proxy for minority groups. Other data that were used for this study were the population of municipalities, the spatial environmental deprivation index (SED) at the department level, and a measure of social deprivation index at the department level. The SED is a composite index used to measure spatial environmental inequalities and includes various indicators such as air pollution, industrial risks, and inadequate housing. The social deprivation index follows the same methodology for socio-economic variables.[35] This index includes indicators related to proportion of elderly people, people without secondary education, and proportion of social housing for example.

Statistical analysis

We estimated the relationship between total incinerator emissions and three socio-economic variables separately (i.e., proportion of unemployed people, percentage of proportion of immigrants and proportion of persons born abroad). To account for the potentially nonlinear relationship between incinerator emissions and socio-economic variables, socio-economic variables were modeled using a cubic spline with two knots (sensitivity analyses were conducted with three or four knots). Multilevel linear models with random effects were conducted to account for the nesting of municipalities within departments. A likelihood ratio test was used to consider the presence of within-department variability. A Hausman test t statistic was conducted for comparison with fixed effects models to ensure that random effect models were not mis-specified.[36,37] Covariates and causal pathways were defined a priori. Population size of the municipality is considered as confounder in order to take into consideration that larger municipalities incinerate more waste, resulting in higher emissions. The population of municipalities and the spatial environmental and social indices were considered as confounders (i.e., control variables). We calculated relative risks (RR) where RRs were presented by terciles of each of the three socio-economic variables, where the terciles with the lowest proportion of the socio-economic variables were used as reference. We first estimated the average predicted value (from the modelling) for each tercile and then the RRs were estimated by calculating the ratio of each tercile estimate to the reference group estimate. We

[35]Benmarhnia, T., et al. 2013. ''Measuring Spatial Environmental Deprivation: A New Index and its Application in France.'' *Environmental Justice* 6: 48–55.

[36]Hausman, J. A. 1978. ''Specification Tests in Econometrics.'' *Econometrica: Journal of the Econometric Society* 46: 1251–1271.

[37]Jeffrey, W. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press. Lower sec. or less. 24, 21.0–23.5.

TABLE 2. NOx EMISSIONS, SED INDEX, AND SOCIAL DEPRIVATION INDEX FOR EACH SOCIO-ECONOMIC VARIABLE, DIVIDED INTO TERCILES

	Unemployment (%)				*Immigrants (%)*				*Born abroad (%)*			
Variable	Q1 (SD)	Q2 (SD)	Q3 (SD)	P value	Q1 (SD)	Q2 (SD)	Q3 (SD)	P value	Q1 (SD)	Q2 (SD)	Q3 (SD)	P value
NOx	125,179 (118,579)	132,630 (144,652)	163,031 (153,117)	0.43	118,956 (107,001)	117,410 (91,238)	184,140 (190,472)	0.046	104,161 (93,248)	113,415 (88,185)	202,569 (190,929)	<0.01
SED[1]	0.32 (1.42)	0.59 (1.45)	1.38 (1.49)	<0.05	0.79 (1.54)	0.61 (1.52)	0.88 (1.49)	0.72	0.97 (1.57)	0.49 (1.53)	0.82 (1.43)	0.35
Social Deprivation Index[2]	0.62 (0.1)	0.57 (0.09)	0.49 (0.12)	<0.05	0.54 (0.12)	0.56 (0.12)	0.58 (0.11)	0.36	0.55 (0.11)	0.56 (0.11)	0.58 (0.13)	0.49

SED = spatial environmental deprivation index; SD = standard deviation.
[1]SED index used to measure spatial environmental inequalities.
[2]Social Deprivation Index—a measure of deprivation using socio-economic variables.

estimated 95% confidence intervals (CI) of the RRs by using bootstrapping (1,000 samples).

RESULTS

Descriptive analysis

Annual incinerator emissions are represented by NOx emissions, which range from 8,040 to 876,000 (kg/year) in the 123 French municipalities analyzed. Table 1 shows descriptive statistics for NOx emissions as well as other variables of interest such as the percentage unemployment, the percentage of immigrants, and the percentage of residents born abroad in all 123 municipalities investigated. For these municipalities, the unemployment rate ranged from 1.97% to 26.77%, the immigration rate ranged from 0% to 23.65%, and the percentage of people born abroad ranged from 0.82% to 32.8%. The mean unemployment rate was 13.80% (standard deviation (SD) = 4.92), the mean percentage of immigrants was 6.40% (SD = 4.98), and the mean percentage of persons born abroad was 10.48% (SD = 6.54).

Table 2 presents incinerator emissions, departmental SED, and social deprivation index divided into terciles for each socio-economic variable. There is a significant difference between the three terciles of emissions for the proportion of persons born abroad variable ($p < 0.01$) and proportion of immigrants ($p < 0.05$). There are significantly higher proportions of immigrants and persons born abroad in municipalities that have the highest incinerator emissions (third tercile). However, no significant difference is found between terciles of the variable unemployment ($p = 0.44$). The SED is significantly higher for municipalities with highest unemployment ($p < 0.01$). However, the SED was not significantly different in municipalities with higher percentage of immigrants ($p = 0.72$) or residents born abroad ($p = 0.35$). Similarly, municipalities in the highest tercile of unemployment had a significantly higher social deprivation index compared to the lowest tercile of unemployment ($p < 0.001$), but not for immigrants ($p = 0.36$) or persons born abroad ($p = 0.49$).

There is a significant difference (positive gradient) between the terciles of SED ($p < 0.01$) for unemployment but not for immigrants ($p = 0.72$) or born abroad ($p = 0.35$). There is also a significant difference for the social deprivation index ($p < 0.001$) for unemployment (negative gradient) but not for immigrant (p = 0.36) or born abroad ($p = 0.49$).

Regression analysis

Table 3 reports results from the multivariate analysis of the factors that impact incinerators' NOx emissions for the three variables of interest—percent unemployment, percent immigrants, and percent born abroad. Relative risk has been computed to show the effects of an increased proportion of social deprivation in a municipality on incinerator emissions. A social gradient was observed with respect to emissions for each of the three socio-economic variables: unemployment, immigration, and born abroad. As the proportion of disadvantaged residents increases in a municipality, incinerator emissions also increase.

Table 3. Relative Risk From Adjusted Regression Model of NOx Emissions for Each Socio-economic Variable, Controlling for Population, SED, and Social Deprivation Index of Municipality

Category	*Unemployment (%) [CI]*	*Immigrants (%) [CI]*	*Born abroad (%) [CI]*
Tercile 1 (Reference)	-	-	-
Tercile 2	1.48 [0.83–2.13]	*1.27 [1.07–1.48]*	*1.50 [1.22–1.78]*
Tercile 3	*1.74 [1.60–1.87]*	*2.43 [2.13–2.72]*	*3.43 [2.99–3.86]*

Italics in table = significant differences from the reference/1st tercile.
SED = spatial environmental deprivation index; CI = confidence interval.

Unemployment is significantly associated with an increase in risk of higher incinerator emissions; both terciles were statistically significantly higher than the reference (Tercile 2 RR [95% CI]: 1.48 [0.83–2.13]; Tercile 3 RR [95% CI]: 1.74 [1.60–1.87]). The proportion of immigrants was significantly associated with an increase in incinerator emissions, although the second tercile was not significantly different from the reference (Tercile 2 RR [95% CI]: 1.27 [1.07–1.48]; Tercile 3 RR [95%]: 2.43 [2.13–2.72]). The proportion of people born abroad was also significantly associated with an increase in incinerator emissions, with both terciles significantly higher than the reference (Tercile 2 RR [95% CI]: 1.50 [0.58–1.42]; Tercile 3 RR [95% CI]: 3.43 [2.99–3.86]). Although all three socio-economic variables were associated with an increased risk in exposure to higher incinerator emissions, the born abroad variable presents the highest risk in comparison to the other variables. Sensitivity analysis conducted using data from the 1999 census showed similar patterns.

DISCUSSION

Previous studies showed that incinerators are more likely to be located in economically deprived and high immigration municipalities. In this study we show that, once sited, incinerator *emissions* increase as municipalities have a higher percentage of unemployment, immigrants and born-abroad residents (even after controlling for population size and regional, social, and environmental characteristics). This reveals an additional source of social inequalities in France from incinerator emissions. However, it is interesting to note that there are differences in the severity of the inequality based on the socio-economic variable considered. For instance, social inequality is stronger for the born abroad variable than the immigrant variable, indicating that there is a stronger disadvantage for municipalities with a higher proportion of populations born abroad, i.e., including long term immigrants, than for municipalities with recent immigrants. Recently, in 2014, Laurian and Funderburg identified spatial inequalities of incinerator locations in France.[38] This study reveals that greater inequalities exist due to incinerator emissions, i.e., the ''intensity'' of the injustice is greater than previously noted. Combined, both studies reveal a ''double level'' of injustice in toxic exposure from incinerators in France.

Although the mechanisms of how these injustices arise are not entirely understood, there is speculation of how they may have evolved. Laurian and Funderburg studied the siting of incinerators based on local population characteristics of all towns *prior* to siting decisions.[39] They found that the distributional inequity is partly attributable to biased siting decisions that target towns with high proportion of immigrants, unemployment, and born-abroad residents at the time of the siting. The authors suggest that departmental waste managers select small communes with cheap land and weak political opposition to place new incinerators.[40] Furthermore our study supports the hypothesis that inequalities regarding emissions can be attributable to the administration and enforcement of regulations and environmental policies, in particular the implementation of emissions-control strategies, post construction.[41] Injustices usually affect those who have the least time, money, and access to decision makers.[42] Well-off populations benefit disproportionately from access to information and to the political and judicial systems. This can increase their relative power in the political decision making for incinerator location and emissions control. The differences in the intensity of the inequality between immigrants and people that were born abroad could be due to the fact that the population born abroad is a wider group that includes long-term immigration. Many persons born abroad are naturalized citizens or French citizens from birth (e.g., from Algeria) and have faced decades of discrimination in France.

Efforts must be made to reduce these injustices and prevent them from occurring in the future, but this will require political (citizen and governmental) recognition and intervention. As Bullard and Johnson (2000) described, ''governments need to live up to their mandate of

[38]Laurian, L. and Funderburg, R. 2014. ''Environmental Justice in France? A Spatio-temporal Analysis of Incinerator Location.'' *Journal of Environmental Planning and Management* 57: 424–446.

[39]Ibid.

[40]Laurian, L. and Funderburg, R. 2014. ''Environmental Justice in France? A Spatio-temporal Analysis of Incinerator Location.'' *Journal of Environmental Planning and Management* 57: 424–446.

[41]Bullard, R. D. and Johnson, G. S., 2000. ''Environmentalism and Public Policy: Environmental Justice: Grassroots Activism and its Impact on Public Policy Decision Making.'' *Journal of Social Issues* 56: 555–578.

[42]Dodds, L. and Hopwood, B. 2006. ''BAN Waste, Environmental Justice and Citizen Participation in Policy Setting.'' *Local Environment* 11: 269–286.

protecting public health and the environment.''[43] The United States started to include environmental justice in policies and action in 1994.[44] However, France currently does not recognize environmental injustice in its laws and procedures for risk management. These research findings emphasize that a problem does exist and that France should be recognizing this as a national justice issue.

In order to reduce these inequalities, empowerment of socially deprived communities should be strengthened in order to include all stakeholders (e.g., residents, local politicians, public health and medical services, schools, etc.) in decision-making processes related to the siting and operational management of incinerators (e.g., capacity, emissions control technologies). This has occurred in some countries, such as the anti-toxics movement in the United States, which aimed to give citizens legal authority to monitor polluting facilities.[45] Although a formal environmental justice movement does not exist in France because of its limited advocacy groups and laws precluding class action lawsuits, collective action is developing and exposure of these inequalities is the first step towards inducing change. Also, a new form of health research, popular epidemiology, is emerging which aims to ''democratize scientific practices associated with documentation, analysis and reporting of public health outcomes.''[46] This research model considers the embeddedness of health in social structures, and strives to make information accessible to all.

There are limitations to the study. Firstly, the socioeconomic data collected from the census and the data on incinerator emissions were not collected from the same year. These were the only datasets that we had accessible for our use, but it would be interesting to conduct the study with more recent data to examine if different patterns emerge. Additionally, there was a limitation with the spatiality of the data, because in order to conduct our study, it had to be assumed that everyone within the municipality had the same exposure to incinerator emissions. In reality, some areas within the municipality may have a higher exposure to emissions, and future research could address this variability based on wind patterns. Future research could then consider incinerator emissions' exposure differences *within* municipalities and identify potential micro-local differences. It would also be interesting to investigate local processes that led to siting and technology choices for incinerators in France and understand which political processes led to the environmental injustices we present in this study.

Although improvements could be made to future studies on this topic, the research was conducted with the best information available at the time. Since inequalities related to incinerator emissions have now been identified in France, there is reason to believe that they may exist elsewhere as well. This issue should be investigated in other countries or areas where spatial inequalities have been identified from the distribution of incinerators, because this additional dimension of environmental injustice may be a widespread phenomenon. Continued research to reveal the injustices generated by waste management facilities is a stride towards acknowledging that they are not managed sustainably or with social equity in mind, and can also be influential in promoting alternative waste management.

AUTHOR DISCLOSURE STATEMENT

The authors have no conflicts of interest or financial ties to disclose.

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[43]Bullard, R. D. and Johnson, G. S., 2000. ''Environmentalism and Public Policy: Environmental Justice: Grassroots Activism and its Impact on Public Policy Decision Making.'' *Journal of Social Issues* 56: 555–578.

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