

## Environmental justice implications of industrial hazardous waste generation in India: a national scale analysis

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## LETTER

## Environmental justice implications of industrial hazardous waste generation in India: a national scale analysis

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23 November 2016Pratyusha Basu<sup>1</sup> and Jayajit Chakraborty

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**Abstract**

While rising air and water pollution have become issues of widespread public concern in India, the relationship between spatial distribution of environmental pollution and social disadvantage has received less attention. This lack of attention becomes particularly relevant in the context of industrial pollution, as India continues to pursue industrial development policies without sufficient regard to its adverse social impacts. This letter examines industrial pollution in India from an environmental justice (EJ) perspective by presenting a national scale study of social inequities in the distribution of industrial hazardous waste generation. Our analysis connects district-level data from the 2009 National Inventory of Hazardous Waste Generating Industries with variables representing urbanization, social disadvantage, and socioeconomic status from the 2011 Census of India. Our results indicate that more urbanized and densely populated districts with a higher proportion of socially and economically disadvantaged residents are significantly more likely to generate hazardous waste. The quantity of hazardous waste generated is significantly higher in more urbanized but sparsely populated districts with a higher proportion of economically disadvantaged households, after accounting for other relevant explanatory factors such as literacy and social disadvantage. These findings underscore the growing need to incorporate EJ considerations in future industrial development and waste management in India.

**1. Introduction**

Environmental justice (EJ) research in India has drawn attention to local struggles against environmental pollution and dispossession (Williams and Mawdsley 2006, Ravi Rajan 2014, Das 2015) as well as measured inequities in exposure to urban air pollution (e.g. Kathuria and Khan 2007, Sabapathy *et al* 2015). However, one aspect of environmental pollution that has not been examined through an EJ perspective is industrial pollution, more specifically how the spatial distribution of industrial pollution relates to the spatial distribution of socially marginalized communities.

The inadequate attention to social inequities in the distribution of India's industrial pollution can be linked, in part, to the fact that industrial development remains a key economic development goal due to relatively low levels of industrialization in the country as a

whole. The lack of industrial development under British colonial rule made industrialization a prime objective in national policies when India gained independence in 1947. Yet, industrial growth has continued to lag and, in 2001, the contribution of manufacturing to India's gross domestic product (GDP) was 14.8% compared to 24.0% for agriculture and allied sectors and 54.0% for services (Planning Commission 2007, p 140). In the same year, the share of main workers employed in manufacturing was 13.4%, while 56.6% of main workers were employed in agriculture and allied sectors and 25.4% in services. Manufacturing thus comprises a relatively small share of total GDP and employment, and lack of access to manufacturing jobs has been one of the reasons for relatively low levels of urban development in India.

There are, however, significant reasons to examine distributive environmental injustices associated with

industrialization in India. The 1984 industrial disaster in the city of Bhopal due to a poisonous gas leak from a Union Carbide factory (since 2001, part of the Dow Chemical Company) led to massive loss of lives and adverse health consequences that continue into the present (Hanna *et al* 2005, Taylor 2014). Since this disaster affected mostly low-income residents residing in the vicinity of the factory, it emphasized the need to understand how social marginalization increases disproportionate exposure to environmental harms. Industrial pollution is also likely to remain an issue of concern in the future since the 2014 announcement of the 'Make in India' program which aims to transform the country into a 'global design and manufacturing hub.' As part of this initiative, less stringent labor and environmental regulations have been designed to attract foreign investment into India, which may further weaken environmental safeguards (Kathuria and Haripriya 2000, Kohli and Menon 2015). It has thus become important to understand how industrial development may be burdening already marginalized populations, and highlight the value of building environment-friendly industrial projects that also remain attentive to promoting social equity.

This letter seeks to address an important research gap in EJ studies in India by providing the first quantitative study of the relationship between spatial distribution of industrial hazardous waste generation and pertinent indicators of social and economic disadvantage. Following distributive EJ studies conducted at the national scale in the U.S. (e.g. United Church of Christ 1987, 2007, Baden *et al* 2007, Bullard *et al* 2008), and Australia (Chakraborty and Green 2014), we seek to determine if socially disadvantaged communities in India are disproportionately burdened by the generation of hazardous waste. Our study combines data from the *National Inventory of Hazardous Waste Generating Industries and Hazardous Waste Management in India* (Central Pollution Control Board 2009), the only publicly available source of hazardous waste data in India, with socio-demographic information obtained from the 2011 Census of India. The unit of analysis for this research is the district—an administrative area below the level of the state in India. Zero-inflated negative binomial (ZINB) regression modeling is used to analyze the likelihood and quantity of hazardous waste generation at the district level, on the basis of explanatory variables representing urbanization, social disadvantage, and socioeconomic characteristics of districts examined.

This letter contributes to EJ analysis of industrial hazardous waste generation in India in three ways. First, it advances distributive EJ research in India by providing a systematic quantitative analysis of the country as a whole, in contrast to studies which often pertain to a single urban area (Kathuria and Khan 2007, Kumar and Foster 2009, Sabapathy *et al* 2015). Moreover, by using district level data, this

letter provides a more geographically detailed assessment compared to previous national-scale studies of hazardous waste generation which have used state level information (Dixit and Srivastava 2015). Second, existing studies of hazardous wastes have not linked the social and economic characteristics of the population to the distribution of industrial pollution, but instead have focused on the quantities and environmental impacts of hazardous wastes (Haq and Chakrabarti 2000, 2007, Dixit and Srivastava 2015). In this letter, the implementation of an EJ approach that combines hazardous waste data with Census variables enables an understanding of how the broader context of social and economic inequity relates to the distribution of industrial waste generation. Finally, this letter moves beyond the notion that hazardous wastes only represent an engineering problem mainly requiring policies for regulation and remediation and specific handling and disposal techniques (Kumar *et al* 2007, Menon *et al* 2014). Instead, we argue that the distribution of hazardous wastes is also a social problem, becoming a marker of environmental and social injustice when it is disproportionately generated in places inhabited by higher proportions of socially and economically disadvantaged groups.

## 2. Data and methods

Under the 2008 Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, hazardous wastes include 'solids, semi-solids, and other industrial wastes' which are not included within prevalent water and air pollution acts. India's Central Pollution Control Board (CPCB) was established in 1974 and entrusted with controlling water pollution under the 1974 Water (Prevention and Control of Pollution) Act and subsequently also made responsible for controlling air pollution under the 1981 Air (Prevention and Control of Pollution) Act. Hazardous wastes became part of environmental regulations in India in 1989, subsequent to the Bhopal disaster, and are partly managed by the CPCB in conjunction with the Ministry of Environment and Forests (MOEF) at the center and various State Pollution Control Boards (SPCBs) and State Pollution Control Committees.

More recently, environmental laws in India have expanded from a concern with pollution control to providing legal mechanisms for adjudication of losses arising due to environmentally hazardous activities (ADB 2012). Two tribunals have been established under the MOEF that seek to enforce environmental rights and provide protection from environmental losses. The National Environment Tribunal was formed in 1995 to adjudicate liability and damages linked to 'accidents caused by handling of hazardous substances,' and the National Green Tribunal was formed in 2010 to enforce rights related to forests and other natural resources and compensation due to

**Table 1.** Summary statistics for study variables.

	<i>N</i>	Min	Max	Mean	Std. Dev.
Hazardous waste generated in metric tonnes per year (MTA)	583	0	595 940	10 786	44 794
Percent urban population	583	0.00	100.00	25.79	19.62
Population density (persons per square km)	583	2	26 705	764	2141
Percent Scheduled Caste	583	0.00	50.17	15.51	8.76
Percent Scheduled Tribe	583	0.00	98.19	16.49	25.73
Percent literate population	583	12.66	97.91	72.14	10.70
Percent households with BPL ration card	548	0.90	95.00	32.53	18.49

damages ‘connected or incidental to’ these resources (MOEF 2010, 1995). While EJ concerns are not explicitly mentioned, the tribunals provide a legal framework within which EJ issues can potentially be raised and addressed (Raj 2014).

The 2009 National Inventory is currently the only comprehensive and reliable data source for hazardous waste generation in India. While the Bhopal disaster was one of the events that impelled the formation of a Toxic Releases Inventory in the U.S., similar efforts to collate data on hazardous emissions did not occur in India at that time (Gokhale-Welch 2009). Instead, India’s National Inventory arose due to a petition filed in 1995 in the Supreme Court by the Research Foundation for Science, Technology and Natural Resource Policy which sought to challenge ‘possible contravention of the Basel Convention, to regulate movements of hazardous wastes between countries, and the illegal dumping of hazardous wastes by industrialized counties in India’ (Gokhale-Welch 2009, p 1). In 2003, the Supreme Court ordered relevant governmental agencies to collect data on hazardous waste generation from various industries in India, leading to the 2009 National Inventory.

### 2.1. Dependent variable: hazardous waste generation

The National Inventory defines hazardous waste as ‘any waste, which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health of environment, whether alone or when in contact with other wastes and substances’ (Central Pollution Control Board 2009, p 2). Hazardous wastes in the National Inventory are measured in metric tonnes per annum (MTA) and comprise three categories: land fillable waste (LFW), incinerable waste (IW), and recyclable waste (RW). In 2007–2008, there were 36 156 hazardous waste generating industries in India producing a total of 6 232 507 MTA. Out of this total, LFW contributed 2 728 326 MTA (43.8%), IW contributed 415 794 MTA (6.7%), and RW was 3 088 387 MTA (49.6%). Gujarat, Maharashtra, and Andhra Pradesh were the top three hazardous waste generating states in India, reflecting their higher levels of industrialization.

The smallest areal unit for which data on hazardous waste generation is provided in the 2009 National Inventory is the district. India currently comprises 29 states and 7 union territories, which are subdivided into 640 districts (DevInfo 2012). However, data on total quantity of hazardous waste generation are not available for all districts, and gaps in data within the National Inventory were addressed in two ways in our study. First, for the 7 states and 2 union territories which provided data at a regional or industrial area level (instead of the district level), data were allocated from these areas to their host districts. Second, for the 7 states and 3 Union Territories which did not provide data to the National Inventory, information for one state was obtained from the website of the SPCB. However, hazardous waste quantities could not be determined at the district level for the remainder. Given these data constraints, our statistical analysis encompasses 583 districts that provided reliable hazardous waste generation information.

### 2.2. Explanatory variables

Inequities in the distribution of hazardous waste generation were analyzed using a set of variables for which data are available at the district level in the 2011 Census of India. These variables are pertinent to describing environmental or social injustices in India (Kathuria and Khan 2007). We used five variables from the 2011 Census of India to capture the extent of economic development and social disadvantage in India: percent urban population, population density, percent Scheduled Caste (SC), percent Scheduled Tribe (ST), and percent literate (Census of India, 2011a, 2011b, DevInfo 2012). An additional variable utilized to measure poverty status (percent of households with Below Poverty Line (BPL) ration card) was obtained from the 2007–2008 District Level Health Survey conducted by the Ministry of Health and Family Welfare of India’s central government (DevInfo 2011). Descriptive statistics for the entire set of variables used in this study are provided in table 1.

Following national scale EJ studies conducted in the U.S., we used the percentage of urban population (Brooks and Sethi 1997, Daniels and Friedman 1999, Baden *et al* 2007) and population density (Ash and Fetter 2004, Baden *et al* 2007, United Church of Christ 2007, Downey and Hawkins 2008) as

explanatory variables for our analysis. The percentage of urban population is calculated by the Census of India in terms of population residing in urban settlements within a district. Urban settlements in India comprise census towns and statutory towns. Census towns are settlements with a population of at least 5000 people, a density of population of at least 400 people per square kilometer, and where at least 75% of main male workers pursued non-agricultural occupations. Statutory towns are those administered by a municipality, corporation, cantonment board or notified area committee. Hazardous waste production in India can be expected to be related to urban concentration in one of two ways. A higher proportion of urban population can both serve to attract industries in search of labor, as well as repel them as urban dwellers organize to ensure that hazardous wastes are not produced in their immediate vicinity (Véron 2006).

Our analysis also includes population density, a commonly used explanatory variable in EJ research. Population density, similar to urban population, can have varying effects on industrial activity and associated pollution patterns. Some studies indicate that densely populated areas are likely to attract more industrial activity and generate more pollution (Mennis and Jordan 2005), while others suggest that industries are often located in areas with vacant land (Downey and Crowder 2011) as local officials tend to focus on reducing pollution levels in areas with higher population densities (Ash and Fetter 2004). Although population density is traditionally measured as persons per square kilometer (or, square mile), a natural logarithmic transformation of this measure is used in our multivariate analysis to account for its skewed distribution, as recommended in previous EJ research (Mennis and Jordan 2005, Pastor *et al* 2005, Gilbert and Chakraborty 2011).

The variables percent SC and percent ST are utilized to represent two main socially marginalized groups in India, both being linked to long histories of exclusion from the economic and social mainstream. Thus, similar to how racial/ethnic minorities such as non-Hispanic Blacks and Hispanics have been utilized to represent socially marginalized subgroups for EJ studies in the U.S., our study used caste (SC) and tribal (ST) status to represent socially disadvantaged populations in India. In the 2011 Census, SCs comprised 16.6% and STs comprised 8.6% of India's total population (Census of India 2011a, 2011b). It should be noted that SC and ST populations show a distinctive spatial distribution within India. SCs are located mostly in northern India, while STs are concentrated in central India and in the northeastern region.

SCs and STs are listed in the Indian Constitution under The Constitution (Scheduled Castes) Order, 1950 and The Constitution (Scheduled Tribes) Order, 1950, respectively. Subject to ill treatment and often entrusted with performing menial or degrading work,

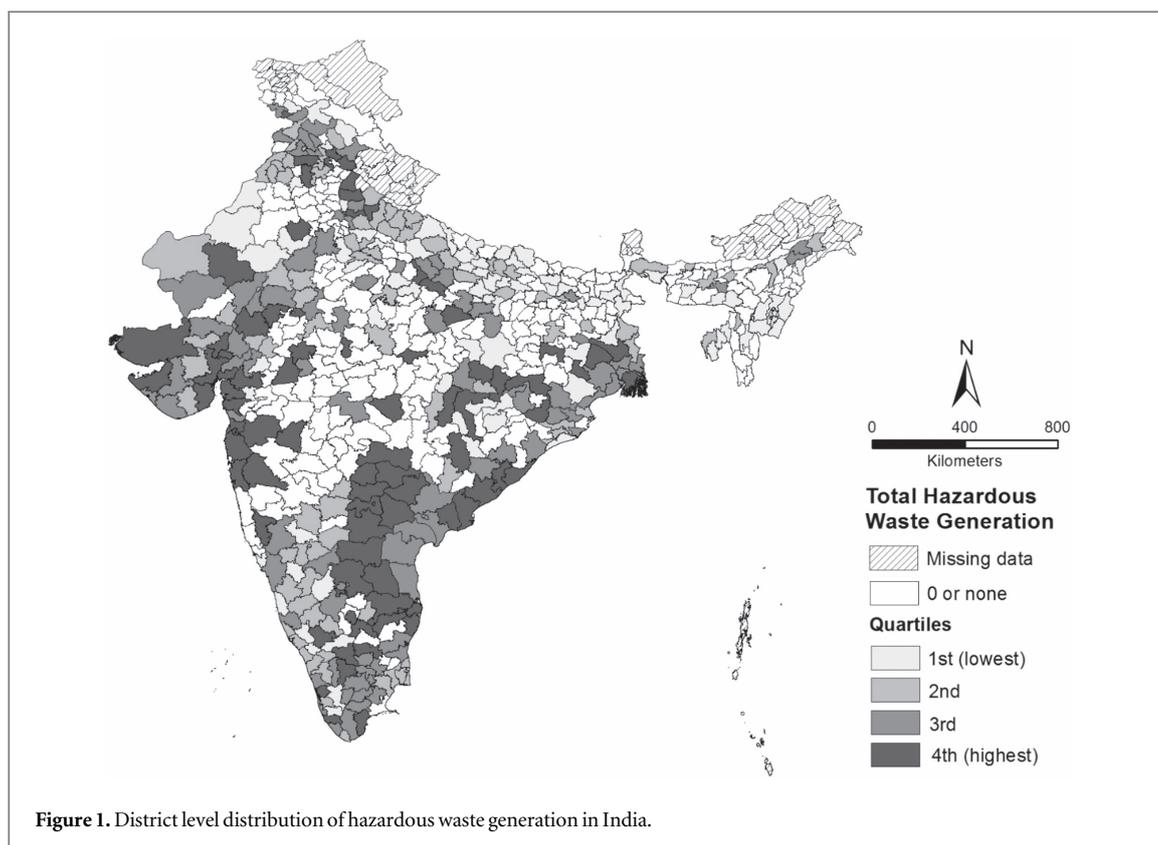
SCs were first given special protections under British colonial rule through the Government of India Act 1935, and this was continued after independence. Within the Hindu caste system, SCs represent the lower castes, and SC groups are considered to be present only within Hindu, Buddhist, and Sikh religious communities. Currently, protections accorded to SCs include reservation policies that set aside a specific number of seats in education, employment and political bodies for SCs, and laws penalizing abuses and atrocities perpetrated against SC groups. The designation ST refers to indigenous social groups that have maintained a distinctive culture, or are relatively isolated. STs can belong to any religious community, and are afforded protections similar to SCs.

To evaluate socioeconomic status, we used two variables. The first is district-level literacy rate which could characterize the suitability of the local labor force for industrial employment (hence attracting industries) as well as ability of a community to become aware of, challenge, and mitigate the adverse consequences of industrial pollution (hence repelling industries). In India, literacy rates are counted for population aged seven years and above. A second variable is the percentage of households with BPL ration card. Access to India's Public Distribution System which provides subsidized food and fuel is available through ration cards based on income level of the household, and BPL ration card becomes a useful measure of district-level eligibility for food aid, and hence possible economic deprivation. However, there are two limitations associated with this measure. First, possession of a BPL ration card may not reflect actual economic status of the household (Planning Commission 2012). Second, data on this variable is available for 548 of the 583 districts in India for which we had hazardous waste generation information. At the present moment, however, this variable remains an easily available measure of district-level poverty, and hence was considered relevant for our research.

### 2.3. Statistical methodology

The first phase of our analysis uses descriptive measures to explore the relationship between each explanatory variable and the presence or absence of hazardous waste generation. More specifically, the average values of each census variable in districts that reported hazardous waste generation are compared to their corresponding values in districts that did not report waste generation. This basic approach has been used in several EJ studies conducted at the national level in the U.S. (Hird 1993, Anderton *et al* 1994, Goldman and Fitton 1994, United Church of Christ 2007, Bullard *et al* 2008) and Australia (Chakraborty and Green 2014).

The second phase of our analysis uses multivariate regression to examine the statistical association between the magnitude of hazardous waste generated



and selected explanatory variables at the district level. A simple application of linear regression was not appropriate for our multivariate analysis because the distribution of the dependent variable was skewed with a large proportion of zeros (about 35% of districts in India did not report any hazardous waste generation in the 2009 National Inventory). To deal with these distributional characteristics, we utilized a ZINB regression model (Jones 2002) that allowed us to simultaneously identify the factors affecting both the likelihood of hazardous waste generation and total quantity of waste generation. ZINB regression is particularly appropriate for modeling overdispersed count variables with excessive zeros (Ismail and Zamani 2013) and is based on the assumption that excess zeros and non-zero values are generated by separate processes that can be modeled independently (Long 1997). The two components of the ZINB model are: (1) a binary model, in this case a logit model, to analyze which set of factors the zero outcome is associated with; and (2) a count model, in this case a negative binomial (NB) model, for the quantity of hazardous waste generated in MTA.

It should be noted that the 2009 National Inventory lists zero as the value of hazardous waste generation for 27 districts that reported 'negligible quantities.' For our descriptive analysis and bivariate comparisons, these are classified as districts that generated hazardous waste. For our multivariate ZINB regression analysis, each of these 27 districts was assumed to generate 0 MTA of hazardous waste.

### 3. Results

Before presenting the results of our statistical analysis, it is useful to consider the geographic distribution of industrial hazardous waste generation in India. The district-level distribution of waste generation is depicted as a classified choropleth map in figure 1, which also shows districts for which data were unavailable and those that did not generate any industrial hazardous waste. The total amount of hazardous wastes generated (in MTA) in each district is used to group districts into four quartiles. As mentioned before and visible in the map, districts generating the greatest volume of hazardous waste (highest quartile or top 25%) are located primarily within two states in the west (Gujarat and Maharashtra) and one state in the south (Andhra Pradesh). In contrast, districts without hazardous waste generation are located mainly in central and northeastern India.

The first phase of our statistical analysis examines differences between districts that generate hazardous waste and those that did not report any waste generation. These results are summarized in table 2, along with the national averages for each variable, based on the districts considered in our study. With the exception of the percentage of households with BPL ration card, our proxy for poverty, the differences in group means (with versus without hazardous waste) are statistically significant for all our explanatory variables. Compared to districts without hazardous waste, the mean urban percentage is more than 12% higher and literate percentage is about 4% higher in districts

**Table 2.** Comparing social characteristics of districts with and without industrial hazardous waste generation in India.

	All districts		Districts with hazardous waste		Districts without hazardous waste		Mean Diff	t-test: <i>p</i> -value
	Mean	<i>N</i>	Mean	<i>N</i>	Mean	<i>N</i>		
Percent urban population	25.79	583	30.10	377	17.92	206	12.18	<.001
Population density	764	583	877	377	559	206	318	<.05
Percent Scheduled Caste	15.51	583	16.76	377	13.22	206	3.54	<.001
Percent Scheduled Tribe	16.49	583	11.73	377	25.19	206	-13.44	<.001
Percent literate population	72.14	583	73.63	377	69.40	206	4.23	<.001
Percent households with BPL ration card	32.53	548	32.60	367	32.38	181	0.23	0.892

**Table 3.** Zero-inflated negative binomial regression analysis of industrial hazardous waste generation.

	Logit			Negative binomial	
	Estimate	<i>z</i> -value	OR	Estimate	<i>z</i> -value
Percent urban population	0.061	3.96***	1.063	0.057	5.92***
Population density (natural log)	0.571	2.85***	1.770	-0.605	-3.05***
Percent Scheduled Caste	0.050	2.50**	1.051	-0.018	-1.01
Percent Scheduled Tribe	0.010	1.36	1.010	0.001	0.09
Percent literate population	0.012	0.80	1.012	0.015	0.84
Percent households with BPL ration card	0.013	1.79*	1.013	0.012	1.97**
Constant	5.817	3.17***		9.908	6.30***
Ln (alpha)	1.693	17.02***			
Alpha	5.434				
Likelihood ratio chi-square test	72.57***				
Multicollinearity condition index	28.87				
Number of districts ( <i>N</i> )	548				
Non-zero observations	346				

\* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

generating hazardous waste. Population density is almost 1.5 times higher in districts that generated hazardous waste. While the mean percentage of the SC population is almost 4% higher, the mean percentage of people belonging to an ST group is more than 13% lower in districts producing hazardous waste, in comparison to those without such waste. Our preliminary analysis thus suggests that more urbanized and densely populated districts with a higher percentage of literate and SC population, but a lower proportion of ST population, are significantly more likely to generate hazardous waste.

While the comparison of group means provides a basic understanding of the association between hazardous waste generation and specific district level characteristics, it does not clarify the underlying pattern. Multivariate regression analysis is used, therefore, to examine whether the suggested differences persist after controlling for contextual factors. Specifically, the next phase of the study uses ZINB regression to model the relationship between hazardous waste generation and the set of explanatory variables examined previously, based on the 548 districts for which complete data on all variables were available. The results of our ZINB model, which include a logit and a NB regression, are summarized in table 3.

The log likelihood ratio (chi-square) test indicates significance for the overall model ( $p < 0.001$ ). The natural log of the alpha statistic (dispersion parameter) is also significant and validates the appropriateness of the ZINB approach for this data. To examine multicollinearity, the condition index was calculated for the combination of independent variables included in this model. This value was found to be smaller than 30 (28.87), indicating the absence of serious collinearity problems.

The original setup of the logit model is to predict the probability of belonging to the group coded as 0 (districts generating 0 MTA of hazardous waste). However, for the convenience of comparing the results to those of the NB regression model that estimates hazardous waste quantities, the signs of the coefficients were reversed so that the logit model reflects the probability of being in the hazardous waste generation group (greater than 0 MTA). In the logit model, variables indicating a statistically significant ( $p < 0.10$ ) association with the odds of hazardous waste generation include percent urban, population density, percent SC, and percent households with BPL ration card. After controlling for the effects of all other explanatory variables, the likelihood of hazardous waste generation is significantly greater in densely populated districts with a higher percentage of

urban and literate residents, SC members, and households with BPL ration card. The odds ratios (OR) for the logit model coefficients suggest that the odds of being a hazardous waste generating district increase by 6.3% for every 1% increase in the urban percentage, by 5.1% for every 1% increase in the SC population, and by 1.3% for every 1% increase in households with BPL ration card. Although the percentages of literate people and ST members were found to have a significant effect when group means were compared (table 2), these variables were not significantly related to hazardous waste generation in presence of other explanatory variables in the logit model (table 3).

The NB model indicates that for districts reporting more than 0 MTA of hazardous waste, the volume of hazardous waste generated is significantly related to percent urban, population density, and percent of households with BPL ration card. After controlling for the effects of other explanatory variables, the quantity of hazardous waste generated is significantly greater in districts with a higher percentage of urban population and households with BPL ration card, but significantly smaller in more densely populated districts. While population density was found to have a significantly positive effect on the likelihood of waste generation, this effect is reversed when the quantity of waste generated is considered, in presence of urban percentage and other explanatory variables.

#### 4. Discussion

The multivariate analyses of both hazardous waste generation and hazardous waste quantity provide important insights on environmental and social injustices associated with the generation of industrial hazardous waste in India. Our statistical results suggest that the more urbanized and densely populated districts with a higher proportion of both socially and economically disadvantaged residents (i.e., SC and households with BPL ration card) are significantly more likely to generate hazardous waste. We also found significantly higher quantities of hazardous waste in more urbanized districts with lower population densities that contain a higher proportion of households with BPL ration card, after accounting for other explanatory factors such as literacy and social disadvantage.

Our results provide useful empirical evidence regarding the effect of specific district-level characteristics on both the likelihood and extent of hazardous waste generation in India. The extent of urbanization, as measured by the urban percentage, plays a persistent explanatory role in the distribution of waste generation, even after controlling for other socio-demographic variables. This can be explained by the fact that urbanized districts are more likely to attract

industrial waste generating activities, and consequently, produce higher volumes of hazardous waste compared to less urbanized or rural districts. While densely populated districts are significantly more likely to generate hazardous waste, the quantity of waste generated was found to decline with increase in population density. National-scale EJ studies in the U.S. have also reported a negative association between population density and pollution levels, after controlling for the extent of urbanization (Ash and Fetter 2004, Baden *et al* 2007). With respect to India, our results suggest that industries generating higher volumes of hazardous waste are more likely to locate in urbanized districts that are sparsely populated, since these districts have higher availability of vacant land that are proximate and accessible to major urban centers. Previous EJ research also suggests that sparsely populated urban areas have less political influence and control over pollution generating activities (Ash and Fetter 2004, Downey and Crowder 2011).

The presence of the two disadvantaged subgroups (SC and ST) is found to have significant, but different statistical associations with hazardous waste generation. Our bivariate comparison indicated a significantly higher SC percentage and lower ST percentage in districts generating hazardous waste, compared to those without hazardous waste. Our multivariate analysis also suggested a positive relationship between the SC percentage and the probability of generating waste, in presence of other explanatory variables. While the positive effect of SC percentage is indicative of an environmental injustice with regards to hazardous waste, the non-significant association with ST percentage does not necessarily imply a just distribution since it reflects the lack of economic and industrial development in these areas.

With regards to socioeconomic characteristics, the percentage of households with BPL ration card is found to be a significant explanatory factor after controlling for urbanization and other explanatory variables. This finding suggests that hazardous waste generating industries in India are more likely to locate in urban districts characterized by lower economic status. The location of industrial waste-related activities in urban lower-class communities can be linked to factors such as lower operating costs, ease of access to low-wage labor, and less political resistance. While our preliminary comparison indicated a significantly higher percentage of literates in districts with hazardous waste, this variable ceased to remain significant in presence of other explanatory factors in our multivariate ZINB model. This non-significant effect of literacy rate on waste generation can be explained, in part, by its strong positive correlation with urban percentage and population density, which suggests a higher proportion of literates in the more urbanized and densely populated districts of India.

## 5. Conclusion

This letter contributes to EJ studies by exploring the relationship between social disadvantage and hazardous waste generation in India, a country where quantitative analysis of distributive EJ had not been previously conducted at the national scale. While our results reveal that urban percentage is one of the strongest predictors, we find that the presence of both socially and economically disadvantaged subgroups are significantly related to industrial hazardous waste generation at the district level. Since industrialization and related hazardous waste generation are likely to continue in India, environmental policies and practices related to pollution control and waste management should incorporate EJ principles to ensure that the negative externalities of industrial development are not disproportionately distributed.

There are several limitations associated with this study linked to the availability of data on hazardous waste generation. First, the *National Inventory of Hazardous Waste Generating Industries* provides data that are aggregated to the state and district levels. Since the district is a relatively coarse unit of analysis, we are unable to clarify whether various social groups residing in the district are also proximate to hazardous waste generating industries. Second, data on facility locations, quantity of waste generated by each facility, and chemical composition of hazardous wastes generated by each facility are not available in the National Inventory. Lack of facility-specific and chemical-specific data thus prevents us from estimating risks posed by hazardous waste generation on local residents based on exposure and toxicity. These limitations underscore the need to improve the format in which data on hazardous waste generation is made available, as well as more broadly improve collection and public dissemination of hazardous waste data in India. The absence of information and the need to improve data collection procedures has also been highlighted in other studies of industrial development in India (World Bank 2003, Kathuria 2009).

In the future, EJ assessment of hazardous waste generation in India could be extended in three main ways. First, one way to go beyond the limitations of the data provided by the National Inventory is to gather facility-specific and chemical-specific data from state-level agencies or through field collection of data. Since this may not be feasible for the entire country, it may require the delimiting of smaller areas for analysis, such as one or more individual states where the problems of industrial waste generation are likely to be more egregious. Second, additional explanatory variables could be included for a more detailed EJ assessment. For instance, shortcomings in the measure of poverty through BPL ration cards can be addressed by measuring poverty in terms of quality of housing and access to basic services (e.g. piped water and electricity). A cost-benefit perspective on industrialization

can be provided by measuring the proportion of workers employed in manufacturing that would allow us to estimate the value of industries to social groups residing in the area. Third, more research is necessary to examine the political, socioeconomic, and spatial processes that are potentially responsible for the environmentally unjust distribution of industrial hazardous waste generation in India. These could include historical trajectories of industrial and economic development, rural to urban migration trends, and role of local factors such as land-use restrictions, land values, and labor availability.

In conclusion, this letter represents an important first step or starting point for future research on EJ in India. Our analysis provides evidence regarding the inequitable distribution of current hazardous waste generation, and reveals that social inequities are experienced in India not only in terms of lack of access to facilities and services, education, and employment, but also in terms of higher potential exposure to environmental harms. An attentiveness to EJ principles therefore becomes highly relevant for industrial development and waste management policy in India.

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