Toward Environmental Justice: Spatial Equity in Ohio and Cleveland

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The inequitable impact of environmental hazards on poor and minority communities is well-documented. In the policy arena, these findings are commonly identified as issues of "environmental equity" or "environmental racism." This paper focuses on one aspect of this debate—the association between race, income, and toxic emissions—via an examination of the spatial distributions of toxic industrial pollution and demographic groups in Ohio and, more specifically, in Ohio's most populous county which includes the City of Cleveland.

The Public-Policy Framework

When President Clinton signed Executive Order 12898 on February 11, 1994, he officially acknowledged the gravity of an environmental issue that has been stirring in the media and public-policy community over the past decade. As a logical sequel to the establishment in 1992 of the Office of Environmental Equity (now the Office of Environmental Justice) in the U.S. Environmental Protection Agency (EPA), Clinton's order (Clinton 1994) required federal agencies to develop a plan within the year "that identifies and addresses disproportionately high and adverse human health or environmental effects of its programs, policies and activities." In so doing, the President directed "federal agencies to make environmental justice a part of all that they do" (Lee 1994).

Environmental justice is the policy rubric within which issues such as environmental equity, environmental discrimination, and environmental racism are embedded (Torres 1994; Gelobter 1994). From the standpoint of politics this rubric acknowledges that environmental decisionmaking involves the role of power and conflict; that decisions about the environment are not simply a trade-off with the economy in terms of efficiency and jobs, but rather are fundamental issues for societal welfare (Taylor 1992). This rubric also acknowledges that society has reason for concern as long as economic activity utilizes common pool resources—often un-priced or under-priced—and generates negative externalities (pollution and waste). In these cases, society has an interest in the levels of production as well as the horizontal (spatial) and vertical incidence of benefits and costs from such activity. Furthermore, since technology is not benign from all social perspectives, the public has a responsibility for guiding or at least responding to the adverse consequences of job loss or pollution generation. Whatever the mode of resolution, be it the traditional regulatory approach or the more recently developed compensation procedure (Boerner and Lambert 1994), a social response to the impacts of environmental hazards is required.

Environmental equity is premised on the notion of fairness in the distribution of environmental hazards, particularly those of a technological origin (Tarlock 1994). The problem of technological hazards has attracted the attention of geographers for over two decades (Zeigler, Johnson, and Brunn 1983), but more recently this literature has focused on more specific operational problems such as airborne toxic releases (Cutter 1987), the emergency management of toxic chemical spills by applying spatial search procedures (Gould, Tatham, and Savitsky 1988), and evacuation planning for technological hazards (Johnson and Zeigler 1986). Geographers have also used GIS for modeling community vulnerability to hazardous materials (McMaster 1990; Marr and Schoolmaster 1988). Scholars in other disciplines also have dealt with these issues (Brown 1987; Goldman 1991; Hadden 1989; Lappe

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1992). And as all of this research accumulated, the EPA issued guidelines and findings on toxic dangers to communities and the need for appropriate response strategies. These initiatives soon coalesced around EPA’s earlier concerns with risk assessment, risk communication, and risk response to technologically based hazards (Wilson 1991; Cutter 1993). These concerns were reinforced by federal legislation which ensured that a community’s right-to-know constitutes a central element in new regulations (Reilly 1992). These new requirements for the collection of data on toxic-chemical release combined with GIS applications inventorying these and collateral data made possible systematic spatial analyses of equity issues (Stockwell et al. 1993; Burke 1993; Glickman 1994).

Although environmental racism was propelled to the forefront of the policy agenda by anecdotal evidence of environmental discrimination in the 1980s and 1990s—some of which had strong racial overtones—the roots of this controversial issue go much deeper. As early as 1971 the President’s Council on Environmental Quality (CEQ) broached the issue of equity in the distribution of environmental hazards (CEQ 1971). These concerns were followed up in the Conservation Foundation’s publication on environmental hazards in urban areas (Smith 1974). In 1983, the Government Accounting Office (GAO) explored the social, economic, and racial correlates of hazardous-landfill siting (GAO 1983), and four years later the United Church of Christ (1987) coined the term “environmental racism.” The scholarly climax came with Bullard’s book Dumping in Dixie: Race, Class and Environmental Quality (1990) which helped to politicize the issues of racial discrimination in hazardous-waste siting. Although protests aimed at stopping a landfill project in the predominantly minority county of Warren County, North Carolina (1992) were successful, Greenpeace had already noted a similar national bias in the siting of waste incinerators in minority communities (Costner and Thornton 1990). And in his sequel to Dumping in Dixie, Bullard’s Confronting Environmental Racism: Voices from the Grassroots (1993) launched an even more pointed attack on environmental discrimination.

These popular movements on behalf of environmental justice found support in federal law, namely the mandate of the Civil Rights Act of 1964. This act requires federal programs to be non-discriminatory, and thus it encompasses federal environmental protection activities. Although research on toxic, hazardous, and commercial waste had long-documented inequalities in the siting of waste facilities (Collins 1992), the federal court first considered these inequalities as a point of law in a case involving the disproportionate placement of landfills among black residents near Richmond, Virginia (R.I.S.E. v. Kay 1991). Although illegal discrimination was not proven, owing to “the intent issue” (i.e., the plaintiff’s necessity to demonstrate “racial animus” or racist intent in order to sustain a charge of discrimination), this case clarified the terms of the legal debate. In cases of environmental equity, unlike other cases of discrimination, the federal courts have not resolved the evidentiary presumption that the totality of circumstances can be used to prove intent in cases of racially based environmental discrimination.

## Research Issues in Environmental Equity

Much of the debate surrounding the policy issue of environmental equity is highly emotive. The controversy pivots on two factors: 1) the extent of the spatial coincidence between the locations of environmental disamenities and minority residence; and 2) the causal interpretation of these relationships. This paper deals exclusively with the first of these two factors. More specifically, it attempts to describe the spatial association between the locations of industrial toxic emissions and the racial and economic status of surrounding populations. Utilizing data from the EPA’s Toxic Release Inventory (TRI) and the 1990 Census of Population and Housing, we attempt to evaluate the associations observed in the context of contemporary methodological controversies on causality and industrial location theory.

The landmark study on race and environmental quality was issued by The United Church of Christ’s (UCC) Commission for Racial Justice (1987). This study, covering 27 commercial hazardous waste facilities nationwide and approximately 10,000 uncontrolled hazardous waste sites (by zip code), concluded
that more than half of all blacks and Hispanics in the United States lived in communities having at least one closed or abandoned hazardous waste dump site. It has since been pointed out, however, that these conclusions should be qualified by the fact that 78 percent of the hazardous waste landfills surveyed in the UCC study are located in areas with larger proportions of whites than minorities—a finding that raises doubts about the impartiality of the UCC’s conclusions on environmental racism (Rees 1992). These doubts notwithstanding, other studies dating to the early 1970s have documented inequities in the spatial distribution of environmental quality (Freeman 1972; Asch and Seneca 1978; Gianessi, Peskin, and Wolff 1979). And more recent studies corroborate these findings (Bullard 1983; Bullard and Wright 1987; 1989; Goldman 1991; Nieves and Nieves 1992). After reviewing fifteen studies on the topic and examining their various conclusions, Mohai and Bryant (1992) conclude that these studies provide “clear and unequivocal evidence that income and racial biases in the distribution of environmental hazards exist.”

In their empirical examination of environmental inequities, Nieves and Nieves (1992) employ nationwide county-level population data and a large range of facility types. Their study reports weak but statistically significant direct correlations between facility-category densities and the proportions of blacks and of Asian Americans. In addition, they document a “moderate to strong relationship between minority population concentration and most facility categories, with the exception of all subgroups in the South and Hispanics in the West.” Their conclusion that minorities tend to be over-represented in counties with greater concentrations of noxious facilities comes with the caveat that research at the sub-county level may be needed in order to obtain the degree of geographical specificity that is required for capturing inequity’s most glaring effects.

Recent studies have attended to the Nieves’ caveat by employing census tracts as their units of analysis. Anderton et al. (1994) do so in comparing race, income, housing value and age, and employment in tracts with and without commercial facilities for treatment, storage, and disposal of hazardous wastes. The authors report that tracts containing these facilities are not more likely to have higher concentrations of minorities and that the aggregation of tracts around these facilities affects the results. Geographic scale, in other words, is an important methodological issue for students of environmental equity (Clark and Avery 1976; Fotheringham and Wong 1991). Burke’s (1993) tract-level analysis of EPA’s Toxic Release Inventory (TRI) for Los Angeles relates the tract location of chemical release sites with the distribution of racial and demographic characteristics. She reports a significant association with minority distributions. Glickman’s (1994) study of Allegheny County, Pennsylvania (the Pittsburgh area) also reports higher proportions of nonwhites and the poor in areas in close proximity to TRI sites than in more distant areas.

The present study also focuses on toxic chemical releases as reported in the Toxic Release Inventory (TRI). We begin with a statewide study of Ohio which, like Nieves and Nieves (1992), employs the county as the geographic unit of analysis. Then, following the recommendations of the Nieves (1992) and Burke (1993), we turn to an examination of TRI data at the sub-county (sub-urban) scale, employing census tracts in Cuyahoga County as the units of analysis and Cuyahoga County as our case in point. Cuyahoga, which includes Cleveland, is Ohio’s most industrial, urban, and populous county. Unlike the analyses of Burke (1993) and Glickman (1994), however, we address both the amounts of chemicals released and the differences in level of chemical toxicity. Our study also identifies important nuances in spatial statistics that are essential for appropriate identification assessment. Finally, we include TRI chemicals which are released on-site as well as those which are transferred off-site to other locations in the state and county. These two categories of data are treated separately and in combination. For our purposes, the off-site data are of lesser importance because in an urbanized place such as Cuyahoga County, a large proportion of the releases are destined for treatment facilities.

Ohio merits examination of environmental equity. From the standpoint of population in Ohio in 1990, whites accounted for over seventy percent of Ohioans living in poverty and blacks had a poverty rate more than three times higher than whites. And from the standpoint of environmental hazards, Ohio occupied first rank in the nation in hazardous waste exports (82.7 million pounds in 1990) and in imports (91.6 million pounds); second rank in
the releases of: 1) toxic chemicals into the air (136.5 million pounds); 2) chemicals known or suspected in causing birth defects (87.6 million pounds); and 3) known or suspected carcinogens (34.1 million pounds); third rank in total toxic releases; and fourth rank in carbon dioxide emissions (The Ohio Almanac 1992). In sum, Ohio is one of the nation’s leading TRI releasers (EPA 1992) into the air, surface water, land, underground, public sewage, and via off-site transfers.

Within Ohio, Cuyahoga County is especially apt for a more detailed sub-county analysis of toxic releases. The county has the highest proportion of minority residents (either black or Hispanic) in the state (26.8 percent). And in its main city, Cleveland, more than one half of the black population lives in poverty (Ohio Poverty Indicators 1993). Cleveland also ranks among the most segregated cities in the United States (Horton and Smith 1990; Van Valey, Roof, and Wilcox 1977). To the extent that statistically significant spatial correlations between race, income, and toxic emissions can be found anywhere, Cuyahoga County and the City of Cleveland would seem to be likely candidates.

Methods

One of the motivations for this study is that scientific and empirical methodologies are needed to verify or dispel popular beliefs about socially relevant topics. For a variety of methodological and practical reasons, any scholarly evaluation of the spatial coincidence between environmental disamenities and minority residence is at best difficult, and at worst contentious.

That having been said, an ideal analysis of the spatial association between race, income, and industrial toxic releases would begin by measuring environmental degradation for each point on the surface of the region under examination. These measurements would then be used for testing the hypothesis that higher levels of degradation are directly associated with minority residence. In other words, given two households located at separate points having different levels of environmental degradation, yet otherwise identical in every respect save for ethnicity, the household at the more degraded site is more likely to be occupied by a minority person. Unfortunately, these idealized methodological conditions are rarely satisfied.

First is the problem of defining the unit of analysis for environmental degradation. The idealized analysis above assumes the existence of a single, unique, and cumulative measurement of all types of degradation for every point on the region’s surface. This point unit must be defined before measurement is meaningful.

Second is the problem of dynamic processes. Given the multiple, interdependent, and changing nature of urban and regional landuse and spatial demographic patterns, the analysis is required to invoke the artificial controls of ceteris paribus. Although spatial statistics may address some of these problems, even the most sophisticated models of dynamic spatial processes result in uncertainties and over-simplifications.

A third problem concerns inferences based on the distance-decay functions of toxic releases. Though in reality these distance-decay effects occur prior to the point measurements of degradation, for all practical purposes the effects of distance on releases must be inferred. The distance-decay properties of air releases, for example, are different than those of water releases or land releases. Distance-decay also varies from substance to substance. In the absence of cumulative post-decay measurements of all types of toxic substances for every point on the region’s surface, assumptions must be made about the decay functions of particular toxic substances in particular release venues. But these assumptions are practically untestable owing to the difficulty of measuring the distance-decay properties of particular toxic substances, the large numbers of chemicals involved, and the variability of landuse and topography between regions and within regions over time. Many of these complexities are masked by the scale-of-analysis assumption.

The TRI data, though the best and most comprehensive currently available on industrial sources of toxic chemicals anywhere in the world, are known to have accuracy problems. They do not include, for example, household-level data, hence aggregation effects cannot be evaluated. Even were household data available it is not clear how these could be translated into individual exposure levels given the variety of life styles that characterize community populations. Furthermore, the TRI data are re-
ported as physical weights of toxic releases (measured in pounds of release) for the various chemicals, and these do not necessarily reflect their levels of toxicity. Recognition of these and other data problems gives methodological pause: Is it better to approach the matter scientifically using data with known shortcomings; should we wait for better data; or should we opt for a more qualitative approach emphasizing anecdotal evidence, personal experience, and common sense?

Geographic Scale of Analysis

As noted above, the study is two-pronged. First, the spatial associations between releases of toxic chemicals and race, poverty, and income measures are analyzed at the county level for the state of Ohio, the state’s 88 counties serving as the spatial units of analysis. These counties display a wide range of demographic and economic characteristics as well as toxic chemical releases. This part of the analysis thus is comparable with others that use county-level aggregates (Nieves and Nieves 1992).

Second, because counties dwarf the size of toxic release facilities, we shift our focus to the smaller census tracts within one county. Conceptually, smaller units of spatial aggregation are more satisfying because they require more modest assumptions about causal and statistical variations in local phenomena. Also these units tend to reduce information loss regarding locational differences. Census tracts are delineated using several criteria, perhaps the most important of which, for Cuyahoga County, is the homogeneity of housing and population. Census tracts in Cuyahoga thus tend to be representative of the demographic composition of neighborhoods either individually or in contiguous groups. Finally, because a comparison of tract-level to county-level results may provide insights on the appropriate geographic scale for analyses of environmental equity, we include an analysis which employs all 495 census tracts in Cleveland’s Cuyahoga County.

The Data: Toxic Releases, Threshold Limits, and Population

This study deploys three sources of data: 1) the 1987–1990 Toxic Release Inventory (TRI);

2) Threshold Limit Values (TLV); and 3) the 1990 Census of Population and Housing.

The Toxic Release Inventory. The TRI is an annual compilation of information on the quantity and location of industrial toxic releases for approximately 320 toxic chemicals. Authorized under Title III, Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 in the Superfund Amendments and Reauthorization Act of 1986 (PL. 99-499), these data cover essentially all releases by manufacturing firms except those by federal facilities; by firms who are able to justify nondisclosure in order to protect trade secrets; by firms with fewer than ten full-time employees; and by firms with releases that fall below designated threshold levels. Every firm subject to the mandate is required to report, by location, the number of pounds of each of the approximately 320 chemicals released. Penalties of $25,000 per day per chemical for each reporting violation may be levied by the EPA; however, no verification of the firms’ release data is required. The consequent issues over the quality and accuracy of the data are the subject of two recent EPA reports (EPA 1991; VIGAN 1992).

The TRI data in this study include all toxic emissions in the United States and Ohio from 1987 through 1990, as reported in three categories: 1) chemicals originating outside of Ohio and transferred into the state for release; 2) chemicals originating within Ohio and released on that same site; and 3) chemicals originating within Ohio and transferred for release to another site in Ohio. We exclude those chemicals that originated in Ohio and were shipped out of the state or that had non-Ohio origins and destinations. We examine the sum of releases over the four-year period in order to minimize annual fluctuations in actual release amounts or in the reporting of releases.

A practical limitation on the TRI data stems from the fact that the reports merely provide release weights, measured in pounds, for the various chemicals. They do not provide inherent toxicity levels for the various chemicals. Release weights alone can be misleading, however, because a small amount of a highly toxic material may be a more serious health hazard than a very large amount of a low toxicity material. Therefore estimates of inherent toxicities should be integrated into release comparisons.
Threshold Limit Values. Threshold Limit Values (TLVs) provide estimates of the inherent toxicity of various chemicals. TLVs are issued by the American Conference of Governmental Industrial Hygienists (ACGIH) to serve as guidelines to assist in the control of health hazards (ACGIH 1991).

Strictly speaking, TLVs refer to airborne concentrations of substances. Concentrations that fall below these limits represent conditions under which repeated exposure of nearly all workers will not result in adverse health effects. The problem with TLVs is that the amount and nature of the information available (and consequently the precision of a TLV) varies from substance to substance. This variation is partially attributable to the sizable differences in the research designs upon which these values are established. Some TLVs, for example, are based upon industrial experience; others are based on various experimental human and animal studies. Moreover, the TLVs are affected by divergent goals. Some are based on the goal of protecting against impairment of health, while others are based on reasonable freedom from irritation, narcosis, nuisance, or other forms of stress. Owing to these differences in study designs and goals, TLVs must be used with caution. They are not intended as fine lines between safe and dangerous concentrations of the chemicals. Yet these measures of inherent toxicity, with all of their imperfections, arguably remain the best estimates available given the current state of research in industrial toxicology.

TLVs are available for 84 percent of the chemicals on the TRI list. As for the rest, it is likely that these have not been assigned a TLV value due to their relatively low toxicity. We say this with some confidence because TLVs are estimated with the safety of workers in mind; hence if chemicals are extremely harmful, TLV values have been assigned. When TLVs are not available for particular chemicals, these are omitted from all of our analyses involving toxicity indices.

The 1990 Census. Census data are the most generally available and consistent (reliable) source of information on the demographic composition and geographic distribution of the population in the United States. Moreover, census data are available for relatively small geographic units of analysis, including the census tract. Collected every ten years, the census data for 1990 match up well with TRI data for 1987 through 1990.4

The Variables

Industrial Toxic Chemicals. In this analysis, toxic chemical releases are measured both in raw pounds and in pounds adjusted for toxicity. The TRI reports the raw poundage of chemicals releases; when these are scaled with the TLV data, we create a region-specific toxicity index in which:

\[ T_i = \sum w_j * r_j \]  

(1)

Where \( T_i \) is the aggregated estimate of toxicity (toxicity index) in region \( i \); \( w_j \) is the weight (converted to metric) of chemical \( j \) in region \( i \) by all TRI facilities in the region (summed for years 1987 through 1990); and \( r_j \) is the inverse of the TLV of chemical \( j \).

In light of the aforementioned limitations of the TLV data, the toxicity index must be interpreted as a rough estimate of the total amount of toxicity of chemical releases in each region. When analyzing particular emissions of interest, such as land emissions in a particular census tract, only these emissions are included in the index. For ease of exposition, the toxicity index is referred to as the “toxicity” of release—that is, the TLV-weighted number of the kilograms of release—as distinguished from the raw weight of the release which is referred to as “pounds” of release.5

The toxic release variables are as follows:

1. total toxicity released in the air;
2. total number of pounds released in the air;
3. total toxicity released in water;
4. total number of pounds released in water;
5. total toxicity released on land;
6. total number of pounds released on land;
7. total toxicity released on-site (air, water, and land);
8. total number of pounds released on-site; 
9. total toxicity released off-site (measured at the destination); 
10. total pounds released off-site;
11. total toxicity released in all venues combined; and 
12. total number of pounds released in all venues combined.
Demographic Variables. Seven census variables for 1990 are used in all analyses:

1. population density;
2. minority (black and/or Hispanic) concentration (density per square kilometer);
3. minority proportion of the total population;
4. poverty as a proportion of the total population;
5. median value of owner-occupied housing;
6. median household income; and
7. median gross rent.

The logic for inclusion of this particular set of demographic variables is straightforward. A spatial association between toxic chemical releases and population concentration, for example, would raise concerns about potential exposure of the residential population to these environmental hazards. Furthermore, a disproportionately high exposure to these potential environmental hazards among minorities, specifically blacks and Hispanics as well as the poor, would underline concerns for environmental equity. Similarly, the variables of median housing value and median gross rent provide insight on the adverse impacts of proximity to noxious facilities (such as the TRI sites) on residential land values and the spatial differentiation of income classes on the basis of housing choice. Median household income and the poverty rate, though related, are distinguishable as measures of economic status. Some working-class neighborhoods reporting, for example, relatively low incomes but high unemployment rates may have relatively low poverty rates. In addition, household income is partially a function of family life-cycle.

Statistical Methods

We employ well-known quantitative methods to analyze the spatial distributions of the variables including, as appropriate, zero-order correlations, partial correlation analysis, and analysis of variance. Zero-order correlations measure the strength of linear association between two variables, ignoring statistical associations with other variables. Partial correlation analysis measures the strength of the relationship between a dependent variable and an independent variable after accounting for (removing the effects of) associations with other independent variables (Harnett 1982). We also employ Moran’s I to test for spatial autocorrelation in the tract-level partial correlation analysis (Odlund 1988; Upton and Fingleton 1985). Analysis of variance is a method of estimating how much of the total variation in a variable is associated with a grouping of observations based on a criterion variable. The method provides a test for the difference in means between two or more groups.

Results: Counties and Census Tracts

This section presents the results first for the county-based statewide assessment and second for the census-tract urban assessment.

Statewide Assessment of County-Level Data

Zero-order correlations between demographic and toxic release variables for counties in Ohio indicate that population density and the two measures of minority concentration—areal density and proportion of population—exhibit strong associations with air, water, and off-site release measures (Table 1). These demographic variables tend not to be correlated with land releases (except for the association of the number of pounds of land release and minority concentration), nor with releases into water (except when these are weighted by inherent toxicity).

Variables associated with economic wealth exhibit much weaker associations with toxic releases. In the case of poverty and toxic releases, there are no statistically significant associations for the 88 Ohio counties; note, however, that all of these associations are negative, except for the poundage of water releases. Equally surprising is that both median household income and median housing value are positively associated with all release types, except unweighted water releases. But only in the cases of pounds of air releases and toxicity of off-site transfers are these associations statistically significant at the 95 percent confidence level. These results—that the greater the amount of release, the higher the household income and housing value—tend to run against the grain of conventional wisdom.

In order to isolate the relationship between each demographic variable and the toxic-re-
lease variables from the influence of other demographic variables, we also conducted a partial correlation analysis in which release amount is the dependent variable and each of the seven demographic variables is the independent variable, with the other six demographic variables held constant (sixth-order partial correlation). Results are presented in Table 2. Once the effects of other demographic variables are statistically removed, some of the associations noted above disappear and others emerge. The analysis thus yields the following associations:

1. the toxicity index for water release is related to population density, housing value, and rent;
2. the toxicity index for off-site releases is related to proportion minority;
3. pounds of on-site releases is related to proportion minority;
4. pounds of air release is related to population density;
5. pounds of off-site release is related to proportion minority and median gross rent; and
6. both the toxicity index and total pounds of release are related to proportion minority.

In sum, venue-specific associations of releases and demographic variables are few in number except for the associations with the proportion of the population that is minority. When TRI data are aggregated to the county level, statistical analysis offers prima facie evidence that higher levels of degradation are directly associated with minority residence.

Causality cannot be presumed on the basis of these statistical observations, however. Many variables remain unaccounted for, including those distinguishing urban and industrial counties from rural counties. We know, for example, that the bulk of the state’s manufacturing and its population are located in counties containing cities such as Cleveland, Cincinnati, Columbus, Akron, Youngstown, Lorain-Elyria, and Toledo, and that the fourteen most “urban” counties also contain approximately 90 percent of the state’s minority population. Figures 1 and 2 show the county-level distributions of toxic chemical releases and TLV-weighted chemical releases in the state summed over the four-year period. The more highly populated urban counties are among those counties with the greatest release amounts.

The statewide correlations may, therefore, be artifacts of differences between urban and industrial counties, on the one hand, and suburban and rural ones, on the other. To test this urban-rural hypothesis we employ an analysis
Table 2. Partial Correlations of Toxic Releases and Socioeconomic Variables: Counties in Ohio (n = 88).

<table>
<thead>
<tr>
<th>Release Venue</th>
<th>Persons/Km²</th>
<th>Minority Persons/Km²</th>
<th>Proportion Minority</th>
<th>Proportion Below Poverty</th>
<th>Median Household Income</th>
<th>Median Housing Value</th>
<th>Median Gross Rent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxicity Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site Releases</td>
<td>-0.0827</td>
<td>0.0587</td>
<td>0.1105</td>
<td>-0.1378</td>
<td>-0.1201</td>
<td>0.1058</td>
<td>0.0516</td>
</tr>
<tr>
<td>Air</td>
<td>-0.0512</td>
<td>0.1320</td>
<td>0.0561</td>
<td>0.1264</td>
<td>0.1564</td>
<td>-0.1748</td>
<td>0.0545</td>
</tr>
<tr>
<td>Water</td>
<td>0.2577a</td>
<td>-0.0946</td>
<td>0.0797</td>
<td>-0.0122</td>
<td>0.0333</td>
<td>0.2240a</td>
<td>-0.3810b</td>
</tr>
<tr>
<td>Land</td>
<td>-0.0856</td>
<td>0.0309</td>
<td>0.1008</td>
<td>-0.0898</td>
<td>-0.1798</td>
<td>0.1616</td>
<td>0.0566</td>
</tr>
<tr>
<td>Off-Site Transfers</td>
<td>0.0696</td>
<td>-0.0719</td>
<td>0.3058b</td>
<td>0.0306</td>
<td>0.0296</td>
<td>0.0392</td>
<td>-0.0677</td>
</tr>
<tr>
<td>All Toxic Releases</td>
<td>-0.0258</td>
<td>0.0059</td>
<td>0.2540a</td>
<td>-0.0904</td>
<td>-0.0770</td>
<td>0.1034</td>
<td>0.0026</td>
</tr>
<tr>
<td>Number of Pounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site Transfers</td>
<td>0.0395</td>
<td>-0.0863</td>
<td>0.3206b</td>
<td>-0.0502</td>
<td>-0.0319</td>
<td>0.0444</td>
<td>-0.0543</td>
</tr>
<tr>
<td>Air</td>
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<td>-0.0947</td>
<td>0.2007</td>
<td>-0.0988</td>
<td>-0.0538</td>
<td>0.0814</td>
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</tr>
<tr>
<td>Water</td>
<td>0.0168</td>
<td>-0.0193</td>
<td>0.0990</td>
<td>-0.0874</td>
<td>-0.1076</td>
<td>0.1344</td>
<td>-0.0562</td>
</tr>
<tr>
<td>Land</td>
<td>0.0489</td>
<td>-0.0409</td>
<td>0.1368</td>
<td>0.0245</td>
<td>0.0827</td>
<td>-0.0582</td>
<td>-0.0807</td>
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<tr>
<td>Off-Site Transfers</td>
<td>0.1235</td>
<td>0.1527</td>
<td>0.2362d</td>
<td>-0.0344</td>
<td>0.0075</td>
<td>0.1203</td>
<td>-0.2165a</td>
</tr>
<tr>
<td>All Toxic Releases</td>
<td>0.0974</td>
<td>0.0015</td>
<td>0.3889b</td>
<td>-0.0617</td>
<td>-0.0244</td>
<td>0.1001</td>
<td>-0.1592</td>
</tr>
</tbody>
</table>

Notes: These are sixth order partial correlations; each is computed using the release venue as the dependent variable, while holding all other variables constant. Chemical releases are summed for the years 1987 through 1990. See text for explanation of toxicity index. Km² signifies square kilometers.

a significant at 0.05 level.
b significant at 0.01 level.

of variance that compares urban and rural counties. Urban is defined as those counties which contained a 1990 MSA central city and rural as those which did not.

Measures of population density, minority density, and proportion minority all are significantly higher in the fourteen urban counties (Table 3). The urban counties also report significantly higher levels of toxic chemical releases. Thus, while the county-level data provide evidence confirming the hypothesis of racial bias in toxic releases, the associations between race and releases at this level of aggregation are also associated with factors which distinguish "urban" from "non-urban" counties.

Metropolitan Assessment of Tract-Level Data

Turning to the intra-metropolitan analysis, our assessment of the spatial association between toxic releases and demographic variables poses two questions at coarse and fine resolutions. First, given that many tracts contain no release sites while others contain one or more, we ask: do tracts with release sites differ in demographic composition from tracts without release sites? Although Burke (1993) has previously examined the relationship between the number of sites and the demographic composition of tracts; her approach fails to distinguish between release facilities, either in terms of the quantity or the kind (how toxic) of material released into the environment. Our second question moves to a finer scale of resolution: what are the spatial associations at the census-tract scale between the amounts and toxicities of chemical releases and demographic variables? The first question is addressed using analysis of variance, the second using both zero-order correlations and partial correlations to identify the independent associations between toxic releases and demographic variables.

Demographic Characteristics of Tracts with and without Toxic Chemical Releases: Results of an Analysis of Variance. Figure 3 maps the distributions of TRI sites and minority population in Cuyahoga County. Visual inspection of this map invites one question above all others: Do areas (i.e., tracts) with TRI sites contain disproportionate concentrations of minority populations? This question is further refined to accommodate the spatial adjacency of demographic groups to tracts with TRI sites.
Figure 1. Total pounds of toxic chemical releases, 1987–1990, Ohio counties. Urban counties are among those with the greatest release amounts. Source: Toxic Release Inventory (EPA 1987–1990).

This question may be addressed by creating a typology of TRI-site tracts and testing for differences in the demographic characteristics of the various groups of tracts. Incorporating the spatial proximity of demographic groups to TRI sites into the typology yields three census-tract classes: 1) tracts with no TRI reported facilities (on-or-off-site) in them or in adjacent tracts; 2) tracts with toxic chemical releases or transfers in one or more adjacent tracts with releases; and 3) tracts with one or more toxic facilities. The first category depicts “clean” tracts with “clean” neighboring tracts. The second category depicts “potentially exposed” tracts. This category recognizes that a tract population may be exposed or endangered by releases from a TRI site nearby. Such is the case when TRI sites occur on or near the boundary of...
census tracts, for example. In addition, tracts with high concentrations of industry and TRI sites may be largely or entirely non-residential, as is the case for Cuyahoga’s five tracts in the so-called “industrial flats” which have no population whatsoever. Yet residential neighborhoods on the fringe of these industrial areas house populations may experience greater exposure to released chemicals than do residents of neighborhoods farther away. In the absence of precise estimates of release decay functions, e.g., variable wind flows, particulate dispersion, and other toxic decay factors, this portion of our analysis represents merely a first approximation of the spatial association of residential populations and TRI sites. The third
Table 3. Comparison of “Urban” and “Non-Urban” Counties in Ohio Using Analysis of Variance and Kruskal-Wallis Test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Urban” (n = 14)</td>
<td>“Non-Urban” (n = 74)</td>
</tr>
<tr>
<td>Demographic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persons / Km²</td>
<td>389.1</td>
<td>52.3</td>
</tr>
<tr>
<td>Minority Persons / Km²</td>
<td>69.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Proportion Minority</td>
<td>13.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Proportion Below Poverty</td>
<td>65.9</td>
<td>61.1</td>
</tr>
<tr>
<td>Median Household Income</td>
<td>$28,026</td>
<td>$26,930</td>
</tr>
<tr>
<td>Median Housing Value</td>
<td>$59,900</td>
<td>$53,532</td>
</tr>
<tr>
<td>Median Gross Rent</td>
<td>$367</td>
<td>$337</td>
</tr>
<tr>
<td>Release Venue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxicity Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site</td>
<td>4,549,606</td>
<td>2,411,053</td>
</tr>
<tr>
<td>Air</td>
<td>3,050,492</td>
<td>799,350</td>
</tr>
<tr>
<td>Water</td>
<td>389,973</td>
<td>11,396</td>
</tr>
<tr>
<td>Land</td>
<td>858,523</td>
<td>1,598,479</td>
</tr>
<tr>
<td>Off-Site</td>
<td>14,601,864</td>
<td>890,553</td>
</tr>
<tr>
<td>All</td>
<td>19,151,469</td>
<td>3,301,605</td>
</tr>
<tr>
<td>Pounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site</td>
<td>42,380,891</td>
<td>5,550,318</td>
</tr>
<tr>
<td>Air</td>
<td>18,968,880</td>
<td>3,489,109</td>
</tr>
<tr>
<td>Water</td>
<td>2,581,669</td>
<td>688,604</td>
</tr>
<tr>
<td>Land</td>
<td>6,717,903</td>
<td>1,161,143</td>
</tr>
<tr>
<td>Off-Site</td>
<td>41,311,701</td>
<td>3,615,508</td>
</tr>
<tr>
<td>All</td>
<td>83,692,592</td>
<td>9,165,856</td>
</tr>
</tbody>
</table>

Notes: “Urban” counties are those with a 1990 MSA central city and “Non-Urban” counties are all others. Chemical releases are summed for the years 1987 through 1990. See text for explanation of toxicity index. Km² signifies square kilometers.

category depicts “dirty” tracts with toxic facility locations. Based on this typology, Cuyahoga County reports 123 “clean” tracts, 147 “dirty” tracts, and 225 tracts which are potentially exposed to releases in adjacent tracts.

Most of Cuyahoga's census tracts do not contain any toxic chemical release sites (70 percent), but 45 percent of all tracts are adjacent to one or more tracts that do (see Table 4). These “potentially exposed” tracts have, on average, the highest density of population (1,896 persons per square kilometer). “Dirty” tracts (at least one toxic release site), by contrast, have the lowest density (1,521 persons per square kilometer). “Clean” tracts (no toxic facility in or adjacent to the tract) have densities that fall between the other two groups. These results are consistent with conventional notions of urban spatial structure which hold that industrial areas have low population densities owing to competition for land (i.e., bid-rent curves differentiate land use types); that residential areas near industrial concentrations have the highest densities of population, mainly consisting of working-class neighborhoods; and that areas further away from the industrial core include both high- and low-density residential neighborhoods.

Minority concentration, whether measured by areal density or proportion of population, is greatest in “clean” tracts and lowest in “dirty” ones. In the latter, minority density falls to just 623 per square kilometer, but the proportion of minorities is just slightly lower (28.9 percent) than in “potentially exposed” tracts (31.5 percent). “Clean” tracts have the highest density of minorities (1,613 per square kilometer) and the highest proportion of minorities (39.0 percent) in the population.12

Some caution is warranted concerning the interpretation of the relationship between the minority proportion and tract proximity to release sites. Because of significant racial housing segregation in the county (see Figure 3), the statistical distribution of the proportion minority is largely bimodal and skewed, i.e., non-normal in distribution. Most tracts, in other words, are virtually all white, while many other tracts are actually or virtually all black; relatively few tracts are integrated. Indeed the Kruskal-
Wallis statistic (employed here because it is independent of any statistical distribution assumptions) indicates that the minority proportions for the three groups of tracts are not significantly different.

In terms of economic indicators, the poverty rate is greatest in "dirty" tracts (20.8 percent) or "potentially exposed" tracts (20.3 percent). Consistent with this finding, average median household income averages $33,431.00 in "clean" tracts and $24,824.00 in "dirty" tracts. Housing values and rents also decline in "potentially exposed" and "dirty" tract groups.

Zero-Order Correlations between Toxic Chemical Releases and Demographic Variables: An Estimate of Exposure Potential. These preliminary findings set the stage for more refined analyses. Given quantitative data on the amounts and kinds of toxic emissions at TRI sites, we take a closer look at the spatial relationship between tract release levels and demographic variables. Figures 4 and 5, respectively, map the distribution of total poundage of toxic chemical release in Cuyahoga County, and the TLV-weighted distribution of these chemicals. Toxic chemical release con-
centrations are largely associated with the industrial Cuyahoga River Valley (in the southcentral portion of the City of Cleveland) and the railroad lines running northeast-southwest through the City of Cleveland near Lake Erie and from the central part of the City toward the southeast corner of the County. Some extensive concentrations are found in suburban industrial development zones such as those found in the southeast corner of the County.

Examining the statistical associations between these two release distributions and the distributions of minorities (see Figure 3) and other demographic variables with zero-order correlations (see Table 5), we find that only one independent variable—population density—is consistently and significantly correlated with toxic chemical releases, both in terms of pounds and toxicity. Population density is significantly and inversely correlated with the toxicity levels and poundage of all releases on-site, of all releases off-site, and of all air releases. Water and land releases are also inversely correlated with population density, but these correlations are statistically insignificant. With respect to minority populations, minority density is negatively associated with the toxicities and pounds of all releases and with all venues of release, though only total release poundage is statistically significant. These correlations thus run in the opposite direction of the one posited by the hypothesis of environmental inequity. Similarly, all but one of the correlations with minority proportion (the toxicity of land releases) are negative, though none are statistically significant. These observations are clearly inconsistent with the hypothesis of environmental inequity which predicts higher levels of degradation in areas with larger proportions of minority residents.

Nor do the socioeconomic variables offer much support for the hypothesis. Correlations of income and housing values with venues of toxic chemical release are almost all negative, with only the poundage of air releases being statistically significant. In addition, the reason for the anomalous positive (but insignificant) association between toxicity-weighted water releases and housing values is not intuitively obvious. Perhaps the water releases are going in to Lake Erie where housing values are higher along the lakefront. Correlations between poverty and toxicity-weighted releases are generally negative and insignificant. The direction of this relationship appears to change when considering poundage, which suggests that chemical releases in Cuyahoga’s higher poverty tracts tend to be less toxic per pound of release.

**Partial Correlation Analysis.** In order to evaluate the statistical relationships between toxic releases and individual demographic variables, we posited that toxic release is a linear function of the demographic variables. This en-
<table>
<thead>
<tr>
<th>Release Venue</th>
<th>Proportion Minority</th>
<th>Proportion Below Poverty</th>
<th>Median Household Income</th>
<th>Median Housing Value</th>
<th>Median Gross Rent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toxicity Index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site Releases</td>
<td>-0.087&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.043</td>
<td>-0.037</td>
<td>-0.017</td>
<td>-0.007</td>
</tr>
<tr>
<td>Air</td>
<td>-0.078&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.042</td>
<td>-0.039</td>
<td>-0.012</td>
<td>-0.004</td>
</tr>
<tr>
<td>Water</td>
<td>-0.056</td>
<td>-0.019</td>
<td>-0.012</td>
<td>-0.020</td>
<td>-0.019</td>
</tr>
<tr>
<td>Land</td>
<td>-0.041</td>
<td>-0.017</td>
<td>-0.003</td>
<td>-0.019</td>
<td>-0.019</td>
</tr>
<tr>
<td>Off-Site Transfers</td>
<td>-0.090&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.051</td>
<td>-0.009</td>
<td>-0.014</td>
<td>-0.015</td>
</tr>
<tr>
<td>All Toxic Releases</td>
<td>-0.113&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.063</td>
<td>-0.020</td>
<td>-0.018</td>
<td>-0.017</td>
</tr>
<tr>
<td><strong>Number of Pounds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site Releases</td>
<td>-0.096&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.051</td>
<td>-0.033</td>
<td>0.0249</td>
<td>-0.061</td>
</tr>
<tr>
<td>Air</td>
<td>-0.130&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.070</td>
<td>-0.015</td>
<td>0.0408</td>
<td>-0.080&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Water</td>
<td>-0.043</td>
<td>-0.010</td>
<td>-0.019</td>
<td>0.0167</td>
<td>-0.036</td>
</tr>
<tr>
<td>Land</td>
<td>-0.060</td>
<td>-0.040</td>
<td>-0.049</td>
<td>0.0052</td>
<td>-0.037</td>
</tr>
<tr>
<td>Off-Site Transfers</td>
<td>-0.105&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.072</td>
<td>-0.060</td>
<td>-0.007</td>
<td>-0.029</td>
</tr>
<tr>
<td>All Toxic Releases</td>
<td>-0.138&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.088&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.068</td>
<td>0.068</td>
<td>-0.056</td>
</tr>
</tbody>
</table>

Notes: Chemical releases are summed for the years 1987 through 1990. See text for explanation of toxicity index. Km² signifies square kilometers.
<sup>a</sup>α significant at 0.05 level (one-tailed; r > 0.074).
<sup>b</sup>α significant at 0.01 level (one-tailed; r > 0.104).

abled us to conduct partial correlation analyses to measure whether or not unit changes in particular demographic variables are statistically related to the levels of toxic releases, while holding all other demographic variables constant. This yields a total of twelve partial correlation analyses, one for each release venue. In each analysis, the demographic variables are the independent variables. Whenever Moran’s I indicates the presence of significant spatial autocorrelation, we use first spatial differences for the dependent variable (Martin 1974). The resulting partial correlations are reported in Table 6.

In terms of the race variables, the only significant relationships between race and releases are inverse. The significant relationships with the toxicities of off-site transfers and all toxic releases are due to the chemicals imported into the county and released, largely in treatment facilities located in the more peripheral areas. We also see a tendency for minorities to reside further away from the locations of air releases (measured in pounds). With regard to toxic release and race, we conclude that minorities in Cuyahoga County have, if anything, a slightly smaller likelihood of residing in the immediate vicinity of a release.

In terms of the income variables, all of the significant relationships reflect off-site transfers (these include receipts from out of the county). We observe negative relationships between: 1) poverty (percent) and off-site transfers (pounds); and 2) median household income and off-site transfers (toxicity). We also see a positive relationship between housing value and toxicity transfers off-site. These results suggest that the transfer sites are not located in the high-poverty tracts with the greatest levels of unemployment and most dilapidated housing (near the center of the city). Rather the sites are located in the more peripheral working-class tracts with slightly lower than average incomes and slightly higher than average housing values. No other statistically significant relationships are observed.

**Conclusions**

An issue as controversial as environmental equity requires research that assesses the spatial coincidence between environmental disamenities and minority or disadvantaged populations prior to an analysis of causation and the role of racial intent. Our results provide little evidence on behalf of an aggregate association between environmental disamenities...
Figure 4. Total pounds of toxic chemical releases, 1987–1990, census tracts in Cuyahoga County. Concentrations are largely found in the industrial valley, along railroad and highway corridors, and in some outlying communities. Source: Toxic Release Inventory (EPA 1987–1990).

and minority concentration, nor do they suggest the systematic operation of racist intent with regard to site selection for industrial toxic releases. These findings do not, however, rule out environmental discrimination in particular cases or situations.

When viewing spatial associations at the state level (using counties as the spatial unit of analysis), the correlations between minority concentration and toxic release amounts are high. However, since industry, minority populations, and toxic releases are concentrated in urban areas, these correlations merely reflect their coincident concentration in urban counties with more industrial jobs. Owing to the coarseness of these spatial associations, we conclude that the issue of environmental equity is not amenable to a county-level analysis. Analyses using smaller spatial units are more appropriate.
Our metropolitan-area census-tract analysis indicates that minority densities are inversely correlated with toxic chemical releases on-site and off-site. Minorities in Cuyahoga County do not, as a rule, reside in neighborhoods with greater industrial toxic chemical releases than do non-minorities. Conversely, we find some evidence of income discrimination with respect to the locations of toxic facilities and the amount of air releases. Toxic industrial release facilities in Cuyahoga County are, in other words, more likely to be located in poorer and less affluent areas than in areas with minority concentrations.

Causal inferences from these findings are more problematic, since economic and industrial location theory offers at least three distinct explanatory frameworks (Hamilton 1995), each with their own causal paths, interpretations, and policy implications. These have not been prejudged in this paper. Our intent instead has been to point out that the analysis of spatial
patterns should be appropriate to the level of decisions that created these patterns. Without appropriate spatial scaling, statistical correlates become highly suspect. In the case of issues as complex as spatial equity and environmental justice, legitimate fears and concerns must be carefully assessed in terms of disaggregated analysis as specific as possible to site and situation. While our results do not negate findings in Los Angeles (Burke 1993) or elsewhere (Hamilton 1993), and are not proof that environmental discrimination within the Cleveland metropolitan area did not happen in specific cases, they do suggest that systematic environmental discrimination cannot be detected from spatial patterns and associations examined there at the census-tract level.

These findings suggest the need for further research. First is the need for more dynamic models. Our study, owing to data limitations, has been confined to investigation of a static pattern—a snapshot at one point in time. More insight on causality might result from analysis of the spatial dynamics of environmental hazards and their socio-economic correlates in terms of issues of environmental justice.

Second is the need to integrate these empirical findings with theories of urban structure. Some evidence suggests that urban cores or nearby urban core industrial sites (often representing earlier industrial location decisions) have been associated with the poor and minorities as wealthier, majority populations and industrial firms abandon the core and seek newer locations outside of the old urban core. Concurrently, firms in the urban core may seek new industrial waste sites that are further out in the suburbs owing to lower land costs in the urban fringe. In these cases, some large census tracts on the fringe may report a mixture of higher incomes, white majority populations, and newer TRI sites. This restructuring of urban geography implies a "U" shaped curve of toxic-waste site locations in which older toxic-waste sites are located in inner-city urbanized areas with high incidences of minority and poor housing, and the newer waste sites are located near higher-income suburbs.

It would be inappropriate, on the basis of this or any similar empirical study, to conclude that environmental disadvantages do not accrue to particular groups anywhere in the United States; our position is that the empirical evidence of systematic discrimination is not im-

### Table 6. Partial Correlations of Toxic Releases and Socioeconomic Variables: Tracts in Cuyahoga County (n = 495).

<table>
<thead>
<tr>
<th>Release Venue</th>
<th>Persons/Km²</th>
<th>Minority Persons/Km²</th>
<th>Proportion Minority</th>
<th>Proportion Below Poverty</th>
<th>Median Household Income</th>
<th>Median Housing Value</th>
<th>Median Gross Rent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxicity Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-Site Releases</td>
<td>-0.0049</td>
<td>-0.0253</td>
<td>-0.0066</td>
<td>-0.0770</td>
<td>0.0022</td>
<td>-0.0212</td>
<td>-0.0068</td>
</tr>
<tr>
<td>Air</td>
<td>-0.0025</td>
<td>-0.0158</td>
<td>-0.0182</td>
<td>0.0036</td>
<td>0.0201</td>
<td>-0.0345</td>
<td>-0.0130</td>
</tr>
<tr>
<td>Water</td>
<td>-0.0108</td>
<td>-0.0218</td>
<td>0.0167</td>
<td>-0.0002</td>
<td>-0.0643</td>
<td>0.0605</td>
<td>0.0534</td>
</tr>
<tr>
<td>Land</td>
<td>-0.0084</td>
<td>-0.0394</td>
<td>0.0425</td>
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<td>0.0564</td>
<td>0.0343</td>
<td>0.0099</td>
</tr>
<tr>
<td>Off-Site Transfers</td>
<td>-0.0214</td>
<td>-0.0932</td>
<td>0.0631</td>
<td>-0.0733</td>
<td>-0.1567</td>
<td>0.1112</td>
<td>0.0185</td>
</tr>
<tr>
<td>All Toxic Releases</td>
<td>-0.0215</td>
<td>-0.0951</td>
<td>0.0547</td>
<td>-0.0698</td>
<td>-0.1420</td>
<td>0.0927</td>
<td>0.0141</td>
</tr>
</tbody>
</table>

### Number of Pounds

| Release Venue          |                      |                      |                     |                         |                         |                     |                   |
|------------------------|----------------------|----------------------|---------------------|-------------------------|-------------------------|---------------------|                   |
| On-Site Releases       | -0.0084              | -0.0423              | -0.0164             | 0.0108                  | -0.0333                 | -0.0068             | -0.0022           |
| Air                    | 0.0762               | -0.0887              | -0.0202             | 0.0650                  | -0.0294                 | 0.0147              | 0.0054            |
| Water                  | -0.0022              | 0.0110               | -0.0374             | 0.0137                  | -0.0022                 | -0.0217             | -0.0021           |
| Land                   | -0.0050              | 0.0004               | -0.0485             | 0.0123                  | -0.0153                 | -0.0139             | -0.0042           |
| Off-Site Transfers     | 0.0278               | -0.0613              | -0.0350             | -0.1055                 | -0.0091                 | 0.0068              | -0.0355           |
| All Toxic Releases     | 0.0339               | -0.0698              | -0.0458             | -0.0723                 | -0.0185                 | -0.0011             | -0.0235           |

Notes: These are sixth order partial correlations; each is computed using the release venue as the dependent variable, holding all other variables constant. Chemical releases are summed for the years 1987 through 1990. See text for explanation of toxicity index. Km² signifies square kilometers.

*α* significant at 0.05 level.

*β* significant at 0.01 level.

First spatial difference of dependent variable is utilized due to spatial autocorrelation.

immediately apparent. Though we are convinced that many places in the United States do experience environmental inequity, we also believe that these controversial issues are too important to be relegated solely to the popular realms of anecdote and political opinion. Rather, the issues of environmental discrimination should be examined empirically, and as systematically and impartially as possible.

Acknowledgments

The authors appreciate the Ohio Urban University Program and the Urban Center in the Levin College of Urban Affairs at Cleveland State University for supporting this research. Appreciation also is due to Heather Moody for her assistance; Professors John Odland and Dan Knudsen in the Geography Department at Indiana University, Bloomington; Arthur Getis, Birch Foundation Professor of Geographic Studies at San Diego State University; and to an anonymous reviewer.

Notes

1. Prior to each decennial census, the U.S. Bureau of the Census provides guidelines to local committees for delineating census tracts. Boundary criteria usually include considerations such as population size, types of boundary features, tract compactness (shape), and demographic homogeneity. Local committees use these flexible guidelines in making recommendations on tract delineations to the Bureau prior to each census of population and housing. The local committee in the Cleveland area placed an extremely high priority on delineating tracts with demographic homogeneity (Salling 1986).

2. Our analyses are not explicitly aimed at the role of scale. See Fotheringham and Wong (1991) for findings on the sensitivity of results to the scale of areal units of analysis. An analysis of the importance of scale on the spatial association between population and environmental hazards surely should include a case-study approach of site-specific releases and their immediately adjacent populations. This is not the approach taken here; our interest is in comparing statewide, county-level patterns with intra-urban, tract-level patterns.

3. This analysis assigns chemical releases to the county in the statewide assessment and to the census-tract level in the metropolitan assessment. TRI data include the longitude and latitude of on-site release facilities. For chemicals that are transferred off-site for treatment and disposal, the TRI report provides the address of the treatment/disposal site. Several sources of error are associated with assigning the data to geographic units: the respondent, the data-entry process, and the matching of addresses and coordinate data to a geographic reference file. For the statewide assessment, we use the county designation in the TRI database. For the on-site locations in Cuyahoga County, the authors obtained an enhanced dataset of facility longitudes and latitudes from Loren Hall of the Environmental Assistance Division of USEPA. These enhancements are documented by ViGYAN, Inc. (1992), an EPA consultant. The enhancement methodology includes error-checking routines that look for "gross errors." Coordinate locations are checked against locations derived from street-address fields in the TRI data. If gross errors (difference of 2 km or more) cannot be improved upon using street-address-defined coordinates, then area (e.g., zip code) centroids are provided. Clearly these coordinates may err somewhat with respect to the location of release sites. They may reflect, for example, the location some distance from the actual release sites. In addition, the geographic reference file used to assign latitude and longitude coordinates, the Census Bureau's TIGER Line™ file, has its own limitations in locational accuracy. Prior experience with TIGER data in Cuyahoga County indicates, however, that errors resulting from TIGER-file errors are probably few when the census tract is the aggregation unit. TIGER was also used to locate off-site addresses in Cuyahoga County. Address-range errors in the Cuyahoga TIGER line file are unlikely to result in many tract misassignments. Nevertheless, aggregating less-than-exact point locations and addresses into census tracts in Cuyahoga County is prone to some error. (See Haining and Arbia 1993 for a discussion of error in map operations.)

4. The spatial demographic patterns identified with the data used in this analysis are not likely to have undergone drastic change in the time period, particularly at the state-level of analysis. In Cuyahoga County, trends between 1980 and 1990 show that residential concentrations of blacks and Hispanics have expanded from inner-city neighborhoods to nearby inner-ring suburbs, particularly in directional paths. Poverty rates and housing costs also have increased in an outward, though less directional, fashion. These relatively short-term trends are less significant to the spatial associations of pollution and disadvantaged populations than are the longer-term trends of associations between industrial migration, population movement, housing and neighborhood segregation and decline, and the siting of nos-ious facilities. But explanation of these trends clearly exceeds the scope of this study.

5. The correlation between the pounds of TRI chemicals released and the aggregated toxicity of those chemicals varies considerably. When considering combined air, land, and water on-site releases in Ohio at the county level, the correlation (r) between pounds and toxicity is 0.132. The correlation with off-site releases is 0.630 and with on-site and off-site releases combined, 0.407. Differences in correlation also exist depending upon the venue. For air alone, the cor-
relation is 0.340; for land alone, 0.086; and for water alone, 0.088. The substantial variation in these correlations undoubtedly is due to differences in the distributions of chemical releases from county to county and from release venue to release venue. Some counties have larger releases of less toxic chemicals; other counties have smaller releases of more toxic ones.  

6. However, census-tract data record the residential (largely evening) population distribution, not the day-time employment distribution. This is one of the advantages of the Glickman (1994) study which uses day-time and evening populations, derived from journey-to-work census tabulations by traffic zone.  

7. The relationship between household income (and socio-economic status) and family life-cycle is conceptualized in models of urban spatial structure and is well documented in the literature on urban residential differentiation. See Timms (1971) for a thorough exposition. 

8. Spatial autocorrelation is not of interest in an analysis of these associations at the county-level; these spatial units are too large in relation to the phenomena being measured (i.e., residential demographic patterns and toxic releases).  

9. Both ANOVA and the Kruskal-Wallis Analysis of Variance are presented in Tables 3 and 4. Kruskal-Wallis is used in order to account for non-normal distributions in (among) the sampled population(s). It is a distribution-free test of medians (Siegel and Castellan, Jr. 1988).  

10. This question is moot for the state-wide, county-level analysis since all 88 counties have toxic release sites.  

11. The use of GIS holds promise for more complex spatial modeling. Glickman (1994) takes a step in this direction using the circular buffering function of geographic information systems to create a typology of areas based on distances (radii) from TRI sites in Allegheny County, Pennsylvania. Comparison of the demographic composition of the area inside the buffer zone, called the “close-proximity region,” to the rest of the county indicates statistically significant differences; close-proximity areas have higher proportions of non-whites and of persons below the poverty level than do areas outside the close proximity areas.  

12. Sample variances do not differ substantially among these variables. Most differences between high and low variances are less than 75 percent. The maximum difference in variance between groups for minority density is 237 percent.  

13. Moran's I identifies the presence of spatial autocorrelation in the release measures in a region which would render unreliable any tests of statistical significance. Regression upon first spatial differences is utilized throughout the multivariate analyses for those variables with significant values of Moran's I. First spatial differences provides a reasonable, if approximate, way to eliminate spatial autocorrelation problems (Martin 1974). Moran's I indicates significant spatial autocorrela-

<table>
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<th>Variable</th>
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<th>Var(I)</th>
<th>z-score</th>
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</table>

aSignificant at 0.10 level.  
bSignificant at 0.01 level.

The relationship between nearby tracts with regard to three of the toxic release measures (Table 7).  

References  

American Conference of Governmental Industrial Hygienists (ACGIH). 1991. Threshold Limit Values for Chemical Substances and Physical Agent and Biological Exposure Indices. Cincinnati, Ohio: ACGIH.  


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A growing body of research documents the inequitable impact of environmental hazards on poor and minority communities. This paper uses the United States Environmental Protection Agency’s Toxic Release Inventory for 1987–1990 and the 1990 Census of Population and Housing to analyze the spatial distribution of toxic industrial pollution and demographic groups in Ohio. In apparent support of the previous body of research, we report high correlations between racial variables and level of toxic release at the county level. The highest levels of toxic release in Ohio occur in the state’s most urban counties, fourteen of which contain approximately 90 percent of the state’s minority population. However, a census-tract examination of the most urban of these counties, Cuyahoga, reveals no relationships between race and toxicity. The tract-level data do provide some evidence of income-environment inequity, and these findings prompt several methodological advisories for further research. The principal conclusion of the paper is that spatial scale is critical in studies of industrial environmental hazards and environmental justice. Key Words: environmental justice, hazardous siting, race, scale of analysis, toxic chemicals.

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