Society and Natural Resources, 21:179–196

ISSN: 0894-1920 print/1521-0723 online
DOI: 10.1080/08941920701618195

Articles

Rationality, Inequity, and Civic Vitality: The Distribution of Treatment, Storage, and Disposal Facilities in the Southeast

SAMMY ZAHRAN

Department of Sociology, Colorado State University, Fort Collins, Colorado, USA

DONALD W. HASTINGS

Department of Sociology, University of Tennessee, Knoxville, Tennessee, USA

SAMUEL D. BRODY

Environmental Planning and Sustainability Research Unit, Department of Landscape Architecture and Urban Planning, Texas A&M University, Texas, USA

This study examines the distribution of commercial treatment, storage, and disposal facilities (TSDFs) of hazardous waste in the southeast. Four hypotheses are tested: (1) economic rationality, (2) social inequity, (3) civic capital, and (4) scientific rationality. The data set is a match of records on operational TSDFs and large quantity generators (LQGs) of hazardous waste from the U.S. Environmental Protection Agency, demographic data from the U.S. Census Bureau, nonprofit organization data from the National Center for Charitable Statistics, and seismic hazard and hydrologic data from the U.S. Geological Survey. Logistic regression results indicate that location outcomes are predictable by the distribution of civic capital assets, the racial composition of a community, the hydrologic suitability of a land use, and TSDF proximity to LQGs. The concentration of LQG activity and the percentage of African Americans in a neighborhood are the most consistent predictors of TSDF location outcomes across spatial measures of risk.

Keywords civic capital, economic rationality, environmental equity, environmental risk, hazardous waste, scientific rationality

The Research Triangle Institute estimates the hazardous waste stream of the United States at 750 million metric tons annually (Watts 1998). Commercial treatment, storage, and disposal facilities (TSDFs) house the physical, chemical, and infectious

Received 11 August 2005; accepted 27 January 2007.
Address correspondence to Sammy Zahran, Department of Sociology, Colorado State University, B235 Clark Building, Fort Collins, CO, 80523-1784, USA. E-mail: szahran@colostate.edu

properties of this waste stream. Because TSDFs handle dangerous substances, they are widely defined as environmentally risky and locally unwanted technologies. In neighborhoods sited for TSDFs, real and perceived declines in physical and psychological health are reported (Capek 1992; Cable and Benson 1993). Public opinion studies reveal that citizens want the benefits of scientific management of hazardous waste, but very few citizens are willing to assume the environmental and public health costs of a facility in their community (U.S. Council on Environmental Quality 1980). Organized resistance to TSDFs testifies to the determination of localities to act on preferences revealed in surveys.[1] Solving this dilemma of diffuse benefit and concentrated costs concerns social scientists, environmental activists, TSD installation operators, and public officials.

The decision on where to place such a TSDF implicates diverse stakeholders with contradictory claims and interests (Bullard 1990; Cable et al. 2002; Pellow 2000). One claim that has received considerable attention is that TSDF location outcomes are demographically unequal. Government reports (GAO 1983), social scientific studies (Bullard 1983; Boer et al. 1997), and studies by environmental activists (United Church of Christ 1987) indicate that TSDFs are located disproportionately in poor communities of color. The claim of inequity is persuasive. However, government and economic agencies deny that location outcomes are discriminatory (Bullard 1983, 1990). Other researchers claim that social and economic forces like price signals (Anderton et al. 1994a, 1994b), patterns of residential settlement (Been 1994, 1995; Oakes et al. 1996), distributions of neighborhood political or social power (Hamilton 1993, 1995; Pastor et al. 2001), and the dispassionate application of scientific and technical criteria (Been 1995; Ringquist 2000) determine TSDF location outcomes. Claims and counterclaims are made, yet few empirical studies have tested these claims in a single model (for summaries of theories see Ringquist 2000; Liu 2001).

This study attempts to explain the cross-sectional distribution of commercial TSDF location outcomes in the southeastern United States. By design, we sidestep important questions answerable only with longitudinal data. Longitudinal studies of facility placement can address hypotheses of discriminatory intent, or test whether differential exposure by community demography is explainable by market dynamics that follow from hazardous facility construction (see Been 1994; Anderton et al. 1994a, 1994b; Liu 2001; Yandle and Burton 1996; Been and Gupta 1997; Pastor, Sadd, and Hipp 2001; Szasz and Meuser 2000). Our study is more preliminary, and our analytic goals more modest. Our aim is to extend the literature on the spatial distribution of hazards by expanding the pool of variables partially correlated with location outcomes for commercial TSDFs. Specifically, we introduce new measures of neighborhood civic capital, and hydrological and geological characteristics of an area that estimate its suitability for hazardous facility operations.

Our article is organized into four sections. Section one presents an abbreviated review of empirical and theoretical literature on the distribution of TSDFs. Following Evan Ringquist (2000), our literature review is organized into four cross-sectional theories of TSDF location outcomes: (1) economic rationality, (2) social inequity, (3) civic capital, and (4) scientific rationality. Section two discusses the study design and methods. Here, we discuss the rationale for focusing on the southeastern United States, data sources, data-set construction, and variable operations. Section three presents results and findings. Section four discusses the hypotheses in relation to results and suggests lines of future inquiry.

Theories of TSDF Location Outcomes

Economic Rationality

As constituted by the Resource Conservation and Recovery Act (RCRA), the management of hazardous substances in the United States is a commercial endeavor (Rosenbaum 1991). The decision on where to locate environmentally risky enterprises is partially driven by economic motives. TSDF operators cost minimize. In the hazardous waste market, cost minimization is a partial function of location. A bad location is costly for freight bills, time lost from traffic congestion, and lack of access to input commodities for production. A bad location also undermines productive efficiency. From an economic standpoint, TSDF operators must maximize utility in location preferences or risk financial ruin.

Alfred Weber (1929) articulated a simple theory of industrial location that applies to commercial TSDF location outcomes. To optimize the value of a location, Weber argued, capital must minimize transport and production costs. Transport costs are a curvilinear function of distance traveled. Transport costs flatten with increasing economies of scale, but the distance function is a powerful constraint. TSDF operators must calculate load, carrier, and journey prices to figure the variable of transport cost. Locations with lower transport costs per unit of weight and distance attract TSDF operations. Commercial TSDFs are more likely to locate to areas where hazardous wastes are generated in order to reduce transport costs and risks associated with hazardous waste transport (Liu 2001).

Another place consideration is the cost of property. Locations with lower property costs attract TSDF installations. Industrial locations with cheap property and proximate access to manufacturing inputs are ideal. Weber's cost reduction theory has been extended to include other location-specific costs like municipal taxes, public utility services and fees, and the effects of agglomeration. Agglomeration effects are difficult to estimate, but the basic idea is that benefits accrue to companies from proximity to complementary enterprises. Companies can share specialized infrastructure and collectively bargain for municipal, state, and federal dollars to subsidize operations (Hannink 1997). Commercial TSDF operators maintain that location outcomes are driven primarily by such cost motives (Freeman 1989).

Empirical support is available for an economic rationality theory of TSDF location outcomes. Anderton et al. (1994a) of the Social and Demographic Research Institute (SADRI) find that areas with TSDFs have a higher percentage of workers in industrial occupations. In another study, Anderton et al. (1994b) discovered that property costs negatively predict TSDF location outcomes. Markham and Rufa's (1997) study of 49 cities with populations of more than 100,000 shows that generators and handlers of hazardous waste seem to cluster spatially. Boer et al. (1997) analyzed the location of 82 TSDFs operating in Los Angeles County, finding that they were concentrated in the central business district near transportation routes. Baden and Coursey (2002) also report that TSDFs settle in areas with proximate access to transportation routes. Krieg (1995) finds that toxic waste facilities in the greater Boston area are located disproportionately in older industrialized areas with cheaper property. Even Robert Bullard (1990), a proponent of the social inequity thesis of TSDF location outcomes, notes that the risk of exposure is higher for communities that border industrial corridors. Finally, Szasz and Meuser (2000) note that the nonrandom distribution of hazards is governed by "normal" processes of economic geography, whereby hazardous facilities locate in industrialized settings. Consistent with these studies and Weber's theory of industrial location, we propose the following testable hypothesis for TSDF location outcomes:

> Hypothesis I. TSDF operations are located in areas with low property and transport costs.

Social Inequity

Robert Bullard (1983) conducted a case study of waste disposal in Houston, TX. Bullard did not examine TSD installations specifically, but the study pointed to a new form of inequity: residential proximity to human and industrial waste. Bullard discovered that 21 of Houston's 25 hazardous waste facilities were located in predominantly minority communities. Bullard rejected the argument that such inequity could be the product of residential choice. For Bullard, the evidence was an outcropping of racial discrimination. In *Dumping in Dixie: Race, Class, and Environmental Quality*, Bullard (1990) examined five communities with histories of environmental distress. Each case fit a pattern of environmental inequity. Communities with hazardous waste operations are depressed economically, disproportionately minority, segregated residentially, and politically marginalized.

Bullard's thesis of social inequity has been independently confirmed nationally and subnationally. In 1987, the United Church of Christ (UCC) Commission for Racial Justice (1987) published the first national, cross-sectional study of 415 commercial hazardous waste facilities in the United States. Communities with the highest percentage of minorities had the highest concentration of hazardous facilities. Statistical controls did not diminish the relationship between race and environmental risk. In fact, "race proved to be the most significant among variables tested in association with the location of commercial hazardous facilities" (UCC 1987, xiii).

Mohai and Bryant (1992) examined the geographic distribution of 14 commercial hazardous waste facilities in the Detroit metropolitan area. Their analyses show that the odds of living within 1 mile of a hazardous facility are 4 times greater for minority persons. Mohai and Bryant conclude: "Results of our Detroit area study provide clear and unequivocal evidence that income and racial biases in the distribution of environmental hazards exist" (1992, 20). Others find that Hispanics (Been 1995; Been and Gupta 1997; Boer et al. 1997; Clarke and Gerlak 1998) and Native Americans (Goetz and Kemlage 1996) are disproportionately burdened by TSDFs.

Many explanations exist for why poor communities of color are unequally burdened by environmental risks. One explanation is the pure prejudice hypothesis. This hypothesis argues that TSDF operators are motivated by racial animus, deriving psychological utility from harming minorities and the poor (see Hamilton 1995). This explanation is difficult to test—it is doubtful commercial operators would confess to such socially distasteful preferences. Structural explanations note that disproportionate TSDF location outcomes flow from racial hierarchies that partially allocate life chances. The vertical organization of society is the culprit of environmental inequity. Poor communities of color are at the bottom of the social hierarchy, with their social power circumscribed by income insecurity and barriers to human and political capital (Pellow 2000; Pulido 1996; Bullard 1990). These structural disadvantages increase the probability that poor communities of color will directly assume the burdens of a TSDF operation. Szasz and Meuser (2000, 628) maintain that environmental inequities by race and ethnicity are churned by "broader processes of racialization that determine people's occupational prospects, income, and more generally, life opportunities."

The permit process for TSDFs illustrates how structure and racial hierarchy disadvantage poor communities of color. For commercial TSDF operators, the permit process is difficult. The costs of proposal preparation are high. Proposals are regularly rejected. In 1987, a national study of permit rejections conducted by the New York Legislative Commission found that only 6 of 81 TSDF applications were accepted. Public opposition was identified as responsible for half of proposal rejections. The technical soundness of a proposal is not enough. Commercial operators hire consultants to navigate regulation, and public relations experts to communicate with targeted communities. TSDF operators are said to target poor communities of color because such communities are assumed less likely to derail proposals (Cole and Foster 2000). Insofar as skin color is an indicator of social power in racially organized societies, TSDF operators possibly use race as a statistical shortcut to predict proposal rejection. Structures of racial dominancy induce TSDFs to use statistically discriminatory reasoning.

Another process in TSDF location outcomes that reveals the effects of racial stratification is the practice of negotiated compensation. By offering direct payments and agreeing to tonnage taxes, TSDF operators can wrestle proposal acceptance from regulators and targeted communities (Boerner and Lambert 1995). Operators prefer poor communities of color because relatively educated, White, and affluent residents presumably place higher value on environmental amenities, perhaps making them less willing to trade environmental risk for economic benefits. Bullard (1990) shows how African American communities in the Southeast are structurally coerced into merciless trade-offs between health and wealth, agreeing to host hazardous facilities because of the promise of jobs, better schools, and recreational amenities. Again, structures of racial hierarchy intersect with economic dictates that increase the risk of toxic exposure for minority communities (Pulido 1996).

Whatever the exact theoretical linkage between race and exposure to environmental hazards (i.e., prejudice or discrimination, whether direct or indirect) environmental justice researchers show that hazards are distributed unevenly in the population with communities of color burdened more than their affluent and white counterparts. Consistent with this body of research, we test the following proposition:

> Hypothesis II. TSDFs are located in communities with higher percentages of African Americans.

Civic Capital

Geographies of civic vitality appear to independently predict TSDF location outcomes (Hamilton 1995; Ringquist 2000). Communities with high levels of civic organization are characterized by norms of trust and reciprocity (Putnam 2000). Norms of trust and reciprocity enable group cooperation to solve social dilemmas (Coleman 1988). According to Robert Putnam (2000), voluntary associations and nonprofit organizations are where civic capital is deposited.

Voluntary associations and nonprofit organizations appear to matter in the regional patterning of environmental risks. The environmental justice literature indicates that population groups vary in their capacity to resist the placement of a hazardous facility in their neighborhood. This capacity is not perfectly reducible to racial characteristics. Not-in-my-backyard (NIMBY) movements are more likely to emerge in civically organized communities. This observation is evident qualitatively in Bullard's research (1990). Quantitatively, Hamilton (1993, 1995) finds that the ability and/or willingness of communities to mobilize politically against noxious facilities are important predictors of TSDF expansion. Following this logic, TSDF location outcomes can be understood as a pinball game with facility proposals bounced from one community to the next, settling in the most socially pliable and least organized communities.

In the context of a national NIMBY game, from the standpoint of TSDF operators and regulators, it is rational to take the path of least resistance. This tendency toward an easier path is structurally induced. Here, the logic overlaps with the economic rationality hypothesis. From a social transaction standpoint, it is cost-effective to avoid public conflict and gridlock. TSDF operators are said to use this rationale in site selection. Researchers note a study commissioned by the California State Waste Management Board that recommended the targeting of socially disorganized communities for placement of trash-to-steam plants (Bullard 1994). For many, this document is definitive proof that civic capacity figures in hazardous waste location outcomes. As suggested by the social inequity hypothesis, researchers argue that TSDF operators demographically profile neighborhoods (Pulido 1996; Bullard 1990)—economic status and racial composition are indicators of a community's propensity to resist facility siting or capacity expansion.

A correspondence exists between community demography and organizational capacity, but not always, and never perfect. Scholars have shown that poor communities of color can mobilize effectively to block hazardous facility placement (Cable and Cable 1995). Mobilization effectiveness depends on civic vitality, a phenomenon partially independent of community demography. This argument is examined in quantitative literature, but researchers tend to use demographic measures as proxies of civic organization. For example, Pastor et al. (2001, 19) note: "Demographics reflecting political weakness—including a higher presence of minorities, a lower presence of home owners, or significant degree of ethnic churning—seem to be the real attractors of TSDFs." We agree with Pastor et al. (2001) that political weakness and civic capital are likely determinants of residential organization and TSDF location outcomes, but question whether minority or socioeconomic status equals low organizational capacity and political weakness. One cannot assume the presence of civic capacity from demographic indicators alone. By examining a neighborhood's organizational infrastructure, one can reasonably estimate its potential for organized and deliberate behavior, particularly the capacity to resist the location of a TSD installation in their community. Therefore, we propose the following testable statement:

> Hypothesis III. TSDF operations are located in areas with lower levels of civic capital.

Scientific Rationality

The last hypothesis—scientific rationality—has received the least attention in quantitative studies on the distribution of environmental risks. Commercial TSDFs are technical enterprises. TSDFs include acid neutralization laboratories, biological treatment units, and long-term storage areas such as landfills and incinerators. TSDFs are engineered to handle hydrocarbons, insecticides, fungicides, soil fumigants, primary explosives, industrial intermediates, polychlorinated biphenyls, and metals and inorganic nonmetals. These facilities absorb millions of tons of hazardous waste annually. Technical requirements for landfills and incinerators reduce the risk of catastrophic failure (Watts 1998).

The U.S. Environmental Protection Agency (EPA) delineates technical criteria for locations appropriate for commercial treatment, storage and disposal of hazardous wastes. A location must be environmentally sound. Environmental soundness is determined by factors of topography, surface soils and subsurface geology, and hydrology and subsurface water characteristics. The U.S. EPA publication on *Sensitive Environments and the Siting of Hazardous Waste Management Facilities* (2003) discourages the placement of TSDFs in floodplains, wetlands and other productive ecosystems, earthquake zones, areas with unfavorable weather conditions, high-value groundwater areas, and on unstable terrains like limestone, gypsum, and dolomite. Such recommendations are designed to reduce the risk of contaminant migration and toxic insults to humans and the environment.

According to U.S. EPA scientists and officials, TSDF location outcomes are driven by scientific and technical logics designed to maximize protection of the public and the environment from harm (Ringquist 2000). In 20-plus years of environmental research on TSDF location outcomes, geologic factors have never been empirically examined. To our knowledge, only one study has examined water, but not in the way intended by our study. Baden and Coursey (2002), in their longitudinal study of hazardous waste outcomes in Chicago, found that proximity to waterways positively predicts installation location outcomes. Their water proximity variable is used as an estimate of economic rationality.

Scientists, engineers, and U.S. EPA officials maintain that scientific criteria matter, as geological and hydrological characteristics are routinely inspected for suitability of land uses (Freeman 1989). According to Ringquist (2000), location outcomes are at least partially dictated by such risk assessments. On the scientific rationality of TSDF operators, Ringquist (2000, 244) writes: "When looking to site a hazardous waste landfill, for example, companies will regard the area's demographics as irrelevant. What matters, they would argue, are the geological characteristics of the site (for example, does the site sit on top of an important drinking-water aquifer?)." Consistent with these claims, we advance the following testable proposition:

> Hypothesis IV. TSDF operations locate in areas with suitable geology and hydrology.

Research Design and Methods

Object of Analysis

U.S. EPA Region IV in the southeastern United States is the object of analysis. Region IV includes Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. The amount of hazardous waste generated in Region IV has increased significantly in the last 20 years. The amount of waste treated, stored, and disposed of in Region IV has increased in tandem with the amount generated.[2] Region IV is now the top recipient of hazardous waste. This fact should not surprise either social inequity or economic rationality theorists.

Inequity theorists would note the region's high concentration of African Americans. Region IV encompasses the Black Belt of the United States—a socio-demographic crescent of geography characterized by depressed quality of life, higher than average rates of poverty and unemployment, and lower levels of educational attainment (Wimberly and Morris 1996). It has a history of racial hierarchy, residential segregation, and economic underdevelopment, with benefits and burdens accruing from the structure of White privilege (Bullard 1990). The concentration of environmental burdens in the Black Belt is consistent with the racial inequity narrative.

Economic rationality theorists would likely note the region's re-industrialization. In the last two decades, various chemical-intensive industries have located to the Southeast. Auto manufacturers in Alabama and Tennessee, automotive suppliers in Georgia and Kentucky, logistics and transport industries in Mississippi, computer hardware manufacturers in South Carolina and Tennessee, and pharmaceutical and bioengineering industries in North Carolina and Georgia have all gravitated to the region. Such manufacturers note the competitive advantages of the Southeast, which include lower average hourly manufacturing wages, right-to-work labor laws, lower levels of workers compensation, and cheaper industrial property both inside and outside central business districts. Increase in industrial activity increases market opportunities for treatment, storage, and disposal of hazardous waste. Differential exposure to environmental risks by race, a pure economic rationality theorist would hold, is not a product of racial discrimination; it is coincidental with re-industrialization, a product of race neutral market processes.

Economic rationality and social inequity theories of TSDF location outcomes are logically testable in the southeastern United States. Beyond its distinction as the nation's leading handler of dangerous substances, other factors make the region appropriate for location outcome studies. The Southeast is often cited as the birthplace of the environmental justice movement (i.e., Warren County, NC), and noted for the proliferation of organizations with overlapping interests in civil rights and environmental equity to combat locally undesirable land uses (Bullard 1990). For these reasons, the civic capital thesis figures nicely. Moreover, the region varies considerably by geology and hydrology, from the rocky tops of Tennessee to the wetlands of Florida, enabling an adequate test of the scientific rationality hypothesis.

Data and Variable Operations

Data on commercial TSDFs are from U.S. EPA sources and John Michael Oakes. The data set yielded a total of 100 commercial TSDFs operating in U.S. EPA Region IV as of 1990. Measures were added on large quantity generator (LQG) activity, population and housing characteristics, community civic capital, earthquake probability, and hydrology. A geo-coding firm was consulted to locate ZIP code records for nonprofit organizations and LQGs at the census tract level. Longitude and latitude coordinates for census tracts were appended for geographic analysis. Our unit of analysis is the commonly used census tract.

The major drawback with this unit of analysis is that hazardous facilities may be sited at the edge of a census tract (Bullard 1996). As burdens originating from

TSDFs are related to distance (see Liu 2001), creation of composite zones can minimize this problem. No consensus exists on the best distance, but the most commonly used zones of impact are 1 and 1.5 miles (see Mohai and Bryant 1992; Boer et al. 1997). Evidence from risk perception, price hedonic, and contaminant studies generally support these distances (Liu 2001). Our study adopts these distances. Distances are measured from the centroid of a census tract to the centroid of the nearest tract hosting a TSDF. The dependent variable includes all tracts containing a TSDF and all adjacent tracts within 1 and 1.5 miles of this suspect land use (see Figure 1).

Several sources of data on LQGs were examined: Biennial Reporting System data files, the RCRA online database, the Enforcement and Compliance History Online database, Office of Solid Waste reports and memos, and the Environmental Justice Geographic Assessment Tool. Demographic variables are derived from 1990 population and housing data from the U.S. Census Bureau. The decennial census is the most comprehensive and important source of socioeconomic data in the United States, but coverage errors must be acknowledged. The 1990 Census missed 4.4% of African Americans, 5% of Hispanics, 2.3% of Asians and Pacific Islanders, and 12% of Native Americans (Prewitt 2000).

Indicators of community civic capital are derived from data provided by the National Center for Charitable Statistics (NCCS). The NCSS Core File of 1990 includes all nonprofit organizations of tax-exempt status with $25,000 in gross receipts that filed 990 Forms for the Internal Revenue Service (IRS). The NCSS Core File merges descriptive information from three cumulative files compiled by the IRS: the Business Master File (BMF), the Return Transaction File (RTF), and the Statistics of Income (SOI) file. The NCCS conducts standardized checks on all information, making the Core File "the most complete and highest quality data source ever available on nonprofit organizations" (Lampkin and Boris 2002, 1683).

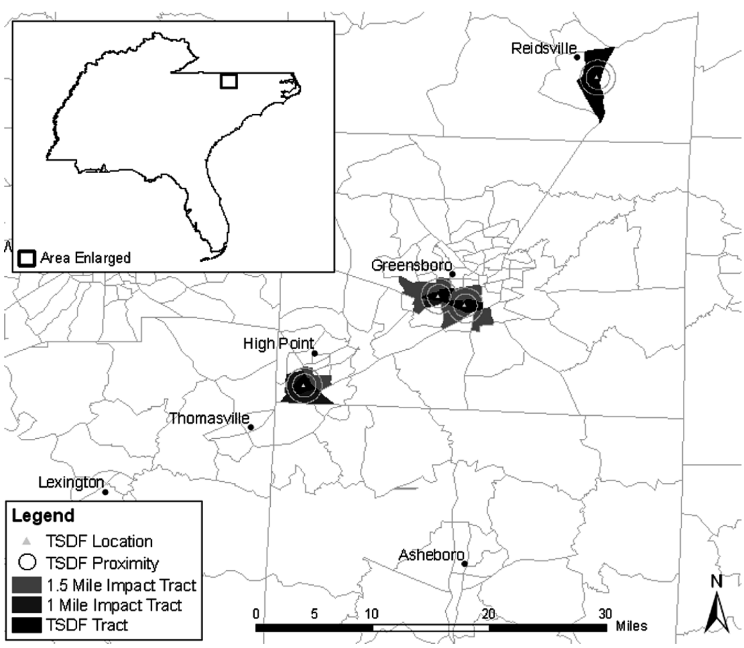

Figure 1. Study area and measurement logic.

Table 1. Variable definition statements and hypothesized direction of relationship

Variable	Definition	Direction
Average price of housing	Aggregate price of specified owner-occupied housing units, divided by the total number of owner-occupied housing units in the census tract area. Price is based on the respondent's estimate of the property's (house and lot, mobile home and lot, or condominium unit) market worth.	−
Large quantity generators	Number of large quantity generators of waste per census tract area. A facility is classified as a large quantity generator if it: generates or imports greater than or equal to 1000 kg of hazardous waste in a calendar month; generates or accumulates at any time more than 1 kg of acute hazardous waste in a month; or more than 100 kg of residue, contaminated soil, waste, or other debris resulting from the cleanup of a spill of acute hazardous waste.	+
Percent Black	Total number of persons identifying themselves as non-Hispanic Black divided by the total number of persons.	+
Civic capital rate	Total assets of non-profit organizations as inventoried by the National Center of Charitable Statistics in a census tract area, divided by the total number of persons in a census tract area.	−
Peak ground acceleration	Maximum acceleration experienced by an object during the course of earthquake motion estimated for each census tract centroid. Acceleration estimates are calculated at the 10% probability of being exceeded in 50 years, and expressed as %g.	−
Hydrologic overlap	Percentage of the hydrologic unit code (HUC) encased in the census tract, weighted by the size of the land area (km^2).	−
Treatment, storage, and disposal facility	Measured dichotomously as presence or absence of a commercial treatment, storage, and disposal installation in a census tract area. Adjacent tracts within 1 and 1.5 miles of facility are also counted as affected tracts.	

The NCSS Core File has flaws. There are no comprehensive data on organizations with less than $5,000 in annual gross receipts, and there are no financial, geographic, or programmatic data on organizations with annual gross receipts of less than $25,000. Data on religious organizations are also incomplete, though 1108 religious organizations appear in the data set for U.S. EPA Region IV. The undercount of religious organizations is a notable measurement error because the church remains a critical organization through which African American social and civic grievances are channeled and expressed. Moreover, the partial exclusion of organizations with less than $5000 in annual gross receipts may undercount grass-roots environmental justice organizations that form to repel or shut down undesirable land uses.

Earthquake hazard data from the National Seismic Hazard Mapping Project (NSHMP) of the U.S. Geological Survey (USGS) are used to indicate the geological suitability of a site. Data are for 1996 estimates (the best date available). The NSHMP estimates ground motion hazard values that have a specified probability of being exceeded in 50 years. The NSHMP online database generates ground motion values expressed as percentages of the acceleration of gravity (%g) for longitude and latitude entries to three decimal points for the contiguous United States. Longitude and latitude coordinates are used to estimate earthquake probabilities at the census tract level. Several estimates of ground motion are available, including peak ground acceleration (PGA), and 0.2-, 0.3-, and 1.0-s period spectral acceleration (SA). PGA is a good hazard measure for buildings of seven stories or less. PGA is expressed as a 10% probability of occurring in 50 years.

USGS hydrologic data are used to measure the hydrological suitability of a site. The USGS reports and catalogues hydrologic unit data for regions and subregions. Our study collects hydrologic data at the watershed (cataloging) level of analysis. A geographic correspondence engine available through the Office of Social and Economic Data Analysis was used to merge watershed and census tract data. This geographic correspondence engine enables users to estimate the percentage of a hydrologic unit code encased in a census tract, weighted by population size.

All variables used in tests are defined in Table 1. For the economic rationality hypothesis, housing prices are evaluated to estimate the cost of property. Large quantity generators of hazardous waste are counted to estimate proximate access to manufacturing inputs and transportation costs. For the scientific rationality hypothesis, the seismology measure of peak ground acceleration expressed as a 10% probability of occurring in 50 years is used to estimate geological suitability. Percentage of hydrologic unit code (HUC) encased in a census tract weighted by size of land area is used to estimate hydrological suitability. For the civic capital hypothesis, data on the capital assets of nonprofit organizations and voluntary associations per capita are used to estimate a civic capital rate. For the social inequity hypothesis, demographic data[3] on percent African American are used.

Results

Binary Logistic Regression Models

Table 2 presents results derived from binary logistic regression models. Coefficients are tabulated for census tract odds of hosting a TSD installation and census tract odds of being located within 1 mile and 1.5 miles of a TSD facility. Column 1 in

Table 2. Binary logistic regression coefficients estimating odds of TSD installation impact in tracts, and 1 and 1.5 mile radii of exposure for U.S. EPA Region IV

	In tract		1 mile		1.5 miles	
Variables	*B*	Exp(*B*)	*B*	Exp(*B*)	*B*	Exp(*B*)
Economic rationality						
Large quantity generators	.542** (.061)	1.719	.495** (.055)	1.641	.448** (.051)	1.565
Mean home value	−.000 (.000)	.999	−.000** (.000)	.999	−.000** (.000)	.999
Social inequity						
Percent Black	.010** (.003)	1.010	.012** (.003)	1.012	.018** (.002)	1.018
Civic capital						
Social capital rate	−.001* (.000)	.999	−.000 (.000)	.999	−.000 (.000)	.999
Scientific rationality						
Peak ground acceleration	.070** (.023)	1.072	.065** (.019)	1.067	.032** (0.16)	1.049
Hydrologic unit code	−1.821 (1.720)	.162	−5.610** (2.205)	.004	−12.681** (2.557)	.000
Constant	−4.928** (.370)	.007	−4.185** (.332)	.015	−3.510** (.274)	.030
Nagelkerke *R*-squared	.105		.110		.157	
−2 Log likelihood	987.77		1376.43		2028.60	
Chi-square	109.72		158.22		335.26	

Note. Numbers in parentheses are standard error estimates. Significance: $^{*}p < .05$; $^{**}p < .01$.

Table 2 indicates commercial TSDF presence in U.S. EPA Region IV is predicted by the following neighborhood characteristics: large quantity generator activity, the percentage of African Americans, civic capital rate, and area seismology.

Beginning with pure economic rationality variables, the concentration of large quantity generators (LQGs) of hazardous waste positively predicts TSDF location outcomes ($B = .542$, $p < .01$). This result partially confirms Weber's theory of industrial location. Commercial TSDFs cluster spatially with LQGs. For each unit increase in LQGs, the odds of TSDF presence increase by 71.9%.

Consistent with claims of environmental inequity, Table 2 column 1 shows that African Americans in U.S. EPA Region IV are burdened disproportionately by TSDFs (.010, $p < .01$), all things held equal. A unit increase in African American composition increases the odds that a tract has a TSDF by 1%. This positive relationship between African American composition and TSDF presence persists even when numerous socioeconomic indicators (i.e., percent on public assistance; poverty rate; and family formation) are loaded into the model.

The scientific rationality variable of peak ground acceleration behaves unexpectedly. TSDF location outcomes in U.S. EPA Region IV are predicted by increased risk of seismological activity (.070, $p < .01$). A unit increase in peak ground acceleration increases the odds of TSDF placement by 7.2%. In fact, 20 of the 100 commercial TSDFs operating in the region are located in areas with peak ground acceleration figures of 9.5%g and above—a threshold level minimally hazardous to building structure integrity. Even more surprising, six installations sit in areas with PGA scores of 16%g and above, with one installation in Tennessee at 21.8%g. Though most installations are located in low earthquake risk areas, it is perplexing to discover a statistically positive relationship between TSDF presence and seismological risk.

As expected, the civic capital variable is negatively related to TSD installation presence ($B = -.001$, $p < .05$). The mean difference between host and nonhost communities is sizable ($1273 versus $1542). An increase of $1000 in the community civic capital rate decreases the probability of TSDF presence by approximately 7%. A closer look at the data shows that census tracts with civic capital rates of $10,000 and above are fully protected from the risk of TSDF exposure. TSDFs are significantly less likely to appear in communities rich in organizational infrastructure, suggesting that a NIMBY game is in play. Overall, 10.5% of variation in TSDF in-tract presence is predicted by the variable pool.

By expanding the definition of at-risk areas to include neighborhoods within 1 and 1.5 miles of a commercial TSDF, predictors behave similarly. At the 1 and 1.5 mile zones of impact, the civic capital variable is statistically insignificant. At 1 mile of impact, 148 census tracts are affected. At 1 mile of impact, pure economic rationality variables perform as hypothesized. LQG activity is positively associated with TSDF presence ($B = .495$, $p < .01$). The odds of a tract falling within 1 mile of a TSDF increase by 64% with a unit increase in the number LQGs present in a census tract. Mean housing value is negatively associated with TSDF impact ($B = -.000$, $p < .01$).

Our social inequity predictor of percent African American performs as hypothesized. The Blackness of a community is positively related to TSD installation impact net the effect of all other predictors. Again, a unit increase in percent African American increases the odds of TSDF impact by 1.2%. African American composition is an almost perfectly proportional estimate of the odds of environmental risks associated with commercial TSD installations in the Southeast.

At the 1 mile zone of TSD installation impact, the scientific rationality measure of hydrologic overlap negatively predicts TSDF impact ($B = -5.625$; $p < .01$). Insofar as one can reason logically from cross-sectional data, TSDF location outcomes appear sensitive to watershed proximity. Again, our peak ground acceleration measure performs unexpectedly ($B = .065$, $p < .01$), increasing rather than decreasing the odds of TSDF impact. Model performance at the 1 mile zone of TSDF impact improves slightly, with 11.0% of variation in commercial TSDF location outcomes explained by the variable set.

At the 1.5 mile zone of impact (Table 2, column 3) the population of affected tracts increases to 254. Economic rationality predictors behave expectedly. The number of LQGs in a census tract is positively associated with TSDF impact ($B = .448$, $p < .01$). Assuming causal direction, lower property costs are a TSDF attractant ($B = -.000$, $p < .01$). A $10,000 increase in average property cost decreases the odds of TSDF impact at the 1.5 mile radius by 2%. The mean difference in property costs between affected and unaffected census tracts at 1.5 miles from this undesirable land use are significant ($53,230 versus $73,916, $t = -12.468$, $p < .01$). No census tract with an average of $105,000 or above is subject to TSDF risks. Results indicate the commercial suitability of an area renders it susceptible to TSDF impact.

At the 1.5 mile measure of environmental risk, percent African American remains a significant positive predictor of TSDF location outcomes. On average, almost half the population in environmentally compromised census tracts is African American (48.85%). This figure more than doubles the average percentage of African Americans in unaffected tracts (21.14%). A unit change in African American composition increases the probability of toxic exposure by almost 2%. Across models, the odds ratio for percent African American increases incrementally as the sphere of impact is widened.

At 1.5 miles from the nearest commercial TSDF, geological and hydrological features of a census tract are significant predictors. The most interesting finding is on watershed overlap. Census tracts with high watershed overlap are almost fully immunized from TSDF impact ($B = -12.681$, $p < .01$, $\exp(B) = .000$). Again, our seismology predictor is positively related to TSDF impact. Overall, model performance at the 1.5 mile zone of TSDF impact for U.S. EPA Region IV is decent, with almost 16% of variation in TSDF impact outcomes explained. This predictive power compares favorably with research teams on the West Coast (see Pastor et al. 2001), and the East Coast (see Anderton et al. 1994a, 1994b).

Conclusion

This study sought to explain the distribution of commercial TSDF location outcomes in the southeastern United States. The main accomplishment of this study is the introduction of new measures for scientific rationality and civic capital theses of location outcomes. Evidence suggests TSDFs are located in areas with more affordable property and areas adjacent to hazardous waste streams that minimize operation costs. As suggested by theories of economic geography, TSDFs cluster spatially with complementary industries. The question of what came first, the LQG or the TSDF, is unanswerable with cross-sectional data. This temporal order question is intriguing in light of our results.

Though LQGs and TSDFs are both regulated by RCRA, and both pose environmental risks to host communities, they are qualitatively different with regard to local desirability. A typical LQG is an automotive assembly facility—hardly a locally undesirable land use. Localities aggressively court such facilities. With plant construction, routine assembly jobs are created. Also, jobs are created indirectly as suppliers gravitate to the area, as wages and salaries are spent in the retail sector, and as regulators spend tax receipts on desirable public goods. The economic multiplier effect of LQGs is significant. If locally undesirable TSDFs arrive first, they may attract more locally desirable LQGs.

Whatever the exact sequence of spatial clustering of hazardous waste operations, RCRA is the regulatory framework that arguably induces this economic geographic rationality. Though RCRA contains provisions designed to protect the public and environment from harm, it encourages market solutions to hazardous waste management (Rosenbaum 1991). Market coordination undoubtedly induces TSDF operators into an economic calculus—they appear to respond sensibly to price signals and agglomerations of scale. Of course, statistical results must be interpreted with caution. Important questions of what came first—the lower property costs or the TSDF—remain unanswered. Nevertheless, results suggest that the drive to minimize costs is strong enough that operators locate in geologically questionable areas—that is, areas with higher peak ground acceleration figures.

Statistical evidence for the scientific rationality hypothesis is mixed. Commercial TSDFs appear sensitive to hydrological concerns—they are likely to appear in areas with lower than average watershed overlap. Watersheds are a strong repellent of TSDF presence. At the 1.5 mile zone of risk, census tracts with fully encased watersheds are practically inoculated from the odds of TSDF exposure. In contrast, TSDFs appear consistently in areas with higher than average seismological risk. The failure to correctly predict TSDF location outcomes using seismological data (in the expected direction) is interesting. Two reasons may account for the "misbehavior" of our seismology measure. First, the probability of catastrophic failure is lowered by good construction. Construction technologies make it possible for TSD installations to locate to geologically questionable areas. Second, the risk of catastrophic seismological activity is low in the Southeast compared to the West Coast. However, the risk is higher in the Southeast than must people presume. According to the Cooperative Central and Southeast U.S. Seismic Network, 100-plus earthquakes are detected every 6 months. These quakes are generally low in magnitude, but the potential for abrupt tectonic movement exists (http://folkworm.ceri.memphis.edu). Future studies could apply our seismology measure more profitably on the West Coast.

Of the four hypotheses advanced, the civic capital argument received the least confirmation. The variable of civic capital rate is indeed statistically significant at the in-tract measure of environmental risk. Totaling nonprofit organization assets in a census tract divided by population size to estimate levels of civic vitality extends the demographic work of Pastor et al. (2001) on political weakness. Reasoning from period data, commercial TSDFs appear to avoid neighborhoods with stronger than average potential for collective action. As qualitative studies suggest, linking and coordinating the activities of nonprofit organizations can enliven civic concern for fair and equitable distribution of environmental risks.

On social inequity, at whatever spatial estimate of environmental impact, African Americans are burdened disproportionately by hazards stemming from commercial TSDF operations. Even with the introduction of numerous controls, the percentage of African Americans in a neighborhood positively predicts TSDF location outcomes. This study cannot comment on temporal dynamics related to TSDF location outcomes. For many scholars (see Bullard 1990; Pulido 1996), it is unimportant whether discriminatory outcomes are intended or caused by anonymous forces. These scholars emphasize differential harm. By design, this study places analytic emphasis on TSDF location outcomes and differential harm. Be it market coordination, structured residential choice, malicious intent on the part of TSDF operators, scientific-technical criteria, or dispassionate economic decision making, African Americans in the southeastern United States live in environmentally higher risk locations. Future studies with more sophisticated longitudinal designs and broader scope may arrive at different conclusions. Szasz and Meuser's (2000) clever analysis of Toxic Release Inventory facilities in Santa Clara, CA, provides a useful framework and methodology for analyzing the "inexorable" social and economic forces that appear to influence the spatial patterning of TSDFs.

Theoretically, our results are consistent with Pellow's (2000) notion of environmental inequality formation (EIF). Pellow argues that unequal exposure to environmental risks results from a collision of many stakeholders with contradictory interests rather than simple "predictor-victim scenarios." The variables examined in our study connect logically to multiple stakeholder interests.

Like all rational actors, commercial TSDF operators pursue maximization of shareholder wealth. Our results suggest that this interest is achieved by locating in areas with affordable property and proximate access to waste generators. Elected officials and functionaries serve and arbitrate many constituencies, and set and enforce rules of conduct. With regard to TSDFs, some rules promote market coordination of hazardous waste. Such rules address the interests of TSDF operators. Other rules specify scientific and technical criteria with regard to location outcomes, presumably designed to protect sensitive environments and the public from harm. Our results suggest that scientific criteria may in fact coordinate location outcomes, at least with regard to hydrology. Last, our results partially confirm stakeholder claims that predominately minority and civically disorganized communities are burdened unequally by exposure to TSDFs. The performances of variables tested indirectly confirm Pellow's claim that many interests figure in the *formation* of non-random distributions of toxic waste.

Our study takes a more quantitative angle on the notion of stakeholder competition. Future studies can more precisely measure the various theses of location outcomes that logically connect to stakeholder interests. Such studies can examine other natural features that characterize an area. For example, from the Spatial Hazard Events and Losses Database for the United States researchers can download records of natural calamity and estimate the extent to which TSDFs are in the direction of various hydro-meteorological disasters. With regard to civic capital, researchers can geographically position environmental justice organizations from the People of Color Environmental Groups Directory. In study areas where multicollinearity is no issue, various socioeconomic and demographic variables can be measured for more rounded estimates of social inequity theses.

Notes

1. Though TSDFs are massive, noisy, and malodorous, cause damage to property and human health, cleave communities, induce residential instability, and are sources of catastrophic risk, Bohon and Humphrey (2000) have discovered that some communities actually court such facilities for economic gain. Courting communities are those experiencing economic decline, in dire need of local employment and taxable wealth, where opportunities for development are scarce. These communities are found in the rust belt of the American Mid-Atlantic and Midwest, as well as the resource-exhausted Appalachian South.
2. Though a very strong correlation ($r = .973$, $p = .000$) exists between the amount of hazardous waste generated and the amount of hazardous waste treated, stored, and disposed of at the regional level for the period of 1991 to 1999, our analysis shows a gradual increase in interstate and interregional trade in hazardous waste. At the state level, Montana, New Hampshire, South Dakota, and Wyoming exported all the nonaqueous waste generated in their territories. In 1999, total state-level exports exceeded 8 million tons, representing a 30% increase in export activity as compared to 1997 totals. At the regional level, 14.28% (5.7 million tons) of nonaqueous waste was exported out of region. Approximately 3.7 million tons of this waste was absorbed interregionally, with the difference (2 million tons) presumably transported out of the country.
3. We collected numerous socioeconomic variables to test the social inequity thesis, including percent of persons on public assistance, percent at or below the poverty line, percent on Social Security income, and percent female-headed households. In the Southeast, these variables are highly correlated with percent African American. Substitution of percent African American for percent at or below the poverty line produced identical results. Inclusion of both caused the poverty rate variable to flip statistical sign. Inclusion of socioeconomic variables in regression models created variance inflation issues. We also tested numerous interaction terms—civic capital $\times$ percent black, LQG $\times$ mean value, and

LQG $\times$ peak ground acceleration. All interactions terms are statistically insignificant, where $p < .10$.

References

Anderton, D. L., A. B. Anderson, J. M. Oakes, M. R. Fraser, E. W. Weber, and E. J. Calabrese. 1994a. Hazardous waste facilities: Environmental equity issues in metropolitan areas. *Eval. Rev.* 18(2):123–140.

Anderton, D. L., A. B. Anderson, J. M. Oakes, and M. R. Fraser. 1994b. Environmental equity: The demographics of dumping. *Demography* 31:229–248.

Baden, B. M. and D. L. Coursey. 2002. The locality of waste sites within the city of Chicago: A demographic, social, and economic analysis. *Resource Energy Econ.* 24:53–93.

Been, V. 1994. Locally undesirable land uses in minority neighborhoods: Disproportionate siting or market dynamics. *Yale Law J.* 103(6):1383–1422.

Been, V. 1995. Analyzing evidence of environmental justice. *Land Use Environ. Law.* 11(1):1–36.

Been, V. and F. Gupta. 1997. Coming to the nuisance or going to the barrios? A longitudinal analysis of environmental justice claims. *Ecol. Law Q.* 24:1–56.

Boer, J. T., M. Pastor, J. L. Sadd, and L. D. Snyder. 1997. Is there environmental racism? The demographics of hazardous waste in Los Angeles County. *Social Sci Q.* 78:793–810.

Boerner, C. and T. Lambert. 1995. Environmental Justice can be achieved through negotiated compensation. In *Environmental justice*, ed. J. Petrikin, 85–99. San Diego, CA: Greenhaven Press.

Bohon, S. and C. R. Humphrey. 2000. Courting LULUs: Characteristics of suitor and objector communities. *Rural Sociol.* 65(3):376–395.

Bullard, R. D. 1983. Solid waste sites and the black Houston community. *Sociol. Inquiry.* 53(2/3):273–288.

Bullard, R. D. 1990. *Dumping in Dixie: Race, class, and environmental quality*. Boulder, CO: Westview Press.

Bullard, R. D. 1994. *Unequal protection: Environmental justice and communities of color*. San Francisco, CA: Sierra Club.

Bullard, R. D. 1996. Environmental justice: It's more than waste facility siting. *Social Sci. Q.* 77:493–499.

Cable, S. and M. Benson. 1993. Acting locally: Environmental injustice and the emergence of grassroots environmental organizations. *Social Problems.* 40:464–480.

Cable, S. and C. Cable. 1995. *Environmental problems, grassroots solutions: The politics of grassroots environmental conflict*. New York: St. Martin's Press.

Cable, S., D. W. Hastings, and T. L. Mix. 2002. Different voices, different venues: Environmental racism claims by activists, researchers, and lawyers. *Hum. Ecol. Rev.* 9(1):26–42.

Capek, S. 1992. Environmental justice, regulation and the local community. *Int. J. Health Serv.* 22:729–746.

Clarke, J. N. and A. K. Gerlak. 1998. Environmental racism in the sunbelt? *Environ. Manage.* 22:857–867.

Cole, L. and S. Foster. 2000. *From the ground up: Environmental racism and the rise of the environmental justice movement*. New York: New York University Press.

Coleman, J. 1988. Social capital in the creation of human capital. *Am. J. Sociol.* 94:95–120.

Freeman, H. M. 1989. *Handbook of hazardous waste treatment and disposal*. New York: McGraw-Hill.

Goetz, S. J. and D. J. Kemlage. 1996. TSDF location and environmental justice. *Rev. Regional Stud.* 26:285–299.

Hamilton, J. T. 1993. Politics and social costs: Estimating the impact of collective action on hazardous waste facilities. *Rand J. Econ.* 24:101–125.

Hamilton, J. T. 1995. Testing for environmental racism: Prejudice, profits, political power? *J. Policy Anal. Manage.* 14(1):107–132.

Hannink, D. M. 1997. *Principles and applications of economic geography*. New York: Wiley.
Krieg, E. J. 1995. A sociohistorical interpretation of toxic waste sites: The case of greater Boston. *Am. J. Econ. Sociol.* 54:1–14.
Lampkin, L. and E. T. Boris. 2002. Nonprofit organization data: What we have and what we need. *Am. Behav. Scientist.* 45:1675–1715.
Liu, F. 2001. *Environmental justice analysis: Theories, methods, and practice*. Boca Raton, FL: Lewis.
Markham, W. T. and E. Rufa. 1997. Class, race, and the disposal of urban waste: Locations of landfills, incinerators, and sewage treatment plants. *Sociol. Spectrum.* 17:235–248.
Mohai, P. and B. Bryant. 1992. Environmental racism. In *Race and the incidence of environmental hazards: A time for discourse*, ed. P. Mohai and B. Bryant, 163–176. Boulder, CO: Westview Press.
Oakes, J. M., D. L. Anderton, and A. B. Anderson. 1996. A longitudinal analysis of environmental equity in communities with hazardous waste facilities. *Social Sci. Res.* 25:125–148.
Pastor, M., J. Sadd, and J. Hipp. 2001. Which came first? Toxic facilities, minority move-in, and environmental justice. *J. Urban Affairs.* 23:1–21.
Pellow, D. 2000. Environmental inequality formation: Toward a theory of environmental justice. *Am. Behav. Sci.* 43:581–601.
Prewitt, K. 2000. *Accuracy and coverage evaluation: Statement on the feasibility of using statistical methods to improve accuracy of the 2000 Census*. Washington, DC: U.S. Bureau of the Census.
Pulido, L. 1996. A critical review of the methodology of environmental racism research. *Antipode.* 28:142–151.
Putnam, R. 2000. *Bowling alone: The collapse and revival of American community*. New York: Simon and Schuster.
Ringquist, E. J. 2000. Environmental justice: Normative concerns and empirical evidence. In *Environmental policy*, 4th ed., ed. N. J. Vig and M. E. Kraft, 232–256. Washington, DC: CQ Press.
Rosenbaum, W. A. 1991. *Environmental politics and policy*. Washington, DC: Congressional Quarterly.
Stretesky, P. and M. J. Hogan. 1998. Environmental justice: An analysis of superfund sites in Florida. *Social Problems.* 45:268–287.
Szasz, A. and M. Meuser. 2000. Unintended, inexorable: The production of environmental inequities in Santa Clara County, California. *Am. Behav. Sci.* 43(4):602–632.
United Church of Christ. 1987. *Toxic wastes and race in the United States: A national report on the racial and socio-economic characteristics with hazardous waste sites*. New York, UCC: Commission for Racial Justice.
U.S. Census Bureau. 2002. *Statistical abstracts 2002*. http//www.census.gov (accessed October 2004).
U.S. Council on Environmental Quality. 1980. *Public opinion on environmental issues: Results of a national public opinion survey*. Washington, DC: Government Printing Office.
U.S. General Accounting Office. 1983. *Siting of hazardous waste landfills and their correlation with racial and economic status of surrounding communities*. Washington, DC: United States GAO.
Watts, R. J. 1998. *Hazardous wastes: Sources, pathways, receptors*. New York: John Wiley & Sons.
Weber, A. 1929. *Theory of the location of industries*, trans. C. J. Friedrich. New York: Atheneum Publishers.
Wimberly, R. and L. Morris. 1996. *The reference book on regional well-being: U.S. regions, the Black Belt, and Appalachia*. Mississippi State: Mississippi State University Southern Rural Development Center.
Yandle, T. and D. Burton. 1996. Reexamining environmental justice: A statistical analysis of historical. *Social Science Quarterly*. 77(3):477–492.