

## **MEASURING LOCAL ENVIRONMENTAL INEQUITY USING GIS AND PUBLICLY-AVAILABLE DATA<sup>1)</sup>**

***(Mengukur Ketidakadilan Lingkungan Lokal Menggunakan  
GIS dan Data yang Tersedia)***

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### **Abstract**

Issues of environmental justice have been raised by advocates for poor and minority communities for over a decade and, more recently, officially recognized by the federal government. Yet, few cities have taken proactive steps to identify environmental inequity much less attempt to understand its causes, remediate its effects, or prevent its reoccurrence.

The purpose of this paper is to demonstrate how communities can analyze readily available census and health data with tools typically available to planners in order to identify poor and minority areas disproportionately exposed to environmental hazards. Geographic Information systems (GIS) and publicly-available health and socioeconomic data were used to classify census block groups within the city of Cincinnati, Ohio, according to socioeconomic and health variables and measure their proximity to known hazardous waste and toxic release sites. The census block groups closer to sites on the Ohio EPA's Master Sites List (MSL), and the U.S. EPA's Toxic Release Inventory (TRI) were found to be poorer, less educated and have a larger proportion of minority residents. Race and median rent were found to be significant predictors of the proximity of a block group to a MSL or TRI site, after controlling for other socioeconomic factors. Furthermore, age-adjusted mortality rates were significantly higher in those census block groups closer to the hazardous sites, after controlling for the effects of other socioeconomic factors, race and proximity to MSL was a significant predictor of age-adjusted mortality, though proximity to TRI was not. Although the analysis does not establish causality, it does suggest the need for further studies to establish if institutional factors may be major contributors to the apparent environmental bias against minority residents, and if the higher rate of mortality among minority residents is the result of such bias.

This study demonstrates the usefulness of GIS for assessment of potential environmental hazards, as well as the need for better design, implementation and evaluation of planning approaches to improve the quality of life for all urban residents.

### **Abstrak**

*Masalah ketidakadilan lingkungan sudah mulai diangkat oleh kelompok yang prihatin terhadap masyarakat minoritas dan miskin selama satu dekade belakangan ini, serta oleh para pengambil keputusan akhir-akhir ini. Meskipun demikian, hanya sedikit kota yang telah mengambil langkah nyata dan aktif untuk mengidentifikasi persoalan ketidakadilan lingkungan,*

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*apalagi untuk mencari penyebabnya, mengatasi persoalan, atau mencegah timbulnya ketidakadilan tersebut.*

*Tujuan tulisan ini adalah untuk menunjukkan cara komunitas menggunakan teknik yang biasa digunakan oleh perencana yang dapat menganalisis data yang tersedia dan dapat diakses oleh umum untuk mengkaji komunitas minoritas dan miskin yang secara tidak proporsional menderita karena tercemarnya lingkungan. Dalam penelitian ini, Geographic Information System (GIS) dan data sosial-ekonomi serta kependudukan yang tersedia digunakan untuk mengkaji kaitan antara kondisi kesehatan kelompok masyarakat tertentu di kota Cincinnati, Ohio, dan kedekatannya terhadap lokasi pembuangan limbah dan toksid yang selama ini diketahui. Ditemukan dalam penelitian ini bahwa komunitas yang tinggal di dekat lokasi pembuangan limbah Ohio (the Ohio EPA's Master Sites List/MSL) dan lokasi pembuangan toksid (the U.S. EPA's Toxic Release Inventory/TRI) cenderung miskin, berpendidikan rendah dan kelompok minoritas. Penelitian ini menunjukkan bahwa ada hubungan yang signifikan antara kelompok etnik/ras serta tingkat kematian penduduk dan kedekatan lokasi mereka dengan tempat pembuangan limbah. Makalah ini menyarankan perlunya penelitian lanjutan untuk mengetahui ada tidaknya kaitan antara kondisi tersebut dan kebijakan publik yang kurang memperhatikan kelompok minoritas dan miskin.*

*Penelitian ini menunjukkan kegunaan GIS untuk mengkaji kemungkinan timbulnya bencana lingkungan, sekaligus juga perlunya perencanaan yang lebih baik untuk meningkatkan kualitas lingkungan hidup seluruh warga kota.*

## I. INTRODUCTION

Industrial plants routinely produce hazardous waste as part of their production processes. Much of this waste is released into the environment at plant sites or at waste treatment facilities. In many locations, the improper management of these releases at some industrial sites has resulted in contamination posing a confirmed or potential threat to human health or the environment (Anonymous, 1997). Sites where substantial amounts of hazardous waste are released, or where environmental degradation has taken place have become a major concern of environmental planners, especially when they are located near densely populated urban neighborhoods. These urban sites may not be evenly distributed spatially, but rather, create an uneven pattern of resident exposure. Therefore, assessment of the environmental effects of such sites is inherently geographic and spatial analysis can be used to reveal the pattern. In research terms, the assessment results provide an important step in describing

problems and in formulating and testing hypotheses about possible links between environment hazards and quality of life. In policy terms, the results have the potential for directing action to areas of greatest need.

The health effects of exposure to environmental contamination have been the subjects of considerable controversy. There are not always precisely defined ways (Anonymous, 1980). Investigations of hazardous waste sites have demonstrated health effects in exposed persons, including low birth weight, cardiac anomalies, headache, fatigue, miscarriages, respiratory problem, and neurobehavioral problem (Berry & Bove, 1997; Geschwind *et. al.* 1992; Washington, 1994; Anonymous, 1991). Some studies have shown higher cancer rates in residents exposed to hazardous waste components (Anonymous, 1991). Clearly, there are reasons to be concerned about the effect of hazardous waste on the environment and human health. Indeed, the social implications of environmental degradation have drawn increasing attention among

scholars and policy makers in environmental, social, and human health studies. Unfortunately, we still lack full knowledge of many of the relationships involved. Further research is especially needed on spatial relationships. The effective handling of spatial information is essential to facilitate an appropriate public policy response. Those charged with safeguarding the public good and making plans that balance the needs of nature and people can turn to geographic variation in health indicators to help identify causes of ill health. An area's mortality rate is certainly one of the better measures of overall health.

Beyond the consideration of health effects of hazardous emissions on urban populations generally, the disproportionate exposure of poor and minority populations raises important issues of environmental justice. Environmental justice has been defined as the equitable sharing of the adverse effects of pollution across racial and income groups (Xia *et al.* 1997). This implies that public policies and regulations, including the siting of polluting industries or the permitting of toxic releases into the environment, should not disproportionately expose minorities or the poor to environmental hazards (Bullard, 1997). Studies investigating environmental justice issues have generally concluded that minorities and the poor are likely to have greater exposure to toxic landfills, waste incinerators, hazardous industrial facilities and other environmentally detrimental activities (Bullard, 1993; Bryant & Mohai, 1992; Buntin, 1994; Ontolano, 1997; Ringquist, 1997; Bullard, 1997; Burby, 1997; Vos, 1997). Other works have found that commercial hazardous waste treatment, storage and disposal facilities (TSDFs) were not more likely to be located in poor and minority communities (Oakes *et al.* 1996; Anderton *et al.* 1994), though a more recent study came to an opposite conclusion (Boer *et al.* 1997). Several researchers have raised

questions about the methods used in some of the early environmental justice studies. Results were found to be different depending on whether a large (county or zip code) or small (census tract) geographic unit was analyzed (Bowen *et al.* 1995, Anderton *et al.* 1994).

Much of the more recent research has moved beyond simply identifying where environmental injustice may exist, to assessing how social, political and economic institutions have contributed to the current state (Been, 1994; Heiman, 1996; Penderhughes, 1996). Indeed, simply sorting out which came first, the environmentally hazardous facility or the residential area, can be a complex and trying exercise. Such efforts much consider how public institutions have allowed or encouraged the siting of new developments or the expansion of existing ones. The absence of minority representation in the siting decision process (Vos, 1997) and the need to limit industrial expansion near residential areas (Burby, 1997) have been cited as two of the areas where public institutions have contributed to environmental injustice.

Planners, public officials and residents concerned with quality of life and environmental justice require analytical tools that enable them to identify and initiate responses to potential threats. These tools much allow for determining the possibility of a significant health threat, and the need for more in depth epidemiological, environmental or land use analyses. The combination of geographic information systems (GIS) and statistical analysis comprises just such a tool to analyze health, environmental and demographic data. Two features offered by GIS are especially useful to help accomplish this. First, GIS allows the construction of maps, identification of nearest neighbors, and display of spatial relationships. A series of patterns, each for a different variable of interest, may be created and combined to

reveal correspondences and disparities. Second, GIS functions, such as the storage, retrieval and manipulation of spatially related data, allow the aggregation of data collected from varying sources. This data in turn, can be used to develop a composite description, and to explore associations, such as the use of distance buffers to identify how the effects of a potential hazard may change as one moves farther away (Wartenberg, 1993).

It is within this context that this study uses GIS and statistical analysis to describe and analyze the spatial relationships between race, socioeconomic status (SES) and proximity to environmental hazards in Cincinnati. Environmental hazards used in this study were sites of reported industrial releases for toxic chemicals or where improper hazardous materials management has resulted in environmental contamination. This study seeks to describe the characteristics of residential areas close to hazardous waste sites and determine whether such areas have different SES characteristics than those farther away. The relationship between the mortality rates, SES and proximity to hazardous sites was also addressed.

## II. DATA

The study area was the City of Cincinnati, Ohio (1990 city population 364,040; 1990 consolidated metropolitan statistical area population 1,744,124). Census block groups from the 1990 US Census were used as the unit of analysis. To integrate the data for this study, five types of digital data files were compiled:

- (1) death records, including location of residence, data and causes of death for all persons who died in Cincinnati from January 1, 1986 to December 31, 1994;
- (2) locations of hazardous waste sites;

- (3) 1990 U.S. census block group population and housing and other socioeconomic characteristics for Cincinnati;
- (4) census block group boundary for Cincinnati; and
- (5) streets in Cincinnati.

Records of all deaths reported to the Cincinnati Health Department for the years 1979 to 1994 were obtained on tape. They were in compressed text format and subsequently converted to a dBase (.dbf) format. The data file contained 35 data items for each of the death records, including last residence of the diseased, cause of death, birth and death dates, and limited socioeconomic information such as race, number of years of education, and state of birth (Anonymous, 1994). Records for Cincinnati residents who may have died outside the city were not included. Also, we excluded the records for non-Cincinnati residents who died in Cincinnati since the study area was limited to the City of Cincinnati.

Two types of environmental contamination and hazardous waste release data were collected: the 1994 Master Sites List (MSL) from the Ohio Environmental Protection Agency's (OEPA), Division of Emergency and Remedial Response (DERR); and the 1992 Toxic Release Inventory (TRI) Annual Report, from OEPA's Division of Air Pollution Control.

The MSL is a database of sites in Ohio where there is evidence of, or it is suspected, that improper hazardous waste management has resulted in the contamination of air, water or soil, and there is a confirmed or potential threat to human health or the environment. The MSL includes a diversity of sites of varied environmental concerns. In addition to those sites in the USEPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) prior to 1989, sites were added to the MSL listing by DERR staff based on inter-program referrals, citizen complaints, or DERR's

discovery efforts. The DERR updates the MSL sites are chemical companies and landfills. The MSL database records contain a field with the street address for each site.

The TRI report contained annually compiled data on the quantity and location of industrial releases for approximately 300 toxic chemicals and 20 chemical categories (Bowen *et al.* 1995). Manufacturing firms subjected to Title III, Section 313 of the Federal Emergency Planning and Community Right-to-Know Act of 1986 are included in the TRI list. These firms are required to report the location and amount of toxic chemicals released to the air, water, or land. In Ohio, the TRI Program within the Division of Air Pollution Control of the OEPA coordinates the collection, digitizing and distribution of TRI data. The TRI sites include a broad range of industrial facilities, from manufacturing and food processing, to chemical plants. Like the MSL database, the locations of the TRI sites are stored in a street address field.

Census population data were directly extracted from the U.S. Census Bureau's 1990 Summary Tape File (STF) 3A available on CD-ROM. The census data are considered the most reliable source for population information by geographic area. Data used in this study include population by age group for each census block groups within the city of Cincinnati and population by age group for the State of Ohio. The total numbers of deaths in Ohio by age group were obtained from the Ohio Department of Health (Anonymous, 1992).

The census block group boundary data were extracted from the First Street geographic data files produced by Wessex Inc. The First Street files were compiled and enhanced from the US Census Bureau's 1992 Topographically Integrated Geographic Encoding and Referencing (TIGER) files. The files contained graphic data (maps) defining census block group boundaries and associated

attribute data. Unique block group identification numbers (Ids) were used to link attribute data to graphic data. There were 417 census block groups in Hamilton County, of which 22 had no residents in 1990. These were eliminated, thus providing a total of 395 census block groups for this study. The street address data used in the study were the 1994 TIGER files. The street files contained street name and address ranges for street sections in Hamilton County.

### III. METHODS

Data files were integrated, based on their spatial location. GIS functions- including geocoding, buffering, and overlay analysis- were used to complete the tasks. Then, statistical tools were used to calculate census block group-based mortality rates and identify predictors of mortality rate from among proximity to hazardous site variables and SES variables. Arc view, a GIS software program (Environmental System Research Institute, Inc.) was used for geographic analysis. SPSS, a statistical analysis software program (SPSS Inc.), was used for statistical analysis.

To control for the age effects when comparing mortality rates by block group, the age-adjusted rates were used for each census block group. Age-adjusted mortality rates for each block group were calculated using the direct age-adjustment method (Friedman, 1994) based on 9-year average crude mortality rates and population age cohorts for the state of Ohio.

#### Statistical Tests

Socioeconomic status indicators were selected to reflect known mortality risk factors, as well as to provide insight of conditions found in each block group. The following indicators were selected: length of residence in unit (percent of households living in the unit more than 10 years); median

household income; median housing unit value (owner-occupied units); median household rent (renter-occupied units); percent of persons 25 years or older with less than a ninth grade education; and percent of population that is African American. A table of bivariate correlation coefficients was constructed for the relationships between age-adjusted mortality rates, distance of the census block group from a hazardous site and the SES indicators.

Multiple linear regression analysis (ordinary least squares) was used to identify statistically significant predictors for proximity to MSL and TRI sites. Based on the correlation table of SES indicators, four were selected for inclusion in the regression analysis (percent of residents in home for more than 20 years, median rent, percent of African American population, and percent of population age over 25 with less than nine years of schooling). Median household income was strongly correlated with median home value and median rent, and moderately correlated with percent African American. Consequently, to avoid multicollinearity among the predictor variables, median income and median home value were not included in the regression. The Durbin-Watson statistic was calculated and plots of residual analyzed to check for autocorrelation and heteroscedasticity. No evidence of these problems was found.

Multiple linear regression analysis (ordinary least squares) was used also to identify statistically significant predictors for age-adjusted mortality rates. The same four SES predictor variables were selected for inclusion in the regression analysis, along with variables for proximity to the MSL and TRI sites. Again, checks revealed no evidence of violation of the regression assumptions.

#### IV. RESULTS AND DISCUSSION

Among the 1979-1994 death records in the Cincinnati Health Department's data file, 96-440 were identified as Hamilton County residents. Of these, 96-235 were geocoded (99,8%) based on the recorded street addresses. After excluding accidental causes of death, this study used records for 31,526 decedents who were Cincinnati residents at the time of their death and died between January 1, 1986 and December 31, 1994.

The locations for 75 MSL sites and 131 TRI sites in Hamilton County were geocoded based on the street addresses of the sites. Only 12 sites were found on both the TRI and MSL lists. Figure 1 displays the MSL sites with corresponding buffer zones. The MSL sites were scattered within the central part of the city while there were no MSL sites in the northwestern and southeastern portions of the city. Several MSL sites were located in the southern part of the city, just to the west of the central business district. Most MSL sites were near major highways or close to waterways. The census block groups within 800 meters of a MSL site were almost all connected, except for those in a small area in the western part of the city.

The distribution of TRI sites shows a similar pattern to that of the MSL sites (Figure 2). There were only a few TRI sites in the western portion of the city, mostly located along the narrow corridor in the southwestern corner. Similarly, there were only a few TRI sites in the southeastern portion of the city. The TRI sites were even more concentrated along the Mill Creek and two major highways, I-71 and I-75, than were the MSL sites. It should be noticed that a number of TRI sites were found in the two communities (Norwood and Elmwood Place) surrounded by the city of Cincinnati. Those sites were

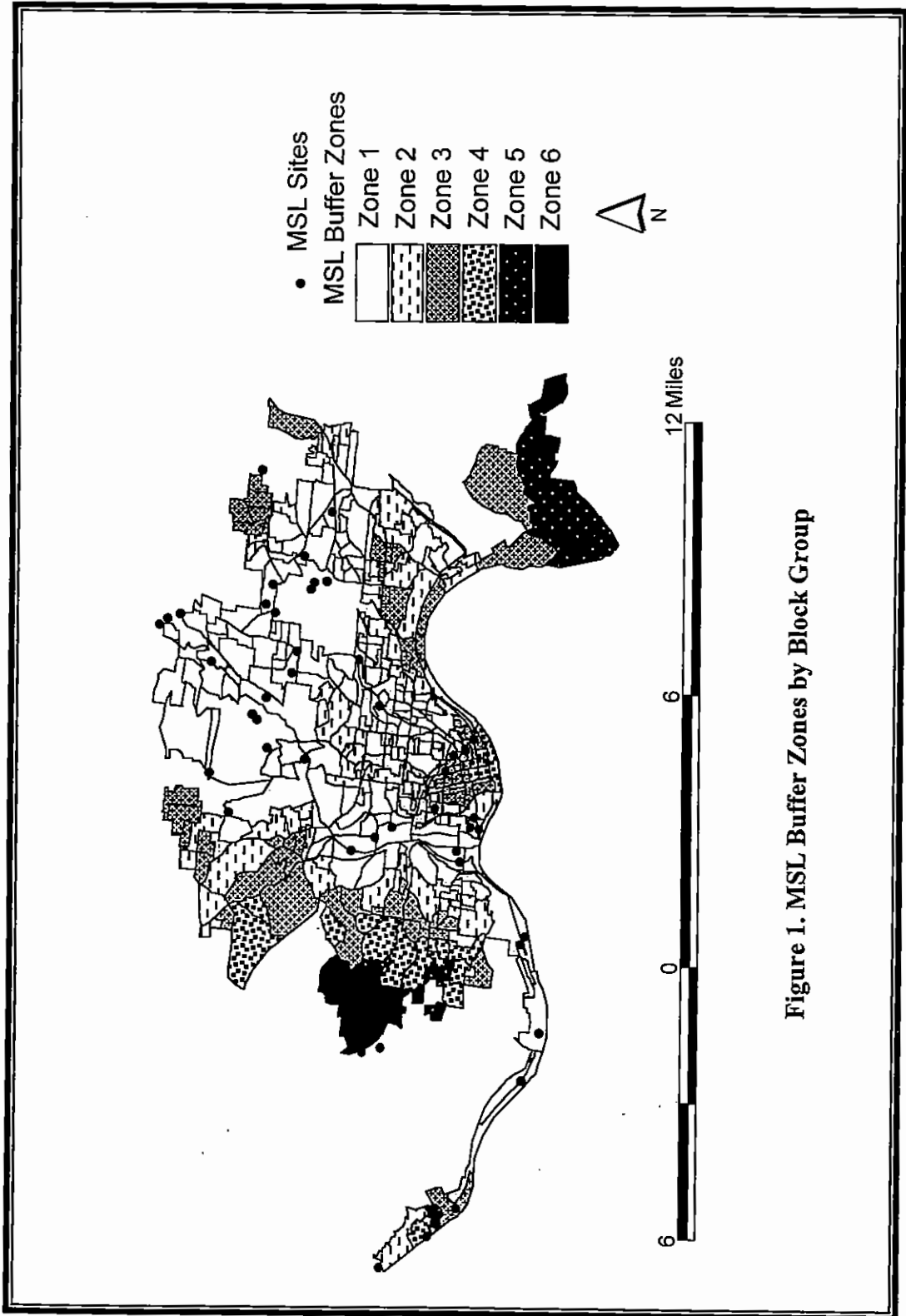


Figure 1. MSL Buffer Zones by Block Group

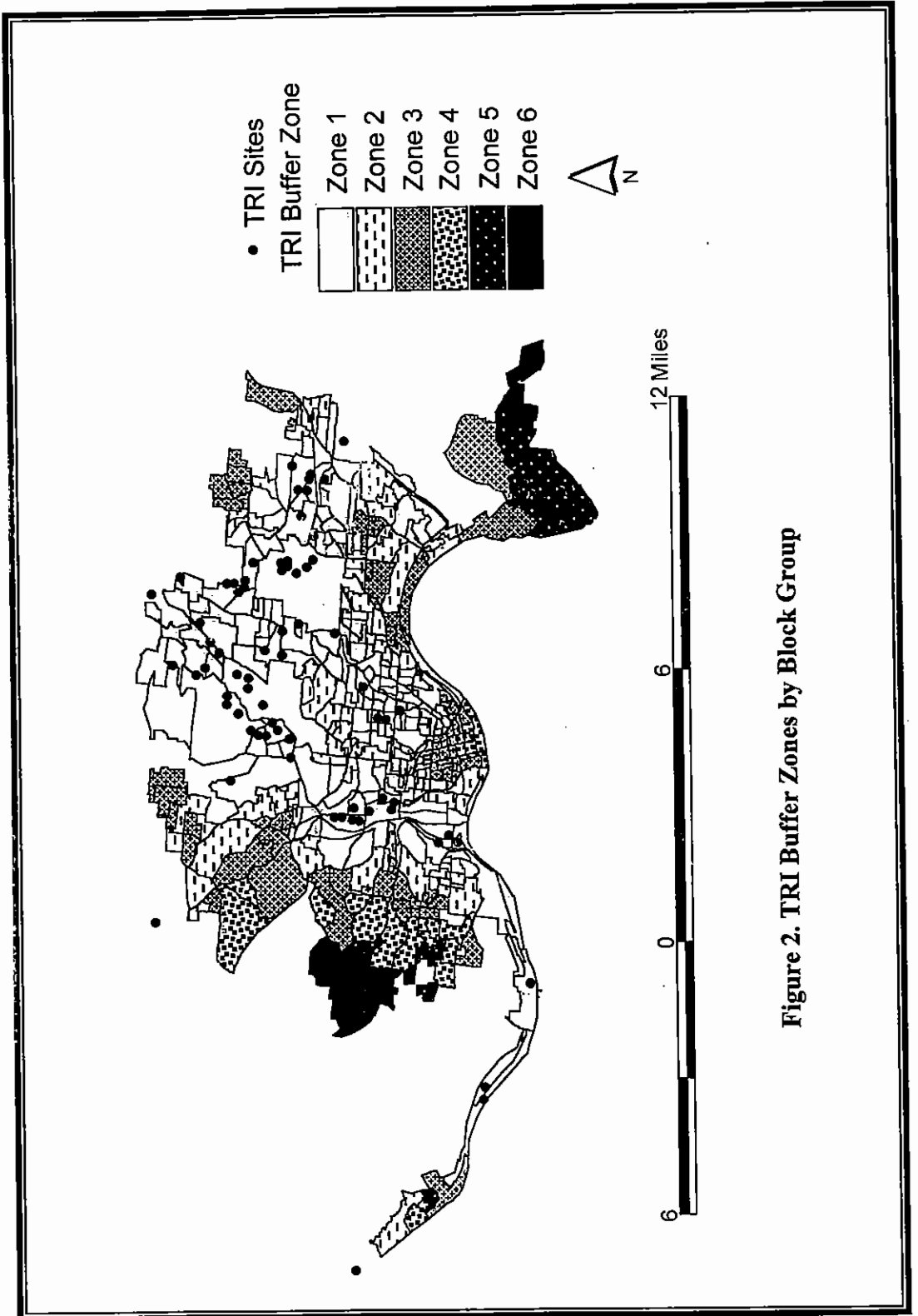


Figure 2. TRI Buffer Zones by Block Group



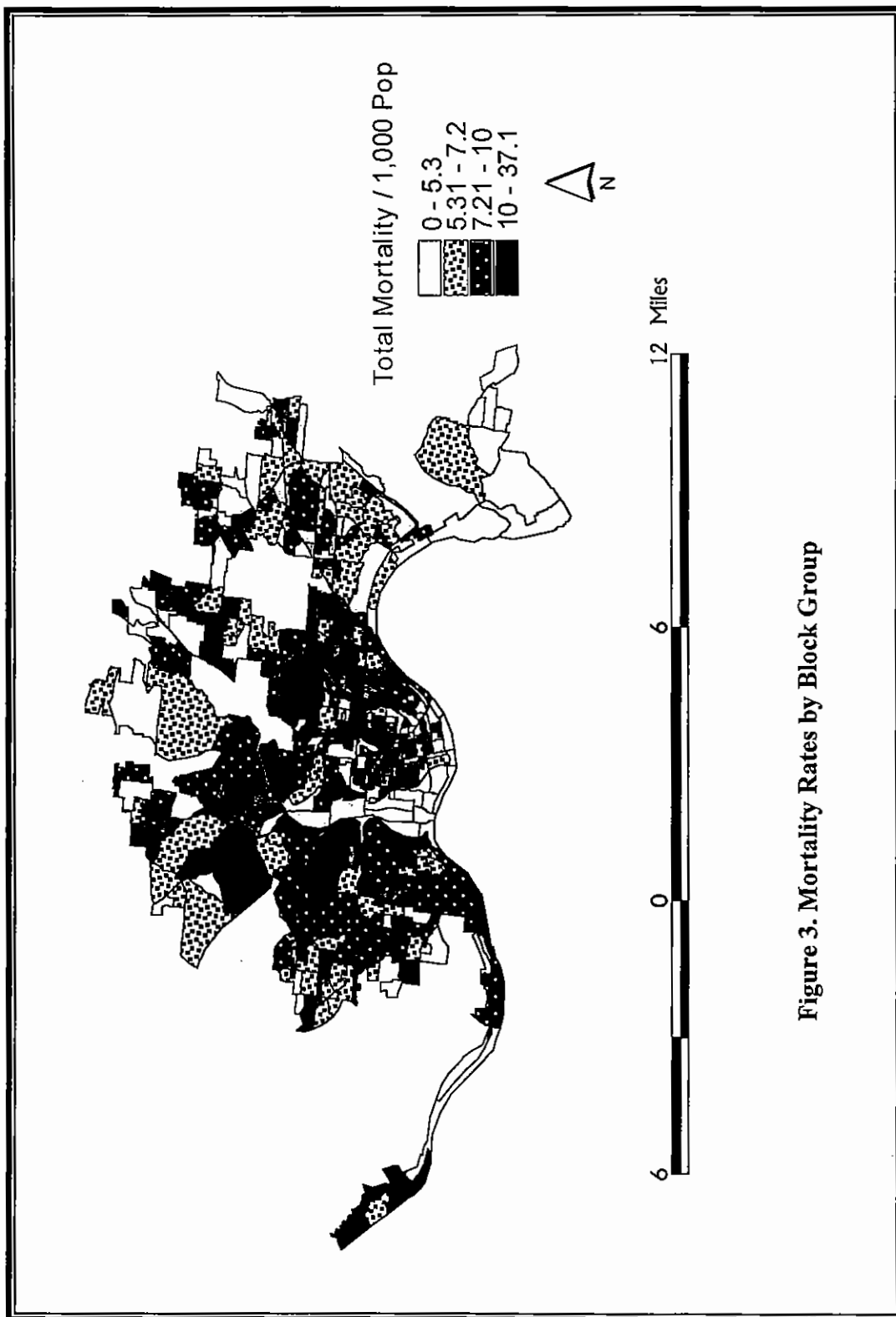


Figure 3. Mortality Rates by Block Group

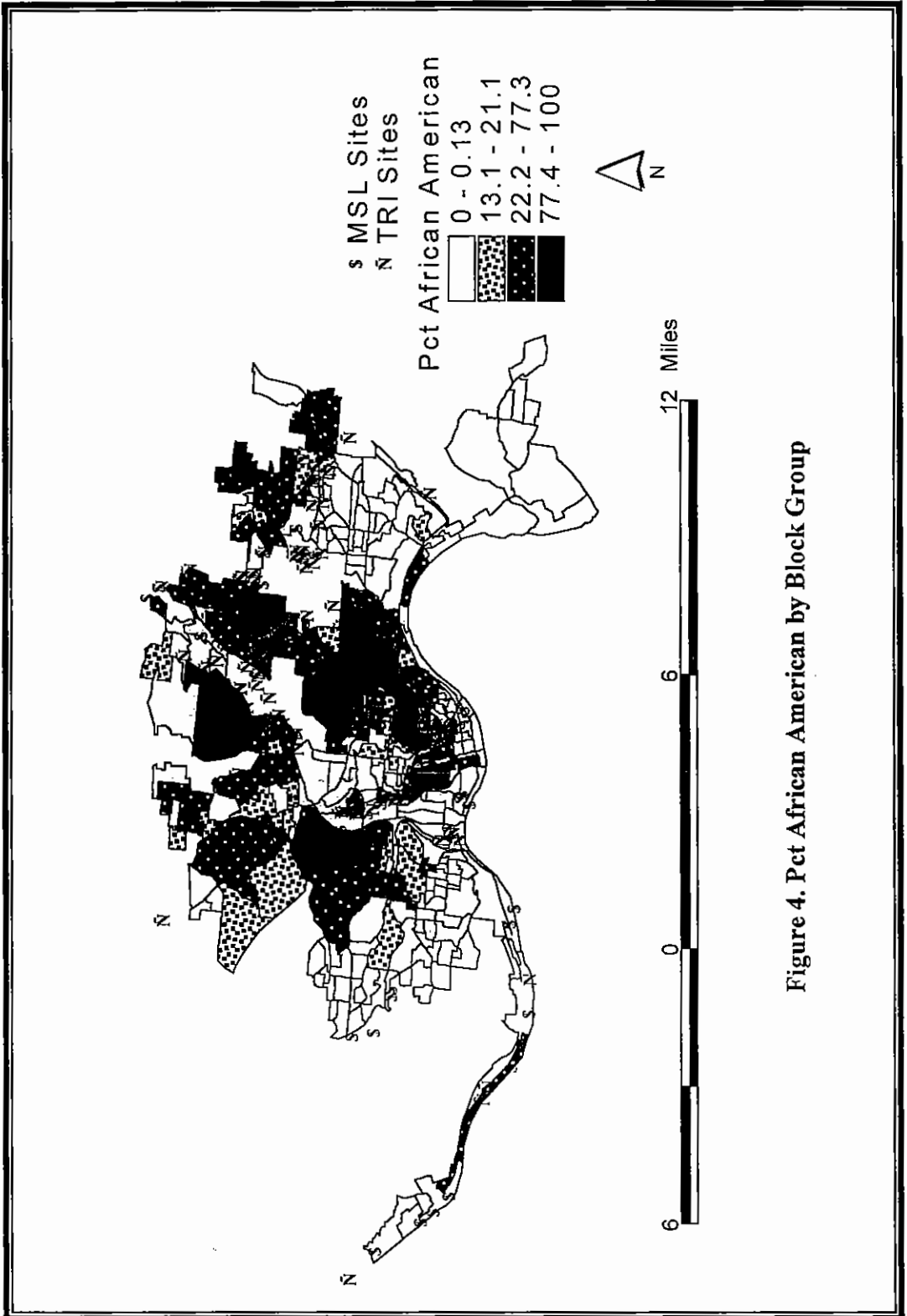


Figure 4. Pct African American by Block Group

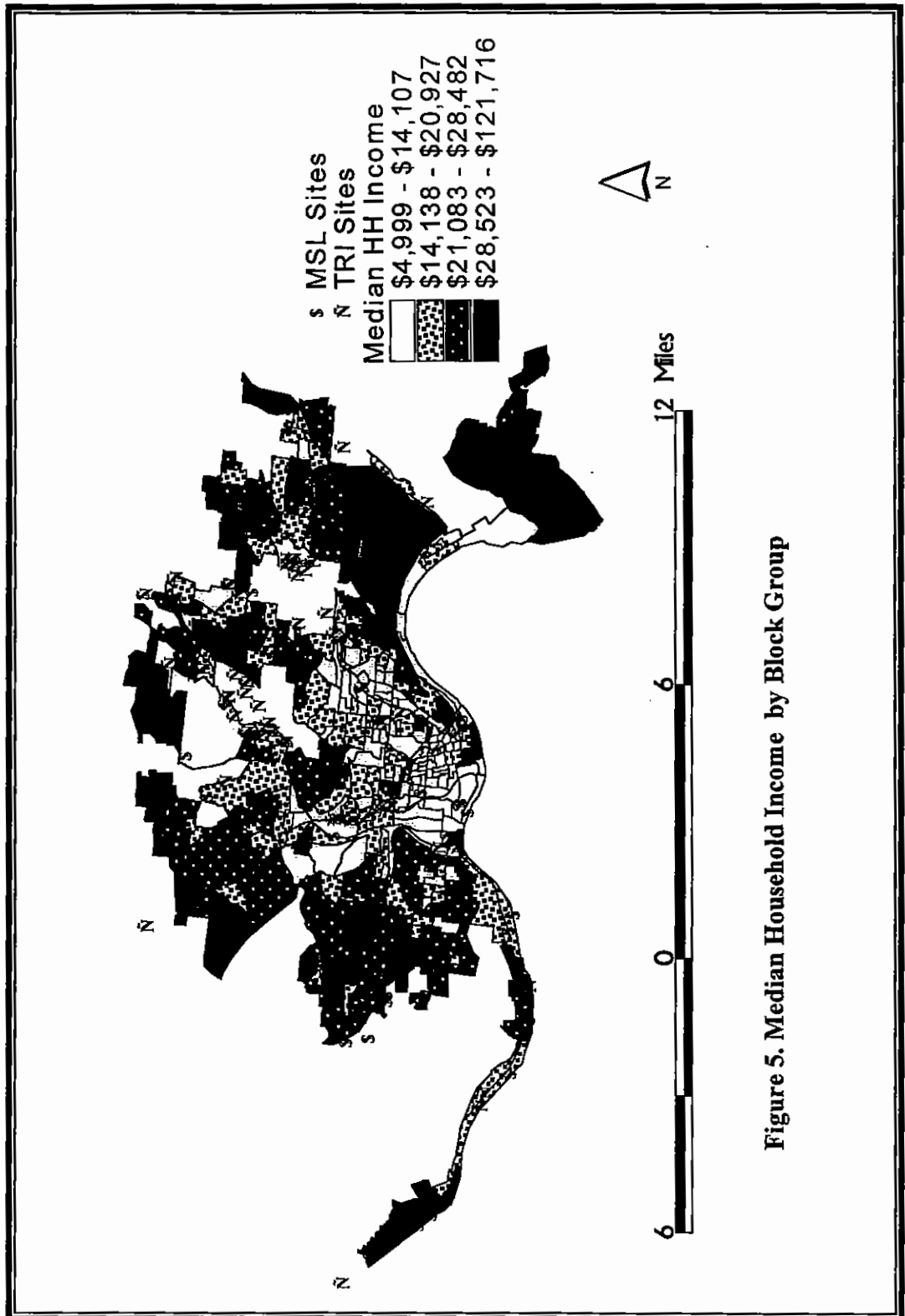


Figure 5. Median Household Income by Block Group

included in the analysis since their impact would not stop at the political boundaries.

The age adjusted mortality rate by census block groups in Cincinnati was displayed in Figure 3. Mortality rates appear higher in the older, less affluent areas in the center and west portions of the city. The newer areas to the east generally have lower mortality rates. Figure 4 and 5 show the percent African American by block group and median household income by block group, respectively.

Table 1 shows the mean values for age-adjusted mortality and the selected SES characteristics for each of the six MSL zones. There are clear declines in mortality, illiteracy and percent African American the farther away a block group is from an MSL site. Income, rent, and home value increase as the block groups become more distant, as does the percent of residents in their home more than 20 years, but to a lesser extent.

Table 2 provides the mean values for age-adjusted mortality and the selected SES characteristics for each of the six TRI zones. The results are similar to, though less pronounced than, those for the MSL zones.

The regression results for predicting proximity to the MSL and TRI sites are presented in Table 3. Race is the strongest predictor among the four SES variables included in the model. Percent African American, median rent and length of residence were significant predictors at a 0.05 level or better. The model implies that a block group that is 75 percent African American, with citywide means for the other SES variables is predicted to be located 0.8 miles from a MSL site, compared to 1.05 miles for a block group that is 25 percent African American. Again, race is the strongest predictor of TRI zone from among the four SES variables included in the model. Percent African American, median rent and percent adult illiterate were significant predictors at a 0.05 level or better. Length of residence was nearly significant

( $p=0.0977$ ). This model implies that a block group that is 75 percent African American, with citywide means for the other SES variables is predicted to be located 0.85 miles from a TRI site, compared to 1.15 miles for a block group that is 25 percent African American.

The regression results for predicting age-adjusted total mortality and age 35-64 cancer mortality are presented in Table 4. Percent African American, median rent, length of residence and MSL zone were significant predictors at 0.05 level or better for the total mortality. The model implies that a block group located in MSL Zone 1 has a 24 percent higher mortality rate than one with citywide values for the predictor variable. For the age 35-64 cancer mortality, percent African American and median rent were significant predictors at 0.05 level or better. This model implies that a block group located in MSL Zone 1 has a 26 percent higher mortality rate than a block group with citywide values for the predictor variables.

## V. CONCLUSIONS

After examining the spatial distribution of hazardous waste sites, mortality rate and six socioeconomic indicators at the census block group level in Cincinnati, we found associations between the distance to hazardous waste sites and the mortality rate and selected socioeconomic indicators. The study has demonstrated the need for more in depth investigations. Four issues raised by the results of this study are especially pertinent for environmental planners and policymakers. The issues are:

- (1) the utility of GIS for assessing environmental hazards;
- (2) the need for targeted follow up study of human health effects;
- (3) the impact of land use controls and public policy in systematically locating people

Measuring Local Environmental Inequity

**Table 1. Differences in Mortality and Socioeconomic Characteristic by MSL Zone**

Variable	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Mortality	9.9	9.6	8.9	5.0	6.9	3.4
Income	\$18,586	\$22,210	\$27,667	\$34,952	\$36,159	\$29,639
Rent	\$305	\$358	\$376	\$428	\$398	\$389
Home Value	\$59,561	\$65,792	\$88,895	\$87,350	\$94,880	\$69,599
Illiteracy	14%	11%	9%	8%	11%	10%
20+Yrs Residence	16%	17%	17%	24%	16%	22%
African Amer'n	47%	39%	20%	17%	1%	2%

**Table 2. Differences in Mortality and Socioeconomic Characteristic by TRI Zone**

Variable	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Mortality	9.6	9.8	9.4	7.3	5.3	6.5
Income	\$19,696	\$22,199	\$24,150	\$26,650	\$31,408	\$27,947
Rent	\$330	\$352	\$323	\$389	\$367	\$389
Home Value	\$56,753	\$75,097	\$92,643	\$66,381	\$68,222	\$68,495
Illiteracy	14%	11%	12%	8%	6%	8%
20+Yrs Residence	17%	18%	13%	13%	23%	23%
African Amer'n	46%	40%	35%	10%	2%	1%

**Table 3. Multiple Regression Predicting Proximity to Hazardous Sites**

Independent Variables	Dependent Var: Proximity to MSL Sites	Dependent Var: Proximity to TRI Sites
	B (Sig t)	B (Sig t)
African	-1.2290 (.0000)	-0.9243 (.0000)
Rent	-0.0014 (.0284)	0.0159 (.0068)
20+Yrs Resident	0.9121 (.0977)	1.2279 (.0122)
Illiteracy	-1.8607 (0.141)	-0.6793 (.3109)
Constant	3.1618 (.0000)	1.6205 (.0000)
Sig F	(.0000)	(.0000)
Adj.R <sup>2</sup>	.1247	.1555
N	389	389

who are poor, less educated and minority in environmentally threatened neighborhoods; and

- (4) the availability of land use and other planning option for remediating the environmental hazards posed by living near hazardous waste sites.

#### **A. Utility of GIS**

A spatial analysis approach was employed to examine the distribution of mortality rates in relation to contamination and hazardous waste release sites. GIS appears to be an effective means for analyzing the multiple kinds of environmental and social factors encountered in this study. The task of finding proper locations for over 96,000 mortality records without using the geocoding functions provided by GIS would have made this project infeasible. Just as important is the higher-order systematization of GIS spatial analyses. The use of GIS allowed data to be effectively and efficiently aggregated based on spatial placement and prepares the data for statistical analysis. The calculation of proximity, overlay analysis and integration of maps and attribute data present the relationship between environment and human health in a way that could not be done with only tabular data. Researchers, planners and policymakers can and should use this tool to better understand complex environmental relationships, and communicate them to the public.

#### **B. Need for Targeted Human Health Studies**

The analysis clearly shows that census block groups closest to the MSL and TRI sites in Cincinnati have significantly higher age-adjusted mortality rates than those farther away. However, the reasons for this association are not clear, and require further study. Although exposure of greater intensity and longer duration to hazardous wastes might be causally related to higher mortality

rates, this study has not sought to identify such a causal relationship. Rather, this is an exploratory effort to determine if proximity and health status are statistically associated in some way. Given that an association has been confirmed, a natural expansion of the research will be to explain the nature of the relationships involved. There may be direct causal relationships, or there may be synergistic effects involving several factors. Also, it is likely there are other confounding factors which are related to both proximity and health status. For example, those census block groups closer to the MSL and TRI sites had significantly lower incomes, lower levels of education and larger proportions of minority residents, and these are important determinants of health status. Closer analysis of the variation in mortality rates among subgroups may provide additional insight, as may scrutinizing other factors such as property values, health care access and utilization, and health-related personal habits. An interdisciplinary team from urban and environmental planning, public health, and environmental engineering is needed to address the complex issues involved. Clearly, developing better understanding of the fundamental nature of the relationships would be of great benefit to planners assisting a wide-range land use-related decisions.

#### **C. Systematic Bias Against the Poor, Uneducated and Minority**

The results here suggest the need for further investigation to clarify why the residential areas closest to the hazardous waste sites are poorer, less educated, and minority. Recent research in this area suggests institutional factors may contribute to the locational bias (Burby, 1997; Vos, 1997). Such areas are generally considered to be less desirable locations to live and property values reflect this. The market economy in the US dictates where people live based on their ability to pay. Consequently, it might be

argued that the disparity identified is simply the result of "the invisible hand" of the market. However, there are at least two reasons to suggest that non-market institutional factors may be major contributors to the apparent bias against the poor, less educated and minority. First, several of the largest residential concentrations closest to the hazardous waste sites are public housing complexes built in the past thirty years. Decision-makers may have determined that the nearby hazardous waste sites posed no hazards, or simply did not consider the issue. That the real estate was relatively inexpensive, and separated from existing neighborhoods made these sites politically attractive for situating public housing. In either case, hindsight suggests this decision making was flawed and biased against the current public housing resident. Second, many of the facilities releasing hazardous wastes were built or substantially expanded in the past thirty years, often on existing industrial sites that had been in use for a century or more. While the industry may have been there first, the residences may have been built when the amount and toxicity of the contaminants and releases of nearby industrial wastes posed a greatly reduced threat. In such a situation, the residences have remained the same, but the hazards posed by the physical environment in which they are located have increased substantially. In this case it would seem that environmental permitting and land-use regulations have failed to adequately protect residents from the evolving hazards of modern industrial processes. Responses have been proposed, such as a limit on the number of industrial facilities that locate near residential areas (Burby 1997). Others have recommended historical analysis of siting to search for evidence of bias in permit decisions (Boer *et al.*, 1997). To the residents it makes little

difference whether this failure was the result of a deliberate conspiracy or simply a reflection of the institutional neglect fostered by existing power structures. Both problems recommend changes in planning processes that would give greater consideration to the hazards resulting from the way in which industrial land is used. For example, performance zoning might be used, based on an enlightened, more comprehensive view of the hazards of industrial use, rather than the current system that assumes all permitted hazardous waste releases pose no hazard to nearby residents.

#### **D. Remediating the Environmental Hazard**

The locations of hazardous waste sites should be considered in making decisions regarding the appropriate land use for nearby properties, as well as environmental remediation and pollution prevention. Planners and communities must take steps to ensure that hazardous waste sites are managed in effective ways in order to prevent the exposure of nearby residents to hazardous levels of toxins. Industrial facilities cannot be allowed to release hazardous wastes, even in small quantities, if the cumulative effect of multiple small releases creates health hazards. Steps must be taken to avoid multiple small hazardous releases that are effectively equivalent to the hazards posed by more seriously contaminated individual sites. Further, while the synergistic effects of likely chemical combinations are not well understood, explicit consideration of the potential for such effects would seem prudent, and should become an integral part of standard land use planning. Also, when resources are allocated for environmental remediation, higher priority generally should be given to sites that individually pose more serious problems, yet the impact of other nearby sites must also be considered.

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