Journal of Exposure Analysis and Environmental Epidemiology (1999) 9, 29–48

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An examination of race and poverty for populations living near industrial sources of air pollution

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This study examines the sociodemographic characteristics of people living near industrial sources of air pollution in three areas of the United States: (1) the Kanawha Valley in West Virginia; (2) the Baton Rouge–New Orleans corridor in Louisiana; and (3) the greater Baltimore metropolitan area in Maryland. Using data from the 1990 Toxics Release Inventory (TRI) and the 1990 Census, we analyze relationships between variables assumed to be independent, such as location of single or multiple industrial emission sources, and the dependent variables of race (black/white) and poverty status (above/below poverty level). Results from all three study areas are consistent and indicate that African Americans and those living in households defined to be below the established poverty level are more likely, on average, to live closer to the nearest TRI facility and to live within 2 miles of multiple TRI facilities. Conversely, whites and those living in households above the poverty level are more likely, on average, to live farther from the nearest TRI facility and to live within 2 miles of fewer facilities, compared to African Americans and poor people.

Keywords: *environmental justice, industrial air pollution, poverty status, race, socioeconomic status, toxic release inventory.*

Introduction

There is mounting concern that economically disadvantaged populations, including a disproportionate number of African Americans, Native Americans, and Hispanics, bear a higher-than-average burden from exposure to pollution and related environmental health risks (U.S. GAO, 1983; United Church of Christ, 1987; U.S. EPA, 1992b; Sexton and Anderson, 1993; Sexton et al., 1993; Executive Order, 1994; Kuehn, 1996; Sexton, 1997). The science and policy issues associated with this topic are typically discussed under the rubric of ‘environmental justice’, where environmental justice refers to the goal of achieving adequate protection from the harmful effects of pollution for everyone, regardless of age, culture, ethnicity, gender, race, or socioeconomic status (Sexton and Anderson, 1993).

Although there is a growing literature on environmental justice, the scarcity of adequate and appropriate data, especially for exposures and related health effects, seriously hinders ongoing efforts to evaluate this issue rigorously and systematically. Most of the published literature consists of anecdotal case studies or observational studies that have tended to find positive statistical correlations between sociodemographic characteristics of populations (i.e., lower socioeconomic status and ethnicity/race) and residential proximity to pollution sources, such as waste sites and industrial plants (Bullard, 1983; Gould, 1986; United Church of Christ, 1987; Goldman, 1991; Mohai and Bryant, 1992; Greenberg, 1993; Burke, 1993; Bowen et al., 1995; Glickman et al., 1995; Heitgerd et al., 1995; Perlin et al., 1995; Sui et al., 1995). A few studies have also found similar positive correlations for estimated industrial air pollution emissions (Perlin et al., 1995) and measured ambient air pollution concentrations (Gelobter, 1989; Nieves and Nieves, 1992).

Perlin et al. (1995) point out that these kinds of observational studies must be interpreted with caution because the results are dependent on several key methodological issues: (a) selection of the geographical unit of analysis (e.g., block groups, tracts, zip codes; areal rings based on distance from a source) (Anderton et al., 1994a,b; Bowen et al., 1995; Glickman et al., 1995; Sui et al., 1995); (b) designation of a ‘reference’ population for purposes of comparison (e.g., whites only, whites plus all other groups); (c) choice of statistical tests for evaluating differences among population subgroups; and (d) assumptions about how indirect surrogates for exposure (e.g., residential proximity to potential pollution sources) relate to actual exposures experienced by people (Sexton et al., 1992).

This study examines relationships among the location of Toxics Release Inventory (TRI) facilities, their total annual air emissions, and sociodemographic characteristics of surrounding populations defined by concentric rings of 0–0.5,

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0.5–1.0, 1.0–1.5, 1.5–2.0 and 2.0–3.0 mile radius around each TRI facility. We have used both existing procedures (Glickman, 1994; Glickman et al., 1995; Sui et al., 1995), as well as new approaches to examine race (black compared to white) and poverty status (household earnings above or below poverty line) of populations relative to the location of single and multiple TRI facilities. These analyses are conducted for three different geographic locations: (1) the industrialized area of Kanawha Valley, West Virginia; (2) the industrial corridor along the lower Mississippi River from Baton Rouge to New Orleans, Louisiana; and (3) the metropolitan area of Baltimore, Maryland.

Methods

This study uses Geographic Information System (GIS) technology to manage, integrate, and analyze two sets of data: selected sociodemographic information from the 1990 Census and information about location of industrial facilities and airborne emissions from the Environmental Protection Agency's (EPA's) 1990 Toxics Release Inventory (TRI).

Sociodemographic data by race (for whites, blacks, Native Americans, Asian Pacific Islanders and Other Races) or ethnicity (for Hispanics) were obtained from the 1990 Census Summary Tape File (STF3A). Data in STF3A are sample data (approximately 1 in 6 households), not whole (100%) population counts, and are aggregated to the block group (BG) level. We were limited to using data from STF3A, since the BG is the smallest Census aggregation that links race/ethnicity, socioeconomic status (e.g., poverty level and household income), and age. After examining the racial and ethnic composition of the three study areas, we decided to limit the current analysis to blacks and whites, since the other race/ethnic groups made up a relatively small percentage of the total populations (see Table 1).

Estimates of industrial air emissions were obtained from the Toxics Release Inventory for the year 1990. The 1990 TRI includes information on about 320 individual chemicals and chemical categories for all U.S. manufacturing facilities that meet the following criteria: (a) employ 10 or more full-time employees; (b) are included in the Standard Industrial Classification (SIC) codes 20–39; and (c) manufacture, process, or import more than 25,000 pounds annually, or otherwise use more than 10,000 pounds annually, of any reportable toxic chemical (U.S. EPA, 1989, 1992c). Companies subject to TRI reporting requirements must report to the EPA the total annual amounts (including routine releases and accidental spills or leaks) of all listed chemicals that are released directly to the air, water, land, or injected into underground wells (U.S. EPA, 1991a). It is important to note that in each of the three study areas, the TRI facilities represent just one component of the total air pollution sources. Each study area has many other industrial facilities that do not meet the TRI reporting requirements and as a result are not in EPA's inventory of TRI facilities (and are not included in this study). Each study area also has power generating facilities, many commercial facilities (such as gasoline stations and dry cleaners) and mobile sources, all of which may contribute to air pollution levels but which are not considered in our analysis.

The geographic locations (i.e., latitude, longitude) of TRI facilities often are reported to EPA with varying degrees of accuracy and need to be verified for analysis below the county level (Hanna, 1993; Talbot, 1993; Perlin et al., 1995). The location information for all TRI facilities used in this study underwent a quality assurance (QA) process to help ensure that the most accurate coordinates available were used. The QA process is described elsewhere (U.S. EPA, 1991b, 1992d). When the best available coordinates were determined, they were used to produce an ARC/INFO point coverage. Facility and emissions information files were created in a relational database structure that allows attribute information (i.e., volume of emissions, types of chemicals released) and TRI facility locations to be used together in a GIS-based analysis.

Defining Study Area Boundaries and Developing Population Estimates

The boundaries of the three study areas (see Figures 1–3) were defined as follows. First, where TRI facilities were clustered along a natural feature, such as a river valley, we selected upstream and downstream boundaries to capture all TRI sources that were in reasonable proximity to each other. This is the approach used for both the Kanawha River valley (West Virginia) and Mississippi River valley between Baton Rouge and New Orleans (Louisiana). Where there was no clustering along a natural feature, as in the Baltimore greater metropolitan area, the study area was defined to include all TRI facilities in the City of Baltimore and the three adjacent counties (Baltimore, Howard and Anne Arundel counties). Second, four concentric half-mile-wide circles with radii of 0.5, 1.0, 1.5 and 2.0 miles, respectively, and an additional 1-mile-wide circle at 3 miles, were drawn around each facility location, assuming that the TRI point location represented the center of the emission source. As indicated in Figures 1–3, the study areas were discontinuous wherever two adjacent TRI facilities were more than 6 miles apart.

Using ARC/INFO, we overlaid the concentric half-mile-wide rings and the 1-mile-wide ring on the census block group (BG) polygons in order to estimate population counts within the study area. There are several different approaches that can be used to estimate the population at a given point in time, for a specific geographic entity (U.S. EPA, 1990a). The method we used is similar to that

Table 1. Comparison of the 1990 demographic characteristics for the three study areas[a]

	Kanawha Valley			Baton Rouge–New Orleans			Baltimore metropolitan area		
	Study area	County[b]	State[c]	Study area	County[d]	State[e]	Study area	County[f]	State[g]
Total population	126,653	247,900	1,755,300	1,159,968	1,526,200	4,219,973	1,563,415	2,699,800	4,925,500
% White	90.0	93.7	96.3	54.8	59.3	67.6	63.3	61.9	72.8
% Black	9.0	5.5	3.0	42.4	37.9	30.5	34.1	34.6	23.3
% Other races[h]	0.9	0.8	0.7	2.9	2.8	1.9	2.6	3.5	3.9
% Hispanic[i]	0.6	0.4	0.4	3.5	3.0	2.1	1.2	1.9	2.4
Density[j] (/mi^2)	911	–	–	1335	–	–	3102	–	–
Age[k]									
% 0–5 years	7.3	7.2	7.3	9.5	9.6	9.8	9.0	9.0	13.9
% 6–11 years	7.7	8.2	8.5	9.5	9.8	10.3	7.9	8.0	7.7
% 12–17 years	7.6	8.5	9.3	8.8	8.9	9.4	6.8	7.2	6.9
% 18–64 years	61.1	61.6	60.3	60.7	61.4	59.7	63.9	65.4	61.5
% > 65 years	16.4	14.6	14.7	11.4	10.3	10.7	12.5	10.5	10.0
Percent below poverty[l]									
Total population	15.2	14.7	19.7	23.9	21.9	23.6	12.9	9.6	7.8
Whites	13.2	13.6	19.1	10.0	9.8	13.4	6.8	5.5	4.9
Blacks	35.8	33.7	36.0	41.5	40.5	45.7	24.3	16.9	16.6
Other races	16.3	0.2	21.9	29.0	26.5	29.7	12.5	10.1	9.5
Hispanic	31.8	26.1	26.1	19.0	18.2	19.5	13.0	11.8	11.3
Annual household income[m]									
No. of households	54,245	100,100	688,700	438,724	569,800	1,498,400	608,885	1,019,900	1,749,300
% < 15 K	31.7	30.8	37.3	35.4	32.9	36.3	21.8	16.7	15.5
% 15–25 K	19.1	19.9	20.5	18.4	17.8	18.9	16.1	14.2	13.5
% 25–35 K	15.3	15.8	15.1	14.7	14.8	14.8	15.8	15.1	14.7
% 35–50 K	15.4	16.2	14.6	14.7	15.6	14.7	19.0	20.0	19.9
% 50–75 K	12.2	12.1	9.0	11.0	12.2	10.3	17.1	20.2	20.8
% > 75 K	6.3	5.2	3.5	5.8	6.7	5.2	10.2	13.8	15.6

[a] Demographic data are taken from the 1990 Census.
[b] The Kanawha Valley study area lies in Putnan and Kanawha Counties.
[c] The Kanawha Valley study area is in West Virginia.
[d] The Baton Rouge–New Orleans corridor study area lies in the following parishes in Louisiana: East Baton Rouge, West Baton Rouge, Iberville, Ascension, St. James, St. John the Baptist, St. Charles, Jefferson, Orleans, Plaquemines and Assumption.
[e] The Baton Rouge–New Orleans corridor study area is in the industrial corridor of the lower Mississippi River in Louisiana.
[f] The Baltimore metropolitan study area encompasses all of Baltimore City and parts of the following counties: Anne Arundel, Baltimore, Howard, and Prince George's.
[g] The Baltimore greater metropolitan study area is in Maryland.
[h] Other races includes all races not classified by the Census Bureau as either white or African American. This category includes Native Americans, Asian Pacific Islanders, and the Census category of 'Other'.
[i] Hispanics are an ethnic subpopulation, not a race. They are counted separately from the racial groups by the Census Bureau. The Census Bureau counts the population two ways: (1) as the sum of all races, and (2) as the sum of Hispanics and non-Hispanics.
[j] Density is calculated by dividing the total number of people in the study area by the total land area of the study area.
[k] Values represent the percent of the total population within the specified age categories. Values sum to 100%.
[l] The poverty level, determined by the U.S. Census Bureau (1990) is US$12,674 for a family of four. Values indicate the percent below poverty for the total population and each of the specified subgroups; therefore, values do not sum to 100%.
[m] Values indicate the total number of households and the percent of households within the specified income categories. Values sum to 100%.

developed for EPA's Population Estimation and Characterization Tool (PECT) (U.S. EPA, 1994).

We assumed that populations were distributed evenly within census BGs, excluding bodies of water. Population counts were made for each BG polygon that fell completely or partially within each ring. For BG polygons falling partially within a ring, we calculated the population based on the percentage of the BG land area encompassed within a particular ring. For example, if 40% of the land area of a BG fell within the 0–0.5-mile ring of a facility, then 40% of each population subgroup of interest was counted in that first half-mile ring. Figure 4 illustrates the process we used for estimating the population within 1 mile of a single TRI facility. The approach for estimating the populations residing within 2 miles of two facilities is illustrated in Figure 5.

Description and comparison of the three study areas

The three study areas were chosen, a priori, to reflect different geographic regions of the country and a range of population characteristics (e.g., urban/rural mix, percentage of African Americans) and TRI characteristics (e.g., number and type of facilities, amount of total annual air releases).

Kanawha Valley

The Kanawha Valley, West Virginia study area (see Figure 1) is the smallest of the three study areas, having 18 TRI facilities and about 127,000 people located within a 143-square-mile site that stretches about 30 miles along the Kanawha River. The valley is relatively narrow, with much of it developed for industrial, urban or residential uses. Although there are relatively few TRI sources, Kanawha Valley is one of the largest chemical manufacturing centers in the United States. Over 200 industrial and manufacturing facilities and numerous hazardous waste sites are located in this area (U.S. EPA, 1987) and they commonly adjoin residential neighborhoods. Airborne emissions are often readily visible and odors associated with operations are routinely detectable. Local topography and meteorology of the valley can confine air pollution emissions, thereby increasing concentrations of potentially hazardous pollutants (Ware et al., 1990).

There has been much interest in evaluating and controlling the industrial emissions in this area, with studies of the problem going back more than 40 years (U.S. DHEW, 1970; NICS, 1987; U.S. EPA, 1987; Cohen et al., 1989, 1991a,b; Sullivan et al., 1989a,b; Trauth, 1990; Ware et al., 1990; Ozkaynak et al., 1992). The predominant type of industry in this study area is chemical manufacturing, with production, storage and transport of many organic chemicals and ferro-alloy and lead production. Many of the chemical facilities have their own coal or oil-fired heating and power-generating units (Cohen et al., 1991a). Other

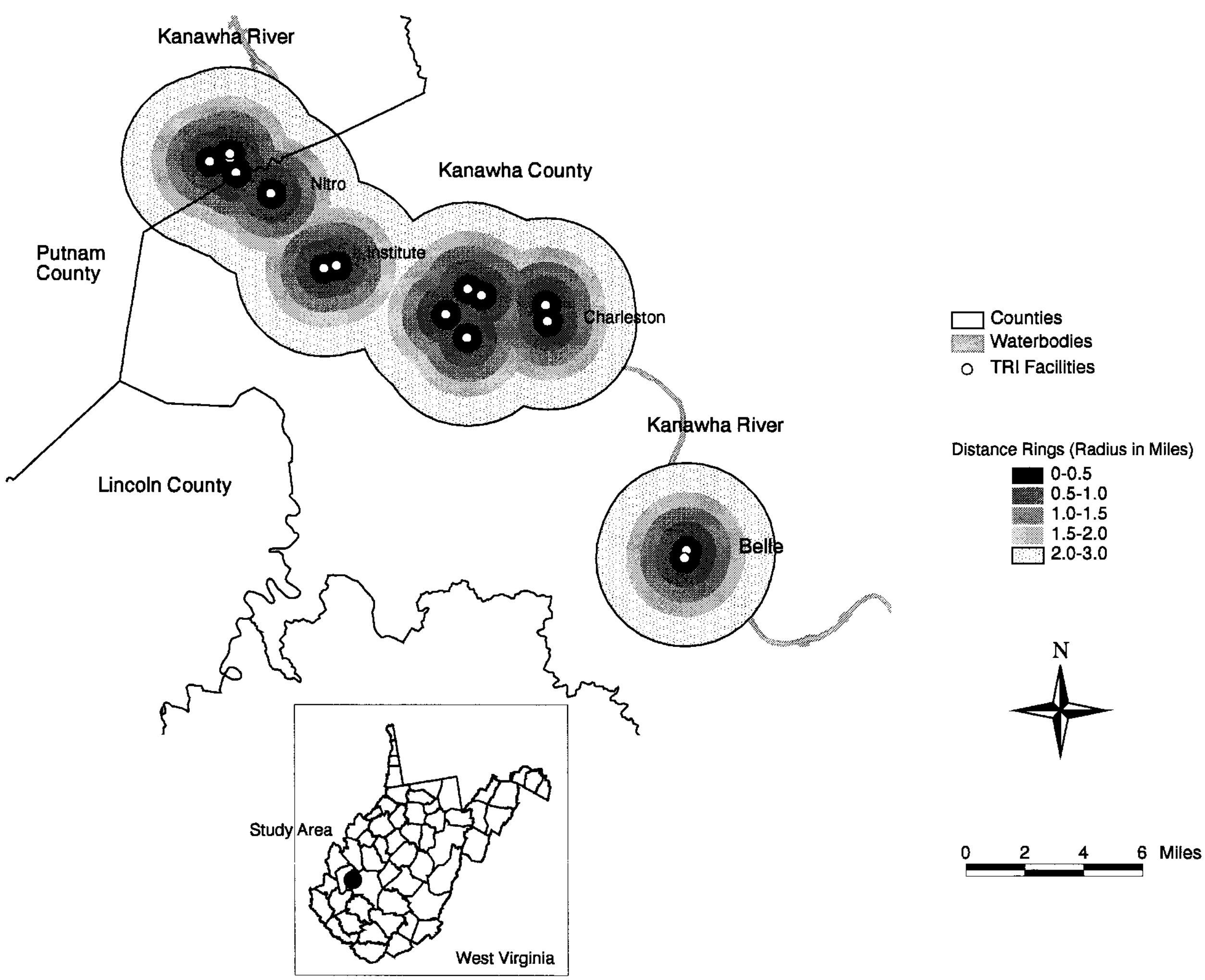

Figure 1. Study area: Kanawha valley, WV.

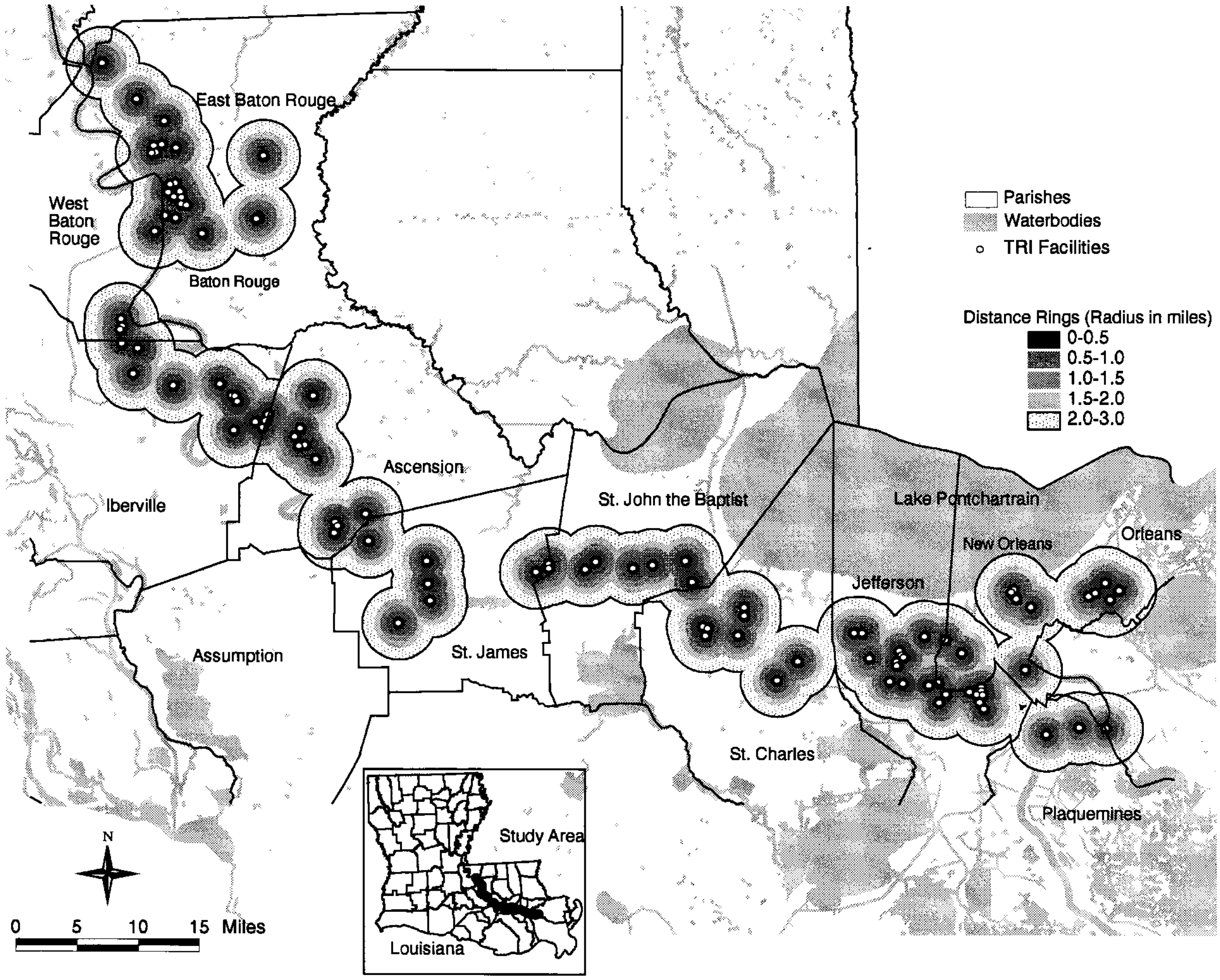

Figure 2. Study area: Baton Rouge–New Orleans corridor, LA.

sources of air pollutants, which are not accounted for in this analysis, include mobile sources associated with three interstate highways, trains that run along the numerous train tracks, and barge traffic along the river (Cohen et al., 1991a).

Most of the people who live in the study area are clustered around the four major industrial centers of Nitro, Institute, Charleston/South Charleston, and Belle. The largest proportion of the population lives in the Charleston and South Charleston areas.

Baton Rouge–New Orleans Corridor

The corridor along the Lower Mississippi River between Baton Rouge and New Orleans is the most heavily industrialized area in Louisiana (see Figure 2). The study area has 126 TRI facilities, numerous Superfund and hazardous waste sites, many non-TRI industries and about 1.2 million people located within a long, narrow geographical area (962 square miles) that extends for about 107 miles along the Mississippi River. This study area contains many industry clusters and a broad range of sizes and types of TRI plants. The predominant types of industry are petrochemical (including oil refineries and petrochemical plants), chemical manufacturing, and natural gas production (LAC, 1993; U.S. EPA, 1993).

There are two densely populated urban areas (Baton Rouge and New Orleans) at either end of the study area, with many low-density rural areas, some of which are agricultural and some of which are wildlife and designated wetlands, in between. There are pockets of moderately dense populations mixed in with the low density rural areas (Police Jury of Parish of Iberville, 1993). Levels of air and water pollution are relatively high in the lower Mississippi River area, and there is longstanding concern about environmental problems and potential adverse health effects for residents (U.S. EPA, 1990b, 1993; LAC, 1993; Lindsey, 1993). Previous studies have shown that in much of the industrial corridor, residential communities, often poor and predominantly African American, are located next to refineries and petrochemical plants. Environmental

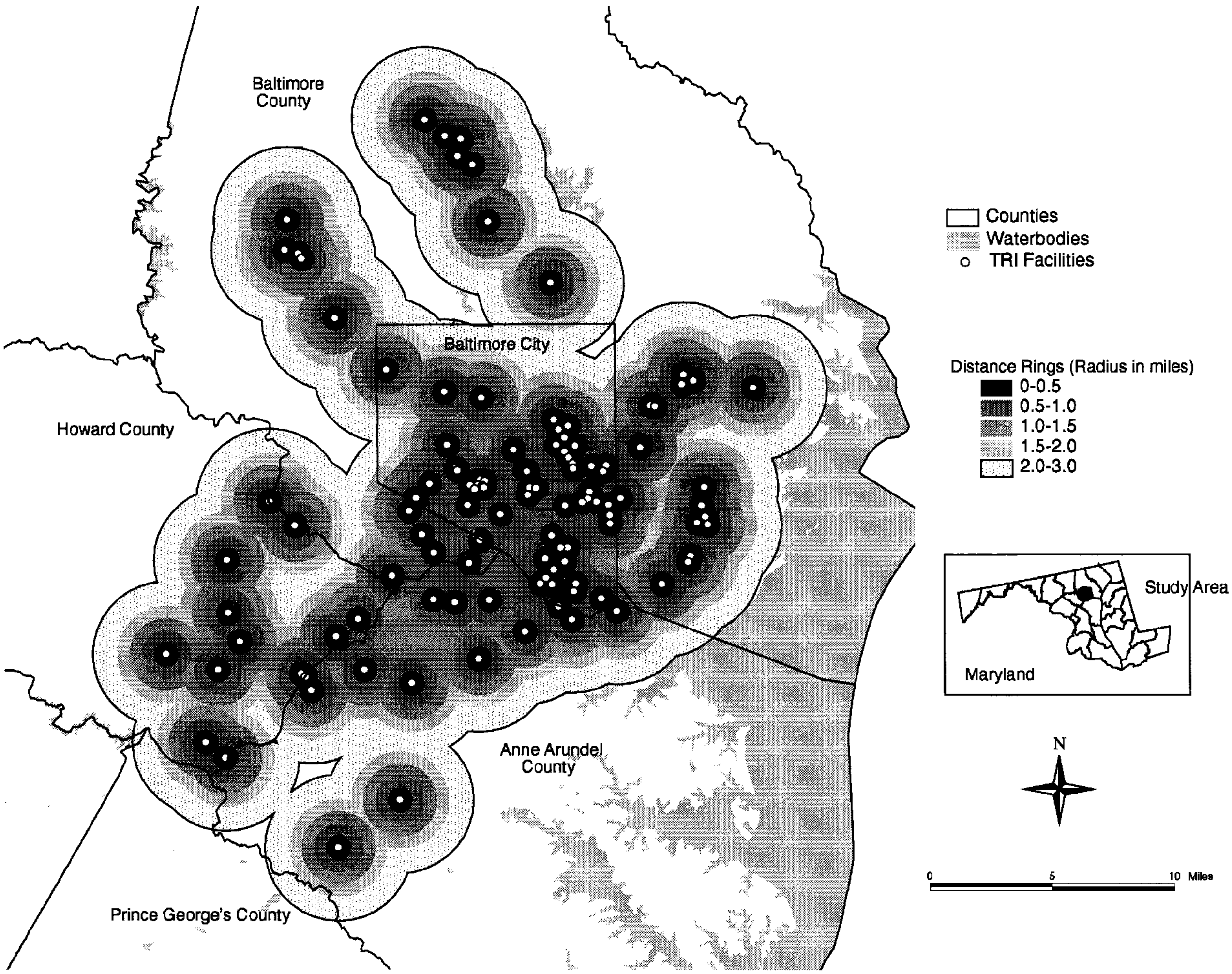

Figure 3. Study area: Baltimore greater metropolitan area, MD.

justice activists sometimes refer to the corridor as 'cancer alley', and often cite it as a prime example of 'environmental injustice' (LAC, 1993).

Baltimore Greater Metropolitan Area

The metropolitan area of Baltimore, Maryland (see Figure 3) has 122 TRI facilities and a population of approximately 1.6 million people within the 542-square-mile study area. There are hundreds of commercial and industrial facilities located throughout the inner-city (U.S. EPA, 1996). Compared to the other two study locations, the Baltimore metropolitan area is primarily an urban setting and the local TRI sources tend to release smaller amounts of air emissions, with about two-thirds emitting less than 10,000 lbs/yr. Roughly half of the TRI facilities are located in the City of Baltimore and the rest are scattered throughout the surrounding counties of Howard, Anne Arundel and Baltimore. Unlike the other two study locations, TRI facilities are not clustered along a river, but rather are spread throughout the metro area.

Issues about environmental quality and related health impacts in the Baltimore metropolitan area have been raised and studied for many years. Recently the Baltimore Urban Environmental Initiative (U.S. EPA, 1996) was started to identify and rank areas of disproportionate risk in the City in order to implement activities to eliminate or reduce these risks (U.S. EPA, 1996).

Comparison of the Three Sites

A comparison of the populations residing in each of our three study areas, including the populations of the relevant counties and states, is presented in Table 1. Based on comparisons of (a) race, age and household income of residents, and (b) characteristics of TRI facilities, there are clear differences among the study areas.

The Kanawha Valley study area has 126,653 residents, which is 51% of the population residing in the surrounding counties and 7% of the population of West Virginia. The Baton Rouge–New Orleans corridor has a population of 1,159,968, which is 76% of those residing in surrounding

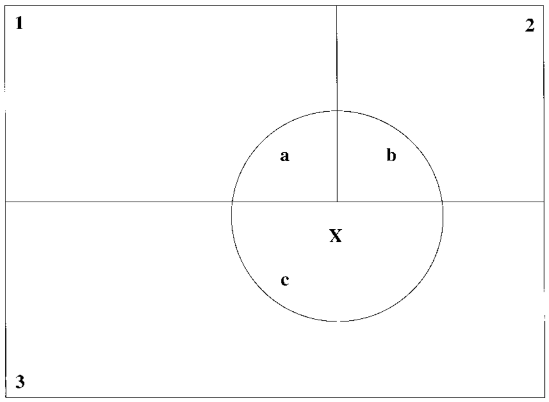

Figure 4. Estimation of population surrounding one TRI facility. For TRI facility X and Block Groups (BG) 1, 2 and 3, the population estimated to be within 1 mile of facility X is calculated as: $P_x = P_a + P_b + P_c$, where the circle is centered on the facility X location and has a radius of 1 mile; P_x = estimate of population within 1 mile of facility X; P_a = population of BG1 estimated to be within polygon a of the circle surrounding facility X; P_b = population of BG2 estimated to be within polygon b of the circle surrounding facility X; P_c = population of BG3 estimated to be within polygon c of the circle surrounding facility X.

counties and 28% of the population of Louisiana. The Baltimore metropolitan study area has a population of 1,563,415, which is 58% of residents of the surrounding counties and 32% of Maryland's population. Population density varies from 911 people per square mile in the Kanawha Valley study area, to 1335 in the Baton Rouge–New Orleans corridor, to 3102 in the Baltimore metropolitan study area.

Race / Ethnicity of Residents

The population in the Kanawha Valley study area is predominately white (90%), while the Baton Rouge–New Orleans corridor study area and the Baltimore metropolitan study area each have a much higher percentage of blacks (42.4% and 34.1%, respectively). In the Baton Rouge–New Orleans corridor, the ratio of whites to blacks is 1.3, while the ratio is 1.6 in the surrounding counties. This ratio is considerably lower than the ratio of 2.2 in the State of Louisiana. The ratio of whites to blacks in the Baltimore metropolitan area is 1.9, while it is 1.8 in the surrounding counties, and 3.1 in the State of Maryland. In Kanawha Valley, the ratio of whites to blacks is 10, which is considerably lower than the ratio of 17 in the surrounding counties and the ratio of 32 in the State of West Virginia. Thus, in all three study areas the ratio of whites to blacks is considerably lower than the ratio in the relevant state.

Percentage of Children and Elderly in the Population

The percentage of children and the elderly in the population is of interest because, for many environmental pollutants, they are likely to be more susceptible to related adverse health effects (Sexton, 1997). Of the three study areas, Kanawha Valley had the lowest percentage of children under the age of 6 years old (7.3%), and the highest percentage of adults 65 years and older (16.4%). The highest percentage of children under 6 years live in the Baton Rouge–New Orleans corridor (9.5%), while the percentage of adults 65 years and older (11.4%) is intermediate between the other two study areas. The percentage of children under 6 years in the Baltimore metropolitan area is 9.0%, while the percentage of adults 65 years and older is 12.5%, the highest of the three study areas. The percentage of the population under age 6 is roughly the same in the study area, the surrounding counties and the relevant state for Kanawha Valley and Baton Rouge–New Orleans. In the State of Maryland almost 14% of residents are less than 6 years old while the corresponding value is 9% in the Baltimore metropolitan area and surrounding counties. The percentage age 65 and over is higher in all three study areas than the surrounding counties and the relevant state.

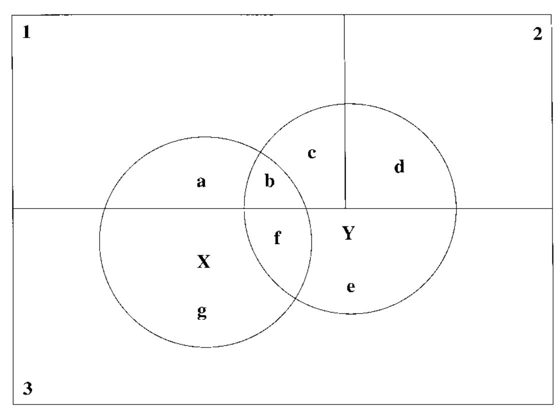

Figure 5. Estimation of population surrounding multiple TRI facilities. For TRI facilities X and Y and Block Groups (BG) 1, 2 and 3, the populations within 2 miles of either X or Y, or within 2 miles of either one or two facilities are calculated as: $P_x = P_a + P_b + P_f + P_g$; $P_y = P_b + P_c + P_d + P_e + P_f$; $P_{1Fac} = P_a + P_c + P_d + P_e + P_g$; $P_{2Fac} = P_b + P_f$, where each circle has a radius of 2 miles and one circle is centered on the location of facility X and the other circle is centered on the location of facility Y, P_x = estimation of population within 2 miles of Facility X, P_y = estimation of population within 2 miles of Facility Y, P_{1Fac} = estimation of population within 2 miles of only one facility, P_{2Fac} = estimation of population within 2 miles of both facilities, P_a = population of BG1 estimated to be within polygon a of the circle surrounding facility X, P_b = population of BG1 estimated to be within polygon b of the circles surrounding both facilities X and Y, P_c = population of BG1 estimated to be within polygon c of the circle surrounding facility Y, P_d = population of BG2 estimated to be within polygon d of the circle surrounding facility Y, P_e = population of BG3 estimated to be within polygon e of the circle surrounding facility Y, P_f = population of BG3 estimated to be within polygon f of the circles surrounding both facilities X and Y, P_g = population of BG3 estimated to be within polygon g of the circle surrounding facility X.

Percentage of Population by Household Income

As reflected in Table 1, the percentage of households in various income categories is similar for the Kanawha Valley and Baton Rouge–New Orleans study areas. In the Baltimore metropolitan study area, the distribution of household incomes is shifted toward higher values. For example, the Baltimore study area has a smaller percentage of households with annual incomes less than US$15,000, i.e., 22% versus 35% in the Baton Rouge–New Orleans corridor and 32% in Kanawha Valley study areas. Conversely, in the Baltimore study area, 10% of household incomes are greater than US$75,000, while the comparable figure in the other two study areas is about 6%.

Percentage of Population Living Below the Poverty Line

The Census Bureau considers size of the family, number of children in the family under 18 years of age, and age of the head of the household in order to calculate the value of the poverty line. For the 1990 Census, the Bureau calculated the weighted average value of US$12,674 as the poverty line for a family of four. The weighted average value of the 1990 poverty line ranges from US$6310 for a family of one, to US$26,480 for a family of nine or more (U.S. Census Bureau, 1990). Based on this definition, the Baltimore metropolitan area has the lowest percentage of people living below the poverty line (12.9%), while the Baton Rouge–New Orleans corridor has the highest percent (23.9%). Similarly, the State of Maryland (7.8%) and the counties around Baltimore (9.6%) have the lowest percentage living in poverty, while the State of Louisiana (23.6%) and counties (i.e., parishes) that encompass the corridor (21.9%) have the highest. The corresponding values for Kanawha Valley (15.2%), the State of West Virginia (19.7%) and the relevant counties (14.7%) were intermediate in all cases.

For all three study areas, the percentage of African Americans below the poverty line is greater compared to the percentage of whites below the poverty line. The ratio of the percentage of African Americans to whites below the poverty line is 4.2 in the Baton Rouge–New Orleans corridor, 3.6 in the Baltimore metropolitan area, and 2.7 in the Kanawha Valley. The rank order is the same for the three states, Louisiana (3.4), Maryland (3.4), and West Virginia (1.9), and for the relevant counties, Baton Rouge–New Orleans corridor counties (4.1), Baltimore counties (3.1), and the Kanawha Valley counties (2.5).

Characteristics of TRI Facilities

The three study areas differ markedly in the number and characteristics of local TRI facilities, as shown in Table 2. The total number of TRI plants in Kanawha Valley (18) is significantly less than the number in the Baton Rouge–New

Table 2. Comparison of 1990 TRI characteristics for the three study areas

	Kanawha Valley	Baton Rouge–New Orleans	Baltimore metropolitan area
Study area characteristics			
Area (square miles)	143.2	961.8	542.5
% Land	96.9	90.3	92.8
No. of TRI facilities[a]	18	126	122
1990 Total releases and transfers (lbs/yr)[b]	16,805,300	373,521,500	14,123,000
1990 Total TRI air releases (lbs/yr)[c]	7,663,239	67,607,435	7,061,479
Air releases as % total releases and transfers[d]	45.6	18.1	50
Facility max (lbs/yr)[e]	3,708,700	14,211,300	2,105,300
No. of TRIs with air releases[f]:			
< 10,000 lbs/yr	5 (28%)	41 (33%)	76 (62%)
10,000–100,000 lbs/yr	6 (33%)	38 (30%)	35 (29%)
100,000–500,000 lbs/yr	2 (11%)	25 (20%)	7 (6%)
> 500,000 lbs/yr	5 (28%)	22 (18%)	4 (3%)
> 1 M lbs/yr	2 (11%)	12 (10%)	1 (1%)

[a] Values represent the total number of TRI facilities, including those with zero air releases. There are 134 TRI facilities in West Virginia, 312 in Louisiana, and 229 in Maryland.

[b] Values indicate the total releases and transfers of all TRI chemicals. This includes releases of chemicals to water, on-site disposal, deep well injection, and transfers of chemicals to publicly owned treatment works and other off-site facilities. Total releases and transfers in the host states are as follows: 53,675,400 lbs in West Virginia; 442,974,200 lbs in Louisiana; and 23,428,800 lbs in Maryland.

[c] Values indicate the total amount of air releases (including fugitive and stack emissions) for all chemicals combined for all TRI facilities. Total air releases in the host states are as follows: 28,295,700 lbs in West Virginia; 106,307,300 lbs in Louisiana; and 12,907,900 lbs in Maryland.

[d] Values indicate total air emissions of all chemicals as a percent of all releases and transfers. Comparable values for the host states are as follows: 52.7% in West Virginia; 24% in Louisiana; and 55.1% in Maryland.

[e] Values indicate the largest amount of total air releases (lbs/yr) for a single TRI facility.

[f] Values indicate the number of TRIs with total air releases in the specified range and the percentage of the total number of TRIs that this represents. The categories of releases > 500,000 lbs/yr and > 1 M lbs/yr are not mutually exclusive, so that some facilities are included in both categories; therefore percentages do not sum to 100%.

Orleans corridor (126) and the Baltimore metropolitan area (122). The three study areas are more similar; however, when one considers the number of TRI facilities per square mile of study area: 0.13 for Kanawha Valley; 0.13 for the Baton Rouge–New Orleans corridor; and 0.22 for the Baltimore metropolitan area.

All three study areas are heavily industrialized and contain a substantial fraction of the TRI facilities and TRI air releases in their respective states. The Kanawha Valley study area, which has 7% of the total population of West Virginia, contains 18% of the state's TRI facilities and accounts for 27% of the total TRI air releases for the state. The Baton Rouge–New Orleans corridor has 28% of Louisiana's population and 40% of the state's TRI facilities, which account for 64% of the state's total TRI air releases. The Baltimore metropolitan area has 32% of Maryland's population and 53% of the state's TRI facilities, which contribute 55% of the state's total TRI airborne releases.

In 1990, the total airborne releases from TRI plants in the Baton Rouge–New Orleans corridor was 67,607,435 lbs, approximately 9 times greater than the total for the Baltimore metropolitan area (7,061,479 lbs) and the total for Kanawha Valley (7,663,239 lbs). Based on total air releases (see Table 2), the Baltimore study area contains predominately lower emitting (e.g., smaller) facilities relative to the other two study areas. For example, 62% of the TRI facilities in the Baltimore metropolitan area release less than 10,000 lbs/yr of TRI chemicals, compared to 33% in the Baton Rouge–New Orleans corridor and 28% in Kanawha Valley. In contrast, 18% of the TRI facilities in the Baton Rouge–New Orleans corridor and 28% in Kanawha Valley release more than 500,000 lbs/yr, compared to just 3% in the Baltimore metropolitan area. Total air releases are reported by the TRI as either fugitive or stack emissions. Fugitive emissions constitute more than half the total air emissions from the Kanawha Valley (55%) and Baltimore metropolitan study areas (58%), but only 16% from the Baton Rouge–New Orleans corridor study area.

Total annual air releases for the TRI facilities in each of the three study areas are summarized in Table 3 for the following four chemical categories: total hazardous air pollutants (HAPs) as defined by the 1990 amendments to the Clean Air Act; total synthetic organic chemicals from the manufacturing industry (SOCMI); total chemicals classified by the TRI as carcinogens; and total chemicals classified by the TRI as metals or metal compounds. These categories are not mutually exclusive, so percentages do not sum to 100 by study area. As shown in Table 3,

Table 3. Comparison of the 1990 air releases (lbs/yr) for all TRI facilities in the three study areas[a]

Study area	No. of TRIs[b]	Total air releases[c]	Total HAPs releases[d]	Total SOCMI releases[e]	Total carcinogen releases[f]	Total metal releases[g]
Kanawha Valley	18	7,663,239	3,338,029	2,473,017	730,519	5025
Baton Rouge–New Orleans corridor	126	67,607,435	18,639,572	16,370,114	3,648,470	138,384
Baltimore metropolitan area	122	7,061,479	6,087,539	4,621,854	340,304	141,630

[a] The lists of chemicals in each of the five categories of this table are not mutually exclusive (e.g., some chemicals listed as carcinogens are also listed as HAPs, and/or SOCMI chemicals).

[b] Values indicate the total number of TRI facilities, including those with zero air releases.

[c] Values indicate the total amount of air releases (including fugitive and stack emissions) for all chemicals combined for all TRI facilities. The largest volume of a single chemical released to the air in each study area in 1990 was: 3.2 million lbs of acetone (Kanawha Valley), 14 million lbs of ammonia (Baton Rouge–New Orleans corridor), and 2 million lbs of toluene (Baltimore metropolitan area).

[d] HAPs are the 189 hazardous air pollutants as defined by the 1990 Clean Air Act Amendments (PL-101-549). The largest volume HAP released in each study area in 1990 was: hydrochloric acid (Kanawha Valley and Baton Rouge–New Orleans corridor) and toluene (Baltimore metropolitan area).

[e] SOCMI are Synthetic Organic Manufacturing Industry Chemicals, a subset of the HAPs, and include feedstock and product chemicals associated with this industry. This industry covers a wide range of manufacturing processes, including resin and plastic manufacture. The 1990 Clean Air Act Amendments required the Environmental Protection Agency to address sources of the SOCMI chemicals for regulation. The largest volume SOCMI chemical released in each study area in 1990 was: methanol (Kanawha Valley), carbon disulfide (Baton Rouge–New Orleans corridor), and toluene (Baltimore metropolitan area).

[f] Only chemicals identified as known or suspected carcinogens in the 1990 TRI data base were used to construct this table. In the TRI, chemicals were considered to be known or suspected carcinogens if they appeared in any of the following three sources: National Toxicology Program, 'Annual Report on Carcinogens' (latest edition); International Agency for Research on Cancer 'Monographs' (latest edition); or 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances, Occupational Safety and Health Administration (U.S. EPA, 1992a). The largest volume carcinogen released to the air in 1990 in each study area was: ethylene oxide and acrylonitrile (Kanawha Valley); dichloromethane (Baton Rouge–New Orleans corridor); and acetaldehyde (Baltimore metropolitan study area).

[g] Only chemicals identified as metals and metal compounds in the 1990 TRI data base were included (U.S. EPA, 1992a). The largest volume metal released in each study area in 1990 was: silver compounds (Kanawha Valley), zinc fume and dust (Baton Rouge–New Orleans corridor), and manganese compounds (Baltimore metropolitan area).

hazardous air pollutants constitute the largest single category of air releases in all three study areas, i.e., Baltimore (86%), Kanawha Valley (44%) and the Baton Rouge–New Orleans corridor (28%), and metals comprise the smallest percentage of total air releases, i.e., 0.07% for Kanawha Valley, 0.2% for the Baton Rouge–New Orleans corridor, and 2.0% for the Baltimore metropolitan area. Carcinogens (as identified by the TRI) also make up a relatively small proportion of the total air releases in each study area, approximately 10% for Kanawha Valley, 5% for Baton Rouge–New Orleans corridor, and 5% for the Baltimore metropolitan area. Table 3 also provides information about which chemicals predominate in each of the five release categories by study area.

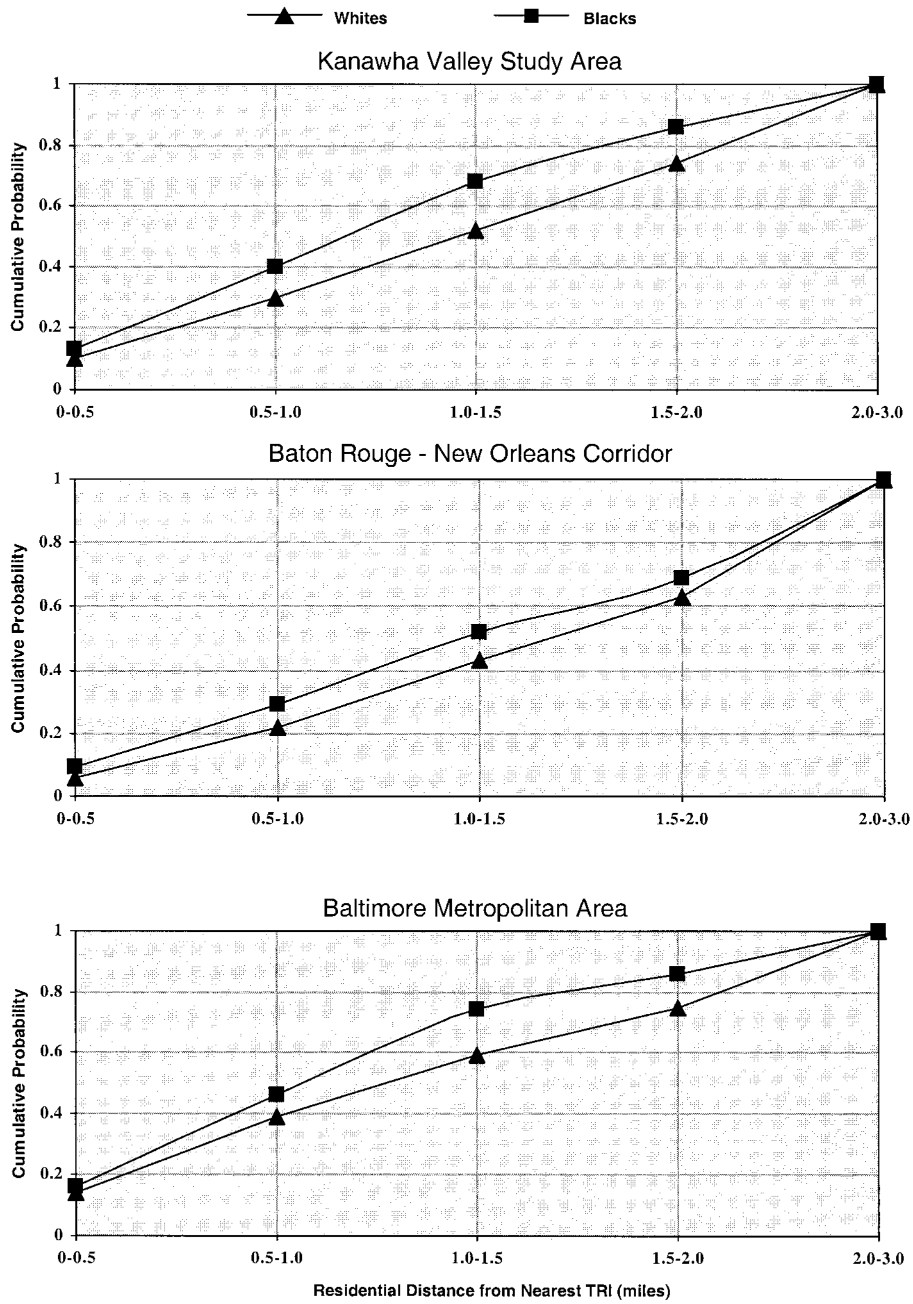

Figure 6. Cumulative distribution of race by residential distance from the nearest TRI. Values indicate the cumulative distribution of whites and blacks by residential distance from the nearest TRI facility. In the Baltimore metropolitan study area, 388,150 whites, or 32.9% of all the whites in the study area, live within 1 mile of the nearest TRI, compared to 247,377 blacks, or 46.4% of all the blacks in the study area.

Results

The subsequent discussion summarizes key findings related to race (black compared to white), poverty (individuals living below or above the poverty line), and residential proximity to one or more TRI facilities.

Race and Proximity to Nearest TRI Facility

In all three study areas, a larger percentage of blacks compared to whites live within 0.0–0.5 miles, 0.5–1.0 miles, and 1.0–1.5 miles of the nearest TRI facility. Conversely, a smaller percentage of blacks compared to whites live 1.5–2.0 miles and 2.0–3.0 miles from the closest TRI plant. In an approach similar to that used by Waller et al. (1997), we have used cumulative distribution functions to compare residential proximity to TRI facilities for white and African American populations. The cumulative probability distributions for whites and blacks as a function of residential proximity to the nearest TRI facility are shown in Figure 6 for all three study areas. The shapes and relative positions of the pairs of curves were similar for all three study areas, indicating that blacks tend to live closer to the nearest TRI facility than whites. It is important to note that the cumulative distribution curves also show that a substantial proportion of both races live in relatively

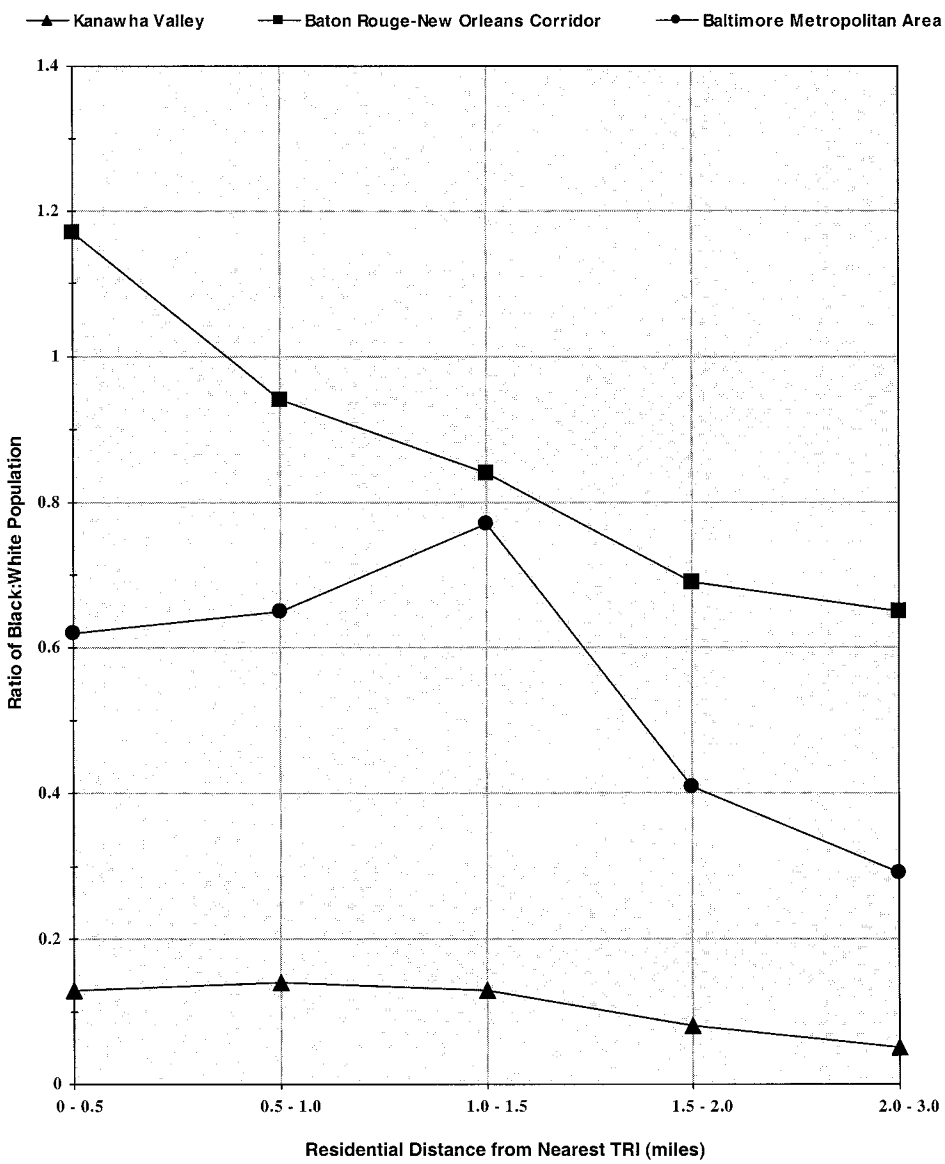

Figure 7. Ratio of black to white population as a function of residential distance from nearest TRI. Values indicate the ratio of the black:white population at the specified residential distances from the nearest TRI facility. In Kanawha Valley, the ratio of black:white population is 0.13 for people living within 0.5 mile of the nearest TRI source.

close proximity to a TRI facility. The data indicate that 30% of whites and 40% of African Americans live within a mile of the nearest TRI facility in Kanawha Valley as compared to 22% of whites and 29% of African Americans in the Baton Rouge–New Orleans corridor, and 39% of whites and 46% of blacks in the Baltimore metropolitan area.

The Kolmogorov–Smirnov (K–S) goodness of fit test was used to compare the cumulative probability distributions for whites and blacks as a function of residential distance from the nearest TRI facility. The results of the K–S test, which compares the maximum absolute difference between two cumulative probability distributions, found a statistically significant difference between the

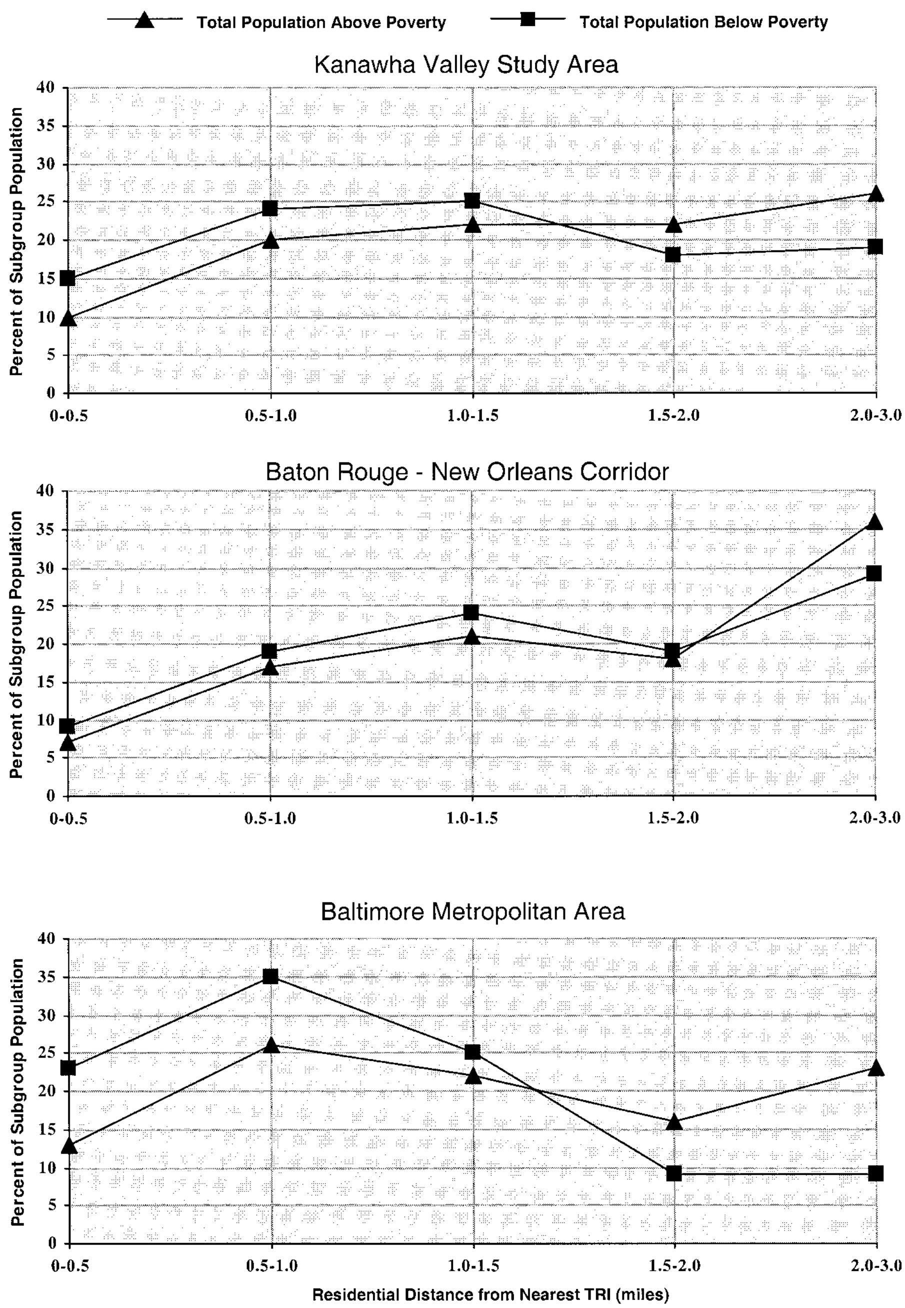

Figure 8. Poverty status of population as a function of residential distance from nearest TRI. Values indicate the distribution of the population by poverty status as a function of residential distance from the nearest TRI. In Kanawha Valley, there are 107,366 people above poverty. Of these, 10,275, or about 10%, live within 0.5 mile of the nearest TRI.

cumulative distributions of whites and African Americans for all three study areas.

It is useful to consider that there are several nonparametric tests available for testing the null hypothesis that there is no difference between two distinct distributions. These tests include the K–S two-sample test (Gibbons, 1985) that we used to compare the cumulative distributions shown in Figure 6. Technically, the distributional theory (K–S) test was developed for continuous distributions but, as indicated by Goodman (1954), the test is conservative when applied to discrete data, such as those in our study. When the K–S test clearly rejects the hypothesis of distributional equity this conservatism is not a problem. Experience has shown that for real-world problems involving

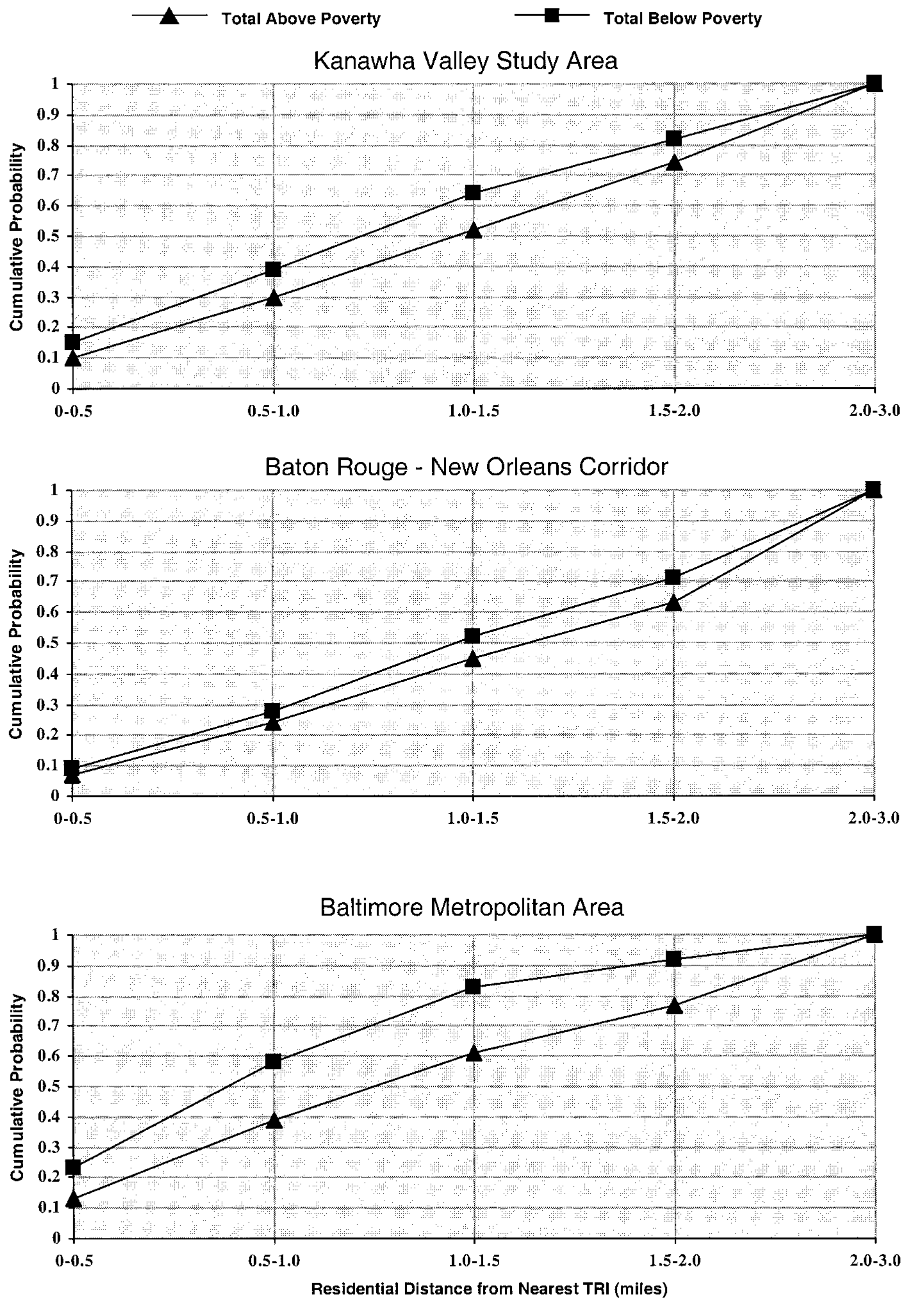

Figure 9. Cumulative distribution of population by poverty status and residential distance from the nearest TRI. Values indicate the cumulative distribution of the populations above and below the poverty line by residential distance from the nearest TRI facility. In the Baltimore metropolitan study area, 533,192 people above poverty, or 39.1% of all those above poverty, live within 1 mile of the nearest TRI compared to 116,807 people below poverty, or 57.9% of all those below poverty.

large sample sizes, the K–S test will often reject the null hypothesis even for identical distributions. A more difficult question is whether observed differences in distributions are of practical significance.

The ratio of the number of black residents to the number of white residents in each concentric distance ring is plotted for the three study areas in Figure 7. For all three study areas, the ratio of blacks to whites is greater at 0–0.5 miles compared to the ratio at 2.0–3.0 miles. For both the Kanawha Valley and Baton Rouge–New Orleans study areas the ratio of blacks to whites steadily decreases with increasing distance from the nearest TRI facility. The same pattern is seen in the Baltimore study area, except at the 0.5–1.0 and 1.0–1.5 mile distance rings, where the ratio of blacks to whites increases above the ratio seen at the 0–0.5 mile ring.

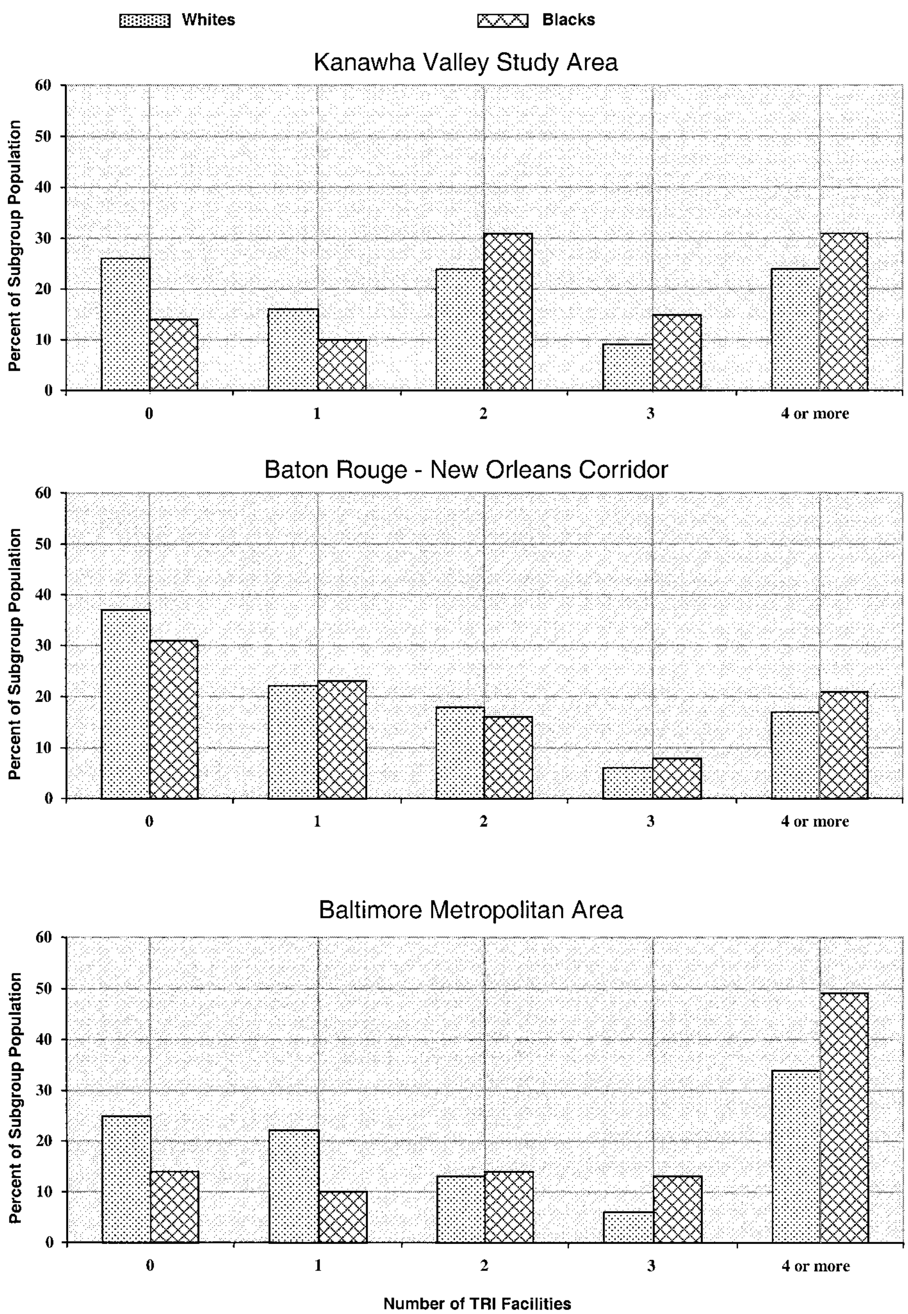

Figure 10. Race of population as a function of residential distance to multiple TRI facilities. Values indicate the percentage of each subpopulation living within 2 miles of the specified number of TRI facilities. In the Kanawha Valley study area, there are 113,959 whites, of which about 30,073, or 26%, live within 2 miles of no TRI facilities. This compares to 14% of the blacks who live within 2 miles of no facilities.

Poverty and Proximity to Nearest TRI Facility
Figure 8 presents a comparison of how the total number of people who are classified as living either above or below the poverty level distribute themselves across the distance rings. In all three study areas, a higher percentage of those below poverty live within 0.0–0.5 miles, 0.5–1.0 miles, and 1.0–1.5 miles of the nearest TRI than the corresponding percentages for those above poverty. Conversely, a lower percentage of those below poverty live 1.5–2.0 miles and 2.0–3.0 miles from the closest TRI plant compared to those above poverty.

The cumulative probability distribution of people above or below poverty, as a function of residential proximity to the nearest TRI facility, is shown for all three study areas

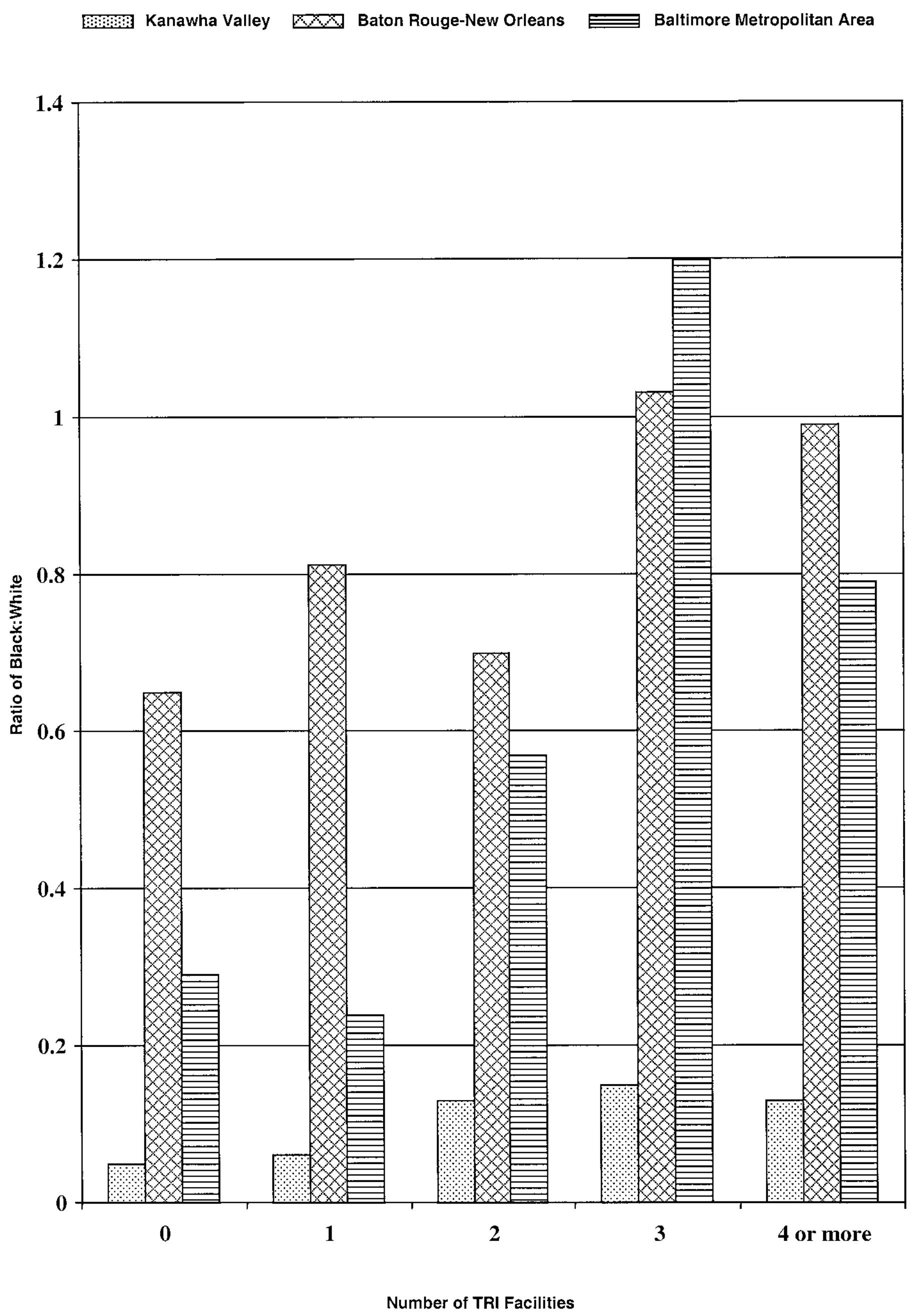

Figure 11. Ratio of black to white population as a function of residential distance to multiple TRI facilities. Values indicate the ratio of the black:white population for those living within 2 miles of the specified number of TRI facilities. In the Baltimore Metropolitan study area, the ratio of blacks:whites is 0.57 for people living within 2 miles of two TRI facilities.

in Figure 9. The differences between the pairs of curves for each distance ring were greatest for the Baltimore study area and smallest for the Baton Rouge–New Orleans study area, with the Kanawha Valley being intermediate. The shapes and positions of the pairs of curves for each study area indicate that people below poverty tend to live closer to the nearest TRI facility than people above poverty. The K–S test showed a statistically significant difference between the cumulative distributions for people above and below poverty in each study area.

These cumulative distribution plots also show that a substantial proportion of the study populations, whether

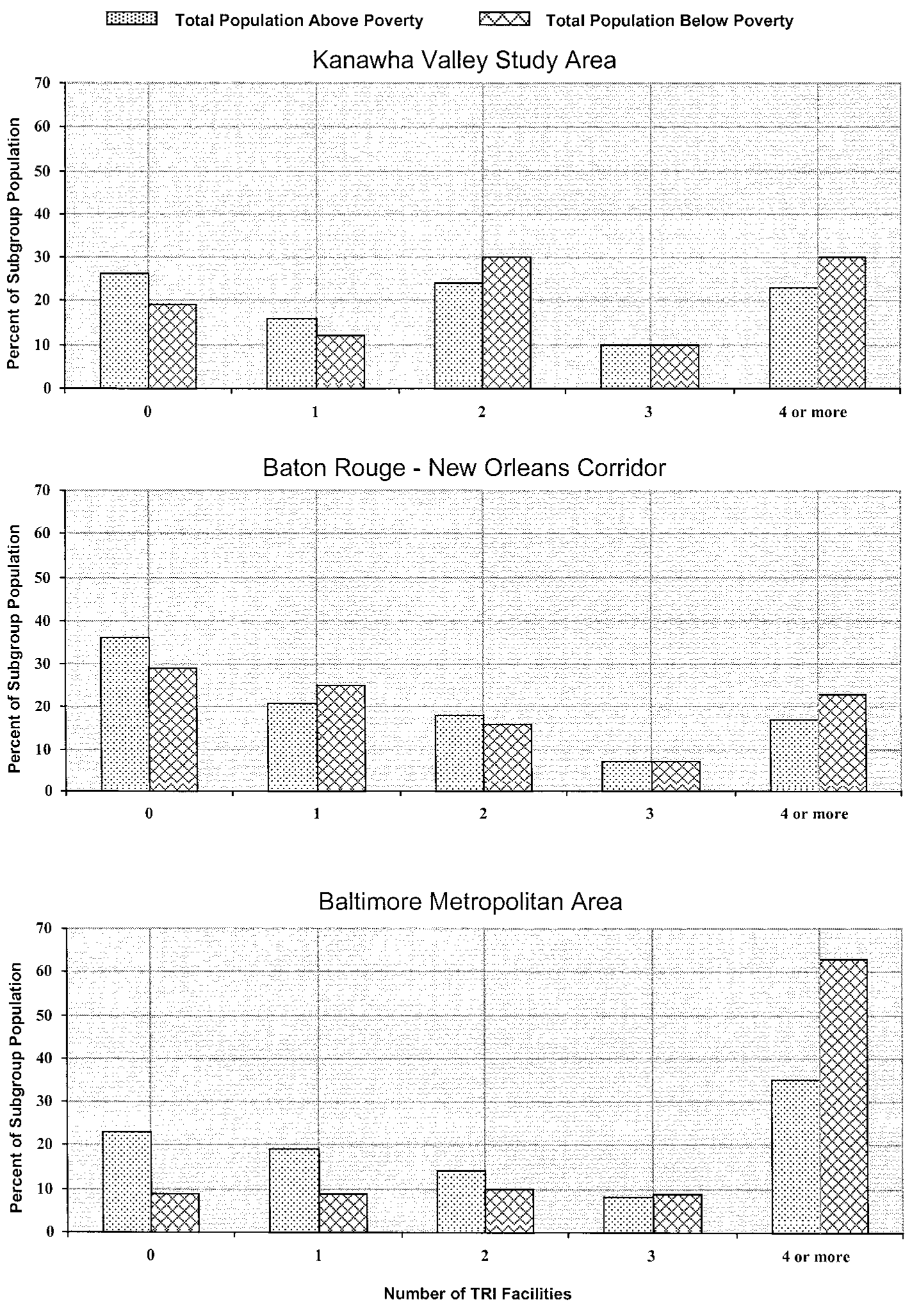

Figure 12. Distribution of the population by poverty status as a function of residential distance to multiple TRI facilities. Values indicate the percentage of the populations, by poverty status, living within 2 miles of the specified number of TRIs. In Kanawha Valley, there are 107,367 people above the poverty line, of which about 28,446 or 26%, live within 2 miles of no TRI facilities. This compares to about 19% of all those below poverty who live within 2 miles of no TRIs.

they were living above or below poverty, reside in relatively close proximity to a TRI facility. The data indicate that 30% of people above poverty and 39% of people below poverty live within a mile of the nearest TRI facility in Kanawha Valley. In the Baton Rouge–New Orleans study area the corresponding values were 24% and 28%, and in the Baltimore study area the values were 39% and 59%.

Race and Proximity to Multiple TRI Facilities

Because all three study areas have many TRI facilities located relatively close together, residents often live near several TRI sources. Seventy-five percent of the total population in the Kanawha Valley study area, 65% in Baton Rouge–New Orleans, and 79% in the Baltimore metropolitan area live within 2 miles of more than one TRI facility. In Figure 10 the percentage distribution of whites living within 2.0 miles of 0, 1, 2, 3, 4 or more TRI facilities is compared to the percentage distribution of blacks for each study area. From the graphs it is obvious that in all cases a higher percentage of whites compared to blacks reside within 2.0 miles of zero TRI facilities, while a higher percentage of blacks compared to whites reside within 2.0 miles of three or more TRI sources. Findings also show that a substantial percentage of both races live within 2 miles of four or more facilities: 25% of whites and 30% of blacks in Kanawha Valley; 17% of whites and 22% of blacks in the Baton Rouge–New Orleans corridor; and 34% of whites and 49% of blacks in the Baltimore metropolitan area.

Cumulative probability distributions of whites and blacks as a function of residential proximity to multiple TRI facilities show a consistent picture across all three study areas. These distributions indicated that whites are more likely to live closer to smaller numbers of facilities and blacks are more likely to live closer to larger numbers of facilities. The K–S test showed a statistically significant difference between the cumulative distribution plots for whites and blacks in all three study areas.

The ratio of black to white residents living within 2 miles of multiple TRI facilities is plotted in Figure 11 for each study area. There is a similar trend in all three locations, with the black-to-white ratio increasing as the number of facilities within 2 miles of the residence increases from 0 to 3. The ratio then decreases, slightly in Kanawha Valley and the Baton Rouge corridor and more dramatically in the Baltimore study area, for populations living within 2 miles of four or more facilities.

Poverty and Residential Proximity to Multiple TRI Facilities

In Figure 12 the relative percentages of people classified above or below the poverty line are compared according to the number of TRI facilities within 2 miles of their residence. For example, in Kanawha Valley about 19% of those below poverty versus 26% of those above poverty live within 2 miles of no TRI facilities, 12% below versus 16% above live within 2 miles of one facility, 30% below versus 25% above live with 2 miles of two facilities, 10% below versus 10% above live within 2 miles of three facilities, and 30% below versus 22% above live within 2 miles of four or more facilities. In all three study areas, a higher percentage of those above poverty compared to those below poverty reside within 2 miles of no TRI sources, while a higher percentage of those below poverty compared to those above poverty reside within 2 miles of four or more TRI facilities.

Cumulative probability distributions for people above and below poverty as a function of residential proximity to multiple TRI facilities revealed a consistent picture across all three study areas. These distributions indicated that people earning more than the poverty level tend to live closer to smaller numbers of facilities and people earning less than the poverty level tend to live closer to larger numbers of facilities. The K–S test showed a statistically significant difference between the cumulative distributions for people above and below poverty in each study area.

Despite these apparent differences according to poverty classification, it is important to note that a substantial percentage of both groups (above and below the poverty line) live within 2 miles of four or more facilities (24% of people above poverty and 29% of people below poverty in Kanawha Valley; 18% of those above poverty and 23% of those below poverty in the Baton Rouge–New Orleans corridor; 36% of those above poverty and 63% of those below poverty in the Baltimore metropolitan area). Furthermore, for all three study areas greater than 70% of people residing within 2 miles of 0, 1, 2, 3, 4 or more TRI facilities are classified as above the poverty line. Each study area did, however, exhibit similar trends: the percentage of those above poverty tended to decrease and the percentage of those below poverty tended to increase as the number of TRI facilities within 2 miles of the residence increased.

Summary and conclusions

We have presented initial analyses of the spatial relationships between the location of TRI facilities and the race and poverty status of populations living nearby. The three study areas were selected because they were deemed to be different based on (a) geographic location, (b) the nature and number of TRI facilities, and (c) the sociodemographic characteristics of local populations. Yet despite obvious differences between the study areas, several important similarities and patterns emerged.

- In all three locations, the percentage of African Americans living in the study area was greater than the percentage living in the relevant state. In the Kanawha Valley and Baton Rouge–New Orleans corridor, the percentage of African Americans in the study population was also much greater than the percentage living in the surrounding counties.
- All three study areas are heavily industrialized and each had a disproportionately large percentage of its state's TRI facilities and total TRI air releases.
- For each study population, a much higher percentage of blacks compared to whites reside in households that are classified below the poverty line. This same pattern was observed in the relevant states and counties.
- In each location, as the residential distance from the nearest TRI facility increased, the percentage of whites and the percentage of people classified as living above poverty tended to increase while the percentage of blacks and the percentage of those below poverty tended to decrease.
- In each study area, as the number of TRI facilities located within 2 miles of the residence increased, the percentage of whites and the percentage of those classified above the poverty line tended to decrease while the percentage of blacks and the percentage of those classified below poverty tended to increase.

These results, while provocative, are not definitive and represent only the first step in an objective and rigorous analysis of the spatial relationships between TRI facilities and socioeconomic status and ethnicity/race of local populations. It is important to keep in mind, for example, that the current data do not provide information on temporal trends. We do not know whether the observed differences are stable or changing over time, nor do we know whether observed disparities occurred before or after siting of pollution sources.

Perhaps most importantly, we do not know the nature of the relationship, if any, between residential proximity of TRI facilities and actual exposures to air pollution. It is common, for instance, to assume that living near one or more TRI facilities increases environmental health risks. Yet this assumption is actually more of a hypothesis, albeit a plausible one, which remains to be tested by rigorous scientific analysis. In point of fact, there are many potentially negative consequences besides elevated exposures that are likely to be associated with living next to industrial emission sources, including odors, noise, traffic, contaminated soil (e.g., brown fields), inferior housing, fewer amenities (e.g., parks, libraries), less safe neighborhoods, and poorer environmental quality. In the absence of evidence to the contrary, it seems reasonable, therefore, to assume that the closer people live to industrial sources of pollution the lower the quality of their environmental and the less healthful their living conditions.

In future studies we will examine, among other things, the link between race and poverty status, and variations in age and household income according to distance from TRI sources. The goal of this and future studies is to increase our knowledge about sociodemographic characteristics of populations residing near industrial sources of air pollution, and thereby improve our understanding of the extent to which low-income groups and people of color bear a disproportionate burden of environmental health risks.

Acknowledgments

We thank Steven Andrews, Gary Hamilton, and Tracey Szajgin from Indus Corp. for developing and managing the GIS components of the study, and Lewis Summers from the U.S. Environmental Protection Agency and Ray Wolf from Lockheed, Inc. for providing GIS technical support. We appreciate helpful suggestions on the manuscript from Lance Waller, University of Minnesota, and Dan Carr, George Mason University. Ken Sexton was partially supported by a grant from the U.S. Environmental Protection Agency.

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