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US Metropolitan-area Variation in Environmental Inequality Outcomes

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Summary

Over the past 20 years a steadily increasing number of researchers have investigated the relationship between neighbourhood demographic composition and environmental hazard presence. However, relatively few researchers have attempted to determine why the distribution of social groups around environmental hazards takes the form that it does or why some studies find strong evidence of environmental racial inequality while others do not. One possible explanation for this is that environmental racial inequality levels vary from one location to another. In order to see if this is the case, the article compares environmental racial inequality levels in the 61 largest metropolitan areas in the continental US, holding the unit of analysis, type of hazard, type of region and comparison population constant across metropolitan areas. Analyses demonstrate that environmental racial inequality levels do vary across metropolitan areas. Thus, after presenting these analyses, hypotheses are tested that make predictions about the determinants of this variation. These hypothesis tests show that neither residential segregation nor racial income inequality does a good job of explaining metropolitan-area variation in environmental inequality outcomes in the US.

1. Introduction

In 1987, Dr Benjamin Chavis, Jr, executive director of the United Church of Christ Commission for Racial Justice (UCCRJ), coined the term environmental racism to describe the findings of a recently released UCCRJ (1987) study that found that in the US hazardous waste sites were disproportionately located in minority communities (Lee, 1992). Since then, a steadily increasing number of researchers have investigated the relationship between neighbourhood demographic composition and environmental hazard presence (Szasz and Meuser, 1997; Bowen, 2002). However, relatively few researchers have attempted to determine why the distribution of social groups around environmental hazards takes the form that it does or why some studies have found strong evidence of environmental racial inequality while others have not (Pastor *et al.*, 2001; Weinberg, 1998).

One possible explanation for why some studies find evidence of environmental racial inequality while others do not is that the type of hazard examined varies across studies (Brown *et al.*, 1997; Clark *et al.*, 1995; Szasz and Meuser, 1997). Another possible explanation is that different researchers use different comparison populations and units of analysis (Anderton *et al.*, 1994a, 1994b; Downey, 1998; Mohai, 1995). A third possible explanation is that studies vary according to the region and type of region (i.e. rural vs urban) examined (Brown *et al.*, 1997; Clark *et al.*, 1995; Szasz and Meuser, 1997).

In this article, I control for variation across all but one of these dimensions by comparing environmental racial inequality levels in the 61 largest metropolitan areas in the continental US, holding the unit of analysis (census tracts), type of hazard (toxicity-weighted air pollutant concentration estimates), type of region (metropolitan areas) and comparison population (all non-emission tracts in each metropolitan area) constant across metropolitan areas. This approach does not tell readers why previous studies have found conflicting evidence regarding environmental racial inequality; nor does it tell readers whether environmental racial inequality levels vary according to the unit of analysis, comparison population or type of hazard studied. It does, however, allow us to determine whether environmental racial inequality levels vary across metropolitan areas while controlling for much of the variation in research design found in earlier studies.

I test for the existence of environmental inequality in each metropolitan area by comparing the residential environmental burden experienced by the average Hispanic, Black and White person in each metropolitan area under consideration. These comparisons demonstrate that environmental racial inequality levels do vary across metropolitan areas. Thus, after presenting these analyses, I test two hypotheses that make predictions about the determinants of this variation. Finally, I use metropolitan-area tract maps to shed further light on the findings of the quantitative analyses.

2. Literature Review

Environmental inequality researchers have studied the distribution of social groups around a variety of environmental hazards, including hazardous waste sites, manufacturing facilities, superfund sites, chemical accidents and air pollutants (Anderton *et al.* 1994a, 1994b; Bowen, 2002; Derezinski *et al.*, 2003; Lester *et al.*, 2001; Morello-Frosch *et al.*, 2001; Szasz and Meuser, 1997). Researchers have found income and poverty to be consistently associated with hazard presence in the expected direction: as environmental hazard presence increases, incomes decrease and poverty rates increase (Ash and Fetter, 2004; Been, 1994; Charkraborty and Armstrong, 1997; Derezinski *et al.*, 2003; Downey, 2003; Hamilton, 1995; Krieg, 1995; Lester *et al.*, 2001; McMaster *et al.*, 1997; Mohai and Bryant, 1992; Morello-Frosch *et al.*, 2001; Oakes *et al.*, 1996; Ringquist, 1997; Stretesky and Hogan, 1998).

Findings regarding the existence of environmental racial inequality have been mixed, however, (Pastor *et al.*, 2004). Although many studies have found strong evidence of environmental racial inequality (Ash and Fetter, 2004; Been, 1994; Downey, 1998, 2003; Hamilton, 1995; Krieg and Faber, 2004; Mohai and Bryant, 1992; Morello-Frosch *et al.*, 2001; Ringquist, 1997; Stretesky and Hogan, 1998; Stretesky and Lynch, 2002), some have found evidence of environmental racial inequality for some minority groups but not others (Brown *et al.*, 1997; Mennis and Jordan, 2005; Pastor *et al.*, 2002; Sadd *et al.*, 1999) and some have found only weak evidence of environmental racial inequality or none at all (Anderton et al. 1994a, 1994b; Atlas 2002; Bowen *et al.* 1995; Clark *et al.*, 1995; Derezinski *et al.*, 2003; Oakes *et al.*, 1996; Yandle and Burton, 1996).

Environmental inequality researchers have also offered several explanations for the existence of environmental inequality, arguing that poor and minority neighbourhoods are more likely than other neighbourhoods to house environmental hazards because: poor and minority communities lack the political capacity to keep hazardous facilities out of their neighbourhoods (Hamilton, 1995; Mohai and Bryant, 1992); housing market racism confines minorities to undesirable neighbourhoods shunned by Whites (Bullard, 1993; Godsil, 1991; Mohai and Bryant, 1992; Morello-Frosch and Jesdale, 2006); and housing costs are relatively low in environmentally hazardous neighbourhoods, making them more attractive to lower-income people who are, in turn, disproportionately non-White (Hamilton, 1995; Mohai and Bryant, 1992; Oakes *et al.*, 1996).

Although these explanations are widely cited in the literature, relatively few researchers have attempted to test them (exceptions include Been and Gupta, 1997; Downey, 2005; Hamilton, 1995; Morello-Frosch and Jesdale, 2006; Oakes *et al.*, 1996; Pastor *et al.*, 2001; Shaikh and Loomis, 1999; Yandle and Burton, 1996).[1] Moreover, only two studies that I am aware of have attempted to explain why environmental racial inequality levels vary from one city or region of the country to another (Ash and Fetter, 2004; Brown *et al.*, 1997).

3. Theoretical Predictions

If environmental inequality researchers are correct in positing that environmental racial inequality is a function of income inequality, political inequality and residential segregation, then environmental racial inequality should vary across metropolitan areas in accordance with metropolitan area variations in these factors. Political inequality is quite difficult to measure, so I will not test the political inequality hypothesis, but income and segregation measures are readily available for US metropolitan areas.

Table 1 ranks the 61 US metropolitan areas that had more than 1 million residents in 2000 according to the degree of residential segregation and racial and ethnic income inequality that existed in each of these metropolitan areas in 2000, with cities at the top of each list experiencing greater inequality than cities at the bottom of each list. Segregation levels are measured using a common segregation indicator, the dissimilarity index. The dissimilarity index tells us

> the proportion of minority members that would have to change their area of residence to achieve an even distribution, with the number of minority members moving being expressed as a proportion of the number that would have to move under conditions of maximum segregation… Segregation [is] maximized when no minority and majority members share a common area of residence (Massey and Denton, 1988, p. 284).

Thus, in the Detroit metropolitan area in 2000 (Table 1, top row, columns (1) and (2)), the number of Blacks that would have had to have moved to overcome residential segregation was 84.7 per cent of the number that would have had to have moved had Detroit been maximally segregated in 2000.

Racial and ethnic income inequality is measured by calculating: the ratio of Black to White median household income in each metropolitan area; the ratio of Hispanic to non-Hispanic-White median household income in each metropolitan area; and the ratio of Black to Hispanic median household income in each metropolitan area.[2] For example, in the Rochester metropolitan area in 2000 (Table 1, top row, columns (7) and (8)), Hispanic median household income was only 47.4 per cent of non-Hispanic-White median household income.

Although it would have been preferable to use non-Hispanic Black median household income data when calculating the Black/Hispanic median income ratios, such data were unavailable. Nevertheless, in only 7 of the 61 largest US metropolitan areas did Hispanic

[1]Several good qualitative case studies have been written that go beyond hypothesis testing in an attempt to build detailed and nuanced explanations of the environmental inequality formation process (for example, see Boone and Modarres, 1999; Boone, 2002; Hurley, 1995; Maantay, 2002; Pulido, 2000; Pellow, 2000; Pellow and Park, 2002)

[2]The Black/Hispanic median household income ratios are included in Table 1 because the income inequality hypothesis applies to all racial and ethnic groups.

Blacks make up more than 5.4 per cent of the Black population in 2000 and in none of these metropolitan areas did Hispanic Blacks make up more than 10 per cent of the Black population in 2000. Thus, the Black/Hispanic income ratios do a relatively good job of comparing Black and Hispanic incomes.

The first two columns in Table 1 rank the 61 metropolitan areas according to Black/White segregation levels and the fifth and sixth columns in Table 1 rank them according to Hispanic/White segregation levels. If the segregation hypothesis is correct, Black/White environmental inequality should be greatest in the Detroit, Milwaukee and New York metropolitan areas and weakest in the San Jose, Salt Lake City and Orange County metropolitan areas, and Hispanic/White environmental inequality should be greatest in the Providence, New York and Newark metropolitan areas and weakest in the Pittsburgh, Saint Louis, and Jacksonville metropolitan areas.

The third and fourth columns in Table 1 rank the metropolitan areas according to Black/White income inequality, the seventh and eighth columns rank them according to Hispanic/non-Hispanic-White income inequality and the ninth and tenth columns rank them according to Black/Hispanic income inequality. If the income inequality hypothesis is correct, Black/White environmental inequality should be greatest in the Minneapolis, Milwaukee and Memphis metropolitan areas and weakest in the Nassau, Middlesex and Riverside metropolitan areas, and Hispanic/White environmental inequality should be greatest in the Rochester, Hartford, New York and Philadelphia metropolitan areas and weakest in the Las Vegas, Riverside and Fort Lauderdale metropolitan areas. Finally, if the income inequality hypothesis is correct, Black environmental inequality levels should be relatively equal to or greater than Hispanic environmental inequality levels in all the metropolitan areas included in Table 1 except Orange County, Phoenix, San Diego, Middlesex, New York, Philadelphia, Hartford and Rochester.

4. Data

In order to determine the relative pollution burden experienced by Hispanics, Blacks and Whites in each metropolitan area included in this study, I merge toxicity-weighted air-pollutant concentration data drawn from the Environmental Protection Agency’s (EPA) year-2000 Risk-Screening Environmental Indicators (RSEI) project with demographic data drawn from the 2000 US census. The census data are used to calculate the median household income ratios discussed in the preceding section as well as the percentage of the population in each metropolitan area that is Hispanic and non-Hispanic Black.

The RSEI model from which the pollution data are derived models the toxicity-weighted concentration of air pollutants released from every facility listed in the EPA’s year-2000 Toxics Release Inventory (TRI) (see Ash and Fetter, 2004, for a discussion of how these data differ from those found in the public RSEI release). The TRI records the number of pounds of specified toxic chemicals released into the environment each year by industrial facilities that fall into one of seven industrial categories (manufacturing, metal mining, coal mining, electric generating facilities that combust coal or oil, chemical wholesale distributors, petroleum terminals and bulk storage), employ the equivalent of 10 or more full-time workers and manufacture, process or otherwise use the specified chemicals in specified quantities. In 2000, the specified quantities were 25 000 pounds for facilities that manufactured or processed TRI chemicals and 10 000 pounds for facilities that otherwise used TRI chemicals (Rtknet, 2004). The TRI chemical list included over 600 chemicals and chemical categories in 2000.

The RSEI estimates a 101-km square pollution plume model (made up of 1-km square grid cells) for each air pollutant released by each TRI facility in a calendar year. Incorporating factors such as wind speed, wind direction, air turbulence, smokestack height, exit gas velocities and rate of chemical decay and deposition, the RSEI model calculates a yearly, average air pollutant concentration value for each 1-km square grid cell in the plume model. Each grid cell value in each air pollutant model is then multiplied by the toxicity weight of the modelled air pollutant and the toxicity-weighted cell values for each air pollutant grid in the US are then summed together to create a toxicity-weighted air concentration grid for the entire nation (see EPA, 2004a or technical details on the RSEI model).

In order to estimate the RSEI pollution burden experienced by the average Black, Hispanic and White person in each metropolitan area, I merged the cell-based pollution data with neighbourhood-level demographic data. To do this, I calculated the proportion of each census tract in the continental US covered by each grid cell that overlapped it and then calculated the weighted average of each tract's overlapping grid cells, using the proportion overlap as my weighting variable. For example, if grid cells 1 and 2 covered 40 per cent and 60 per cent of tract A respectively, and if the toxicity-weighted concentration values of these grid cells were 10 and 20 respectively, then the toxicity-weighted concentration value of tract A would equal [(10 * 0.4) + (20 * 0.6)].[3]

Finally, I estimated the RSEI pollution burden experienced by the average Hispanic, Black and White person in each metropolitan area. I did this for each racial/ethnic group by: multiplying the toxicity-weighted pollution values in each metropolitan-area census tract by the number of group members living in each census tract; summing up these product values separately for each metropolitan area; and dividing these metropolitan-area product sums by the number of group members in each metropolitan area. For example, if a metropolitan area had 3 census tracts, with 20, 30 and 50 Hispanics respectively, and toxic concentration levels of 0, 5 and 10 respectively, the RSEI pollution burden experienced by the average Hispanic person in this metropolitan area would equal [(20 * 0) + (30 * 5) + (50 10)]/(20 + 30 + 50). I will refer to these residentially based toxic concentration averages using the following terms: Hispanic toxic concentration, Black toxic concentration and White toxic concentration.

Advantages and Limitations of RSEI Data

RSEI data represent a real improvement in many respects over hazard proximity data, which have been used in most environmental inequality research.[4] The most important difference between RSEI data and hazard proximity data is that RSEI data provide researchers with much better estimates of the potential health risks of living in specific neighbourhoods or near specific facilities than do hazard proximity data, which tend to ignore chemical fate, transport and toxicity, and which have been heavily criticised by several researchers (see Bowen, 2002).

Another important difference between RSEI data and hazard proximity data is that the RSEI plume modelling approach allows the concentration of air pollutants and, therefore, the estimated health risks associated with these air pollutants to decline continuously as distance from the emitting source increases and to vary in intensity according to compass direction.

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[3]It is important to note that RSEI data are not exposure estimates. They are unitless measures that allow researchers to 'assess the relative hazard and risk of chemicals, facilities, regions, and industries' and are only meaningful in relation to other RSEI data values (EPA, 2004b). Thus, the tract-level, toxicity-weighted, air-pollutant concentration data used in this study provide estimates of the relative risk of each census tract in the study area in relation to every other census tract in the study area.

[4]Most environmental inequality researchers use hazard proximity data because of the difficulty of obtaining pollutant concentration and exposure data rather than because they think that proximity data are superior to pollutant concentration and exposure data.

In addition, the pollution plume models used to derive RSEI risk estimates extend for miles in all directions. Thus, unlike most hazard proximity data models, the RSEI model allows hazards and emissions in one analysis unit to impact people living in analysis units quite far removed from the hazard's host unit.

RSEI data are not without their own set of limitations, however. For example, RSEI data are derived from plume model estimates of TRI air releases and as a result do not provide researchers with actual neighbourhood-level measurements of air pollutant concentration levels or with estimates of non-TRI air pollutant concentration levels. In addition, several simplifying assumptions have to be made in order to estimate pollutant concentration models for tens of thousands of facilities and hundreds of thousands of releases across the entire US. For example, the RSEI model assumes continuous and constant pollutant emissions rates and smokestack height has to be imputed for many TRI facilities (Bouwes and Hassur, 1999; EPA, 2004a).

Finally, the health risks associated with pollution exposure are not the only set of risks associated with environmental hazards. Environmental hazards can also negatively affect nearby property values, psychological stress, local employment opportunities, sense of community and local economic activity (Downey and van Willigen, 2005; Liu, 2001; Mohai, 1995; Sadd *et al.*, 1999). For researchers interested in these potential negative impacts, hazard proximity data may very well be more appropriate.

Nevertheless, because: environmental inequality researchers and activists are very interested in the physical health risks posed by industrial activity; it is impossible to create a national, industrial air pollutant concentration dataset without making simplifying assumptions; and the RSEI is the only database of its kind currently available to researchers, it is a very valuable research tool that will be used increasingly by researchers and activists alike.

5. Study Area

Data for Tables 1–5 were drawn from all the metropolitan areas in the continental US with more than 1 million residents in 2000 (the continental US refers to the 48 contiguous states and Washington, DC). These tables focus on large metropolitan areas for three reasons. First, presenting the results found in these tables for all the metropolitan areas in the US would take up too much space. Secondly, large metropolitan areas have been the focus of much prior environmental inequality research (Bowen, 2002; Sadd *et al.*, 1999; Szasz and Meuser, 1997). Thirdly, a large percentage of the US population lives in these 61 metropolitan areas: approximately 52 per cent of the US population, 67 per cent of the Hispanic population, 65 per cent of the non-Hispanic Black population and 47 per cent of the non-Hispanic White population live in the 61 metropolitan areas included in this study. Thus, the findings reported in Tables 1–5 have important implications for the majority of this nation's Blacks and Hispanics and nearly half of this nation's Whites.

Data for Table 6 were drawn from all the metropolitan areas that existed in the continental US in 2000. Table 6 uses data from these 329 metropolitan areas in order to increase the power of the regression analyses presented in Table 6 and because the data in Tables 1–5 cannot be generalised to smaller metropolitan areas.

Finally, all the metropolitan areas included in this study were defined by the US Census Bureau as being metropolitan statistical areas (MSAs) or primary metropolitan statistical areas (PMSAs). Thus, consolidated metropolitan statistical areas such as Los Angeles and New York are separated into their constituent MSAs and PMSAs.

6. Results

Table 2 ranks the 61 largest metropolitan areas in the US according to the residential toxic concentration burden experienced by the average person in each of these metropolitan areas, with the most highly polluted metropolitan areas at the top of the list and the least polluted metropolitan areas at the bottom of the list. For example, Table 2 shows that in 2000, the Louisville metropolitan area had a population of 1 025 598 and that the average person in the metropolitan area lived in a census tract with a toxic concentration value of 3416.18. The average non-Hispanic Black person in the metropolitan area lived in a census tract with a toxic concentration value of 7340.86; the average Hispanic person lived in a census tract with a toxic concentration value of 4140.70, and the average non-Hispanic White person lived in a census tract with a toxic concentration value of 2720.66.

In order to determine whether environmental racial inequality existed in any of the 61 metropolitan areas in 2000, I calculated a non-Hispanic Black to non-Hispanic White toxic concentration ratio, a non-Hispanic Black to Hispanic toxic concentration ratio and a Hispanic to non-Hispanic White toxic concentration ratio. In the Louisville metropolitan area, for example, the non-Hispanic Black to non-Hispanic White toxic concentration ratio equalled 7340.86 divided by 2720.66, or 2.7.

Table 3 lists the non-Hispanic Black to non-Hispanic White toxic concentration ratios for all 61 metropolitan areas, with the metropolitan areas at the top of the list having the largest Black/White toxic concentration ratios and those at the bottom of the list having the smallest. Table 3 also lists each metropolitan area’s dissimilarity index value (and rank) and income ratio (and rank). Thus, the Orlando metropolitan area has a Black/White toxic concentration ratio of 3.8, a dissimilarity index value of 57.04, which makes it the 43rd most highly segregated metropolitan area in the list, and a Black/White income ratio of 0.76, which makes it the 53rd most income-unequal metropolitan area in the list (in other words, Orlando is one of the least income-unequal metropolitan areas in the list). Thus, Table 3 allows readers to compare actual Black/White environmental inequality levels with predicted Black/White environmental inequality levels.

Table 3 shows that the Black/White toxic concentration ratios range from a low of 0.51 in the Nassau/Suffolk metropolitan area to a high of 3.8 in the Orlando metropolitan area. Of the 61 metropolitan areas in Table 3, 14 have ratios less than 1, indicating that the average White person in these metropolitan areas lives in a neighbourhood with a higher toxic concentration value than the average Black person in these metropolitan areas, and 46 have ratios greater than 1, indicating that the average Black person in these metropolitan areas lives in a neighbourhood with a higher toxic concentration value than the average White person in these metropolitan areas. Finally, the significance tests tell us that the toxic concentration values that were used to calculate the toxic concentration ratios are significantly different from each other in 60 of the 61 metropolitan areas. The sole exception is the Salt Lake City/Ogden metropolitan area.

These results demonstrate that Black/White environmental inequality levels vary greatly across metropolitan areas. They also contradict the residential segregation and income inequality hypotheses. According to the residential segregation hypothesis, Black/White environmental inequality should be greatest in the Detroit, Milwaukee and New York metropolitan areas and weakest in the San Jose, Salt Lake City and Orange County metropolitan areas; and according to the income inequality hypothesis, Black/White environmental inequality should be strongest in the Minneapolis, Milwaukee and Memphis metropolitan areas and weakest in the Nassau/Suffolk, Middlesex and Riverside metropolitan areas. However, the data show that Black/White environmental inequality is greatest in the Orlando, Norfolk, Louisville and Portland metropolitan areas and weakest in the Baltimore, Las Vegas, Boston and Nassau/Suffolk metropolitan areas.

Moreover, the last four columns of Table 3 show that almost none of the metropolitan areas with the highest toxic concentration ratios have high segregation or income inequality levels: of the 12 metropolitan areas with a toxic concentration ratio greater than 2, only 3 are among the 12 most highly segregated metropolitan areas included in the table and none is among the 12 metropolitan areas with the smallest Black/White income ratios.

Table 4 lists the Hispanic to non-Hispanic White toxic concentration ratios for the 61 metropolitan areas. Table 4 shows that these ratios range from a low of 0.68 in the Washington, DC metropolitan area to a high of 5.34 in the Philadelphia metropolitan area. Nine of the metropolitan areas have ratios less than 1, 46 have ratios greater than 1, and in 6 of the metropolitan areas there is no statistically significant difference between the Hispanic and non-Hispanic White toxic concentration values.

In addition to showing that Hispanic/White environmental inequality varies greatly across metropolitan areas, Table 4 also contradicts the residential segregation and income inequality hypotheses. According to the segregation hypothesis, Hispanic/White environmental inequality should be strongest in the Providence, New York and Newark metropolitan areas and weakest in the Cincinnati, Pittsburgh, Saint Louis and Jacksonville metropolitan areas; and according to the income inequality hypothesis, Hispanic/White environmental inequality should be strongest in the Rochester, Hartford, New York and Philadelphia metropolitan areas and weakest in the Las Vegas, Riverside and Fort Lauderdale metropolitan areas.

However, the data show that Hispanic/White environmental inequality is greatest in the Philadelphia, Milwaukee, Kansas City and Chicago metropolitan areas and weakest in the Las Vegas, Nassau/Suffolk, San Antonio and Washington, DC metropolitan areas. Moreover, of the 13 metropolitan areas with a Hispanic/White toxic concentration ratio greater than 1.8, only 5 are among the 13 most highly segregated metropolitan areas included in the table and only 3 are among the 13 most income-unequal metropolitan areas included in the table.

Table 5 lists the non-Hispanic Black to Hispanic toxic concentration ratios for the 61 metropolitan areas. These ratios range from a low of 0.36 in the Philadelphia metropolitan area to a high of 3.08 in the Orlando metropolitan area. Of the 61 metropolitan areas, 28 have ratios less than 1, 29 have ratios greater than 1, and in 4 of the metropolitan areas there is no statistically significant difference between the Black and Hispanic toxic concentration values.

In addition to showing that Black/Hispanic environmental inequality varies greatly across metropolitan areas, Table 5 also contradicts the income inequality hypothesis. As noted earlier, if the income inequality hypothesis is correct, Black environmental inequality levels should be relatively equal to Hispanic environmental inequality levels in the 17 metropolitan areas where the Black/Hispanic income ratio equals 1 and greater than Hispanic environmental inequality levels in the 36 metropolitan areas where the Black/Hispanic income ratio is less than 1. However, Black toxic concentration levels are greater than or equal to Hispanic toxic concentration levels in only 33 of the 61 metropolitan areas included in Table 5. Moreover, in only 8 of the metropolitan areas in which the Black/Hispanic income ratio equals 1 does the Black/Hispanic toxic concentration ratio fall between 0.8 and 1.25 (ratios of 0.8 and 1.25 represent the same degree of inequality because 1/0.8 = 1.25).

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7. Regression Results

The results presented in the previous section demonstrate that environmental racial inequality varies greatly across metropolitan areas, that the mix of metropolitan areas with the strongest and weakest Black environmental inequality is different from the mix of metropolitan areas with the strongest and weakest Hispanic environmental inequality and that in some metropolitan areas, Whites are more highly burdened by RSEI air pollutants than are Hispanics or Blacks. These results also contradict the residential segregation and income inequality hypotheses.

This section further tests these two hypotheses by regressing the Black/White, Hispanic/White and Black/Hispanic toxic concentration ratios on metropolitan-area dissimilarity scores and metropolitan-area income ratios, controlling for the percentage of Hispanics and non-Hispanic Blacks in each metropolitan area, the neighbourhood toxic concentration value of the average individual in each metropolitan area (average toxic concentration), population size and region of the country. All 329 metropolitan areas in the continental US are included in the analysis so that conclusions can be drawn about metropolitan areas with populations less than 1 000 000. Moreover, the regression results for these 329 metropolitan areas are substantively identical to the unreported regression results for the 61 largest US metropolitan.

Because the toxic concentration and median household income ratios can range from 0 to 1 when the numerator is smaller than the denominator, but from 1 to infinity when the numerator is larger than the denominator, I transformed these ratios as follows: if the ratio was less than 1, I took the inverse of the ratio, multiplied the inverse by −1, and then added 2 to this negative product [(1/ratio * −1) + 2]. Ratio values greater than 1 were not transformed.

These transformations result in a set of variables in which ratios that fall between 0 and 1 in the original metric are now allowed to range from negative infinity to 1. The new variable values are also symmetric around the value 1 (around equality). For example, if the numerator is half as big as the denominator, the original ratio would equal 0.5, the negative inverse would equal 1/0.5 * −1, or −2, and the transformed variable would equal 0. Zero is the same distance away from 1 (equality) as is the variable value when the numerator is twice as big as the denominator.

Population size is coded as a set of dummy variables, 1 variable for metropolitan areas with populations less than 250 000 residents (the excluded variable), 1 variable for metropolitan areas with populations between 250 000 and 500 000, 1 variable for metropolitan areas with populations between 500 000 and 1 000 000 and 1 variable for metropolitan areas with populations greater than 1 000 000. Metropolitan areas receive a value of 1 if they belong to a specific population category and 0 otherwise.

Metropolitan areas were also categorised according to the region of the country in which they are located, using the US Census Bureau’s nine-fold classification scheme to categorise them. The nine regions include New England (the excluded category), the Mid-Atlantic, the East North Central, the West North Central, the South Atlantic, the East South Central, the West South Central, the Mountain and the Pacific. Metropolitan areas receive a value of 1 if they belong to a specific region and 0 otherwise.

Table 6 presents a full and reduced OLS regression model for each transformed toxic concentration ratio. The reduced models regress each of these transformed ratios on the appropriate dissimilarity score and transformed income ratio. The full models include all the control variables. No intermediate models are included because the results of the intermediate models are substantively identical to the results of the full models. In addition, no interaction terms are included because analyses not reported here indicate that none of the relevant interaction terms was significantly associated with any of the dependent variables.

Table 6 shows that the transformed Black/White toxic concentration ratio is positively associated with the Black/White dissimilarity score but insignificantly associated with the transformed Black/White income ratio in both the full and reduced models (models 1 and 2). However, the R^2 values in these models are very small (0.045 and 0.084 respectively). Thus, Black/White environmental inequality levels do increase as Black/White segregation levels increase, but Black/White segregation levels account for very little of the variation in the dependent variable.

Turning our attention to models 3 and 4, we see that the transformed Hispanic/White toxic concentration ratio is positively associated with the Hispanic/White dissimilarity score and insignificantly associated with the transformed Hispanic/White income ratio in both models. However, as in models 1 and 2, the R^2 values in models 3 and 4 are both very small (0.046 and 0.097 respectively). Thus, Hispanic/White environmental inequality levels do increase as Hispanic/White segregation levels increase, but Hispanic/White segregation levels account for very little variation in the dependent variable.

Finally, models 5 and 6 show that the transformed Black/Hispanic toxic concentration ratio is insignificantly associated with the Black/Hispanic dissimilarity score in the full and reduced regression models and negatively and significantly associated with the transformed Black/Hispanic income ratio in the reduced, but not the full, regression model. Thus, in the reduced model, the Hispanic pollution burden increases relative to the Black pollution burden as Hispanic incomes decrease relative to Black incomes. Once again, however, the reduced model explains little of the variation in the dependent variable (R^2 equals 0.017 in the reduced model).

8. Segregation

The regression analyses presented in the previous section demonstrate that residential segregation and racial income inequality play a role, but only a very limited role, in shaping environmental racial inequality, a conclusion that is quite at odds with the prominence of these explanations in the literature (Downey, 2005; Pastor *et al.*, 2001).[5] The obvious question we must ask is why is this the case? Why do these explanations do such a poor job of predicting environmental inequality outcomes?

One possible, albeit tentative, answer to this question is that these explanations fail to take the spatial distribution of environmental hazards within metropolitan areas into account. This is problematic because the spatial distribution of environmental hazards can vary greatly across metropolitan areas. For example, environmental hazards can be dispersed evenly across urban space or they can be spatially concentrated, either around a core set of neighbourhoods or along transport routes such as highways, railroad lines and waterways. They can also be concentrated in the urban core or the suburbs.

Residential segregation levels can also vary greatly across metropolitan areas (see Table 1), and highly segregated groups can be segregated in the urban core or the suburbs or in contiguous or non-contiguous neighbourhoods (Massey and Denton, 1988). It is reasonable

[5]Although one might argue that better variable selection would have increased the explanatory power of the regression analyses, the fact of the matter is that when the dissimilarity scores and income ratios are the only variables included in the regression models, they explain almost none of the variation in the dependent variables.

to conclude, therefore, that residential segregation can separate racial and ethnic minorities from environmental hazards when environmental hazards are dispersed throughout a metropolitan area or when hazards and minorities are both spatially concentrated, but in different sets of neighbourhoods.[6]

In order to demonstrate that this can occur, Figure 1 examines the distribution of Blacks, Hispanics and Whites around RSEI air emissions in the Baltimore metropolitan area. In Baltimore, the Black/White toxic concentration ratio equals 0.72; the Hispanic/White toxic concentration ratio equals 0.92; Black/White segregation is relatively high (D = 67.93); and Hispanic/White segregation is relatively low (D = 36.19). Thus, in Baltimore, high segregation levels do not result in Black/White environmental inequality and Hispanics are more highly exposed to RSEI air pollutants than are Blacks even though Hispanic/White segregation levels are lower than Black/White segregation levels.

The maps in Figure 1 are restricted to that portion of the Baltimore metropolitan area with the highest toxic concentration levels. Census tracts are categorised according to their toxic concentration values and each dot represents 100 Hispanics in map (b), 500 non-Hispanic Blacks in map (c) and 500 non-Hispanic Whites in map (d). (There were not enough Hispanics in the Baltimore metropolitan area to set each dot equal to 500 Hispanics.)

The maps in Figure 1 show that RSEI air emissions are relatively spread out in a band running north-east from just below the city centre (Baltimore’s TRI facilities are also spread out along this band), with Blacks (map c) highly segregated in the urban core just to the north-west of the southern portion of this band. Baltimore’s Hispanic population (map b) is a bit more residentially dispersed than is Baltimore’s Black population and, as a result, Hispanics are a bit more likely than Blacks to live in polluted neighbourhoods. However, neither Blacks nor Hispanics are as residentially dispersed or as highly concentrated in Baltimore’s high-pollution neighbourhoods as is Baltimore’s White population.

Thus, it appears that, in the Baltimore metropolitan area, segregation has reduced Black and, to a lesser extent, Hispanic proximity to RSEI emissions, a conclusion that is consistent with Boone’s (2002) finding that Baltimore’s Black population is segregated into neighbourhoods with relatively few TRI facilities.

Figure 2, which examines the most polluted portion of the Milwaukee metropolitan area, demonstrates that residential segregation can confine one minority group to a small set of highly polluted neighbourhoods while simultaneously confining another minority group to a set of much less polluted neighbourhoods.

In Milwaukee, the Black/White toxic concentration ratio is 1.22, the Hispanic/White toxic concentration ratio is 3.03 and the Hispanic/Black toxic concentration ratio is 2.5. Blacks are extremely segregated from Whites (D = 82.2) and Hispanics (D = 77.9), and Hispanics are highly segregated from Whites (D = 59.6).

Figure 2 shows that there are three RSEI hot-spots in the Milwaukee metropolitan area, two of which are located near each other in the urban core and one of which is located outside the urban core. The majority of Milwaukee’s Hispanic residents live in or near one of these three hot-spots, the majority of Milwaukee’s Black residents live in census tracts with low to

[6]It is beyond the scope of this article to explain why minorities and hazards might be concentrated in different sets of core neighbourhoods. Nevertheless, such a situation could occur if poor or working-class Whites wanted to live near industrial jobs without living near minorities or if minority group members were able to buy their way out of highly polluted neighbourhoods without being able to overcome residential segregation. Conversely, such a situation might develop out of more general and historical patterns of settlement, conflict and industrialisation that are unique to specific metropolitan areas.

medium toxic concentration values and Milwaukee's White residents are dispersed throughout the metropolitan area in tracts with low, medium and high toxic concentration values. However, enough Whites live in low toxic concentration tracts to offset those who live in high toxic concentration tracts. As a result, Whites are, on average, less burdened by RSEI air pollutants than are Blacks who, in turn, are much less burdened than Hispanics.

Thus, it appears that, in the Milwaukee metropolitan area, segregation has increased Black and Hispanic proximity to RSEI emissions, but much more so for Hispanics than for Blacks.

9. Conclusion

This article attempts to increase our understanding of urban environmental inequality by answering two questions. Do environmental racial inequality levels vary across metropolitan areas? If so, is this variation due to metropolitan-area variation in residential segregation levels or racial and ethnic income inequality?

In answering these questions, this study provides some new insights into urban environmental inequality. As with any study, however, it is important that we interpret its findings cautiously. For example, because the sample of 61 metropolitan areas was not selected randomly, the results that pertain solely to these metropolitan areas cannot be generalised to other US metropolitan areas. Likewise, because this study focuses on a single type of environmental hazard, its findings cannot be generalised to other environmental hazards. Finally, although the maps presented in the previous section are highly suggestive, they are no substitute for careful historical analysis. Thus, any conclusions drawn from them need to be supported with further research.

These caveats notwithstanding, the evidence presented in this article demonstrates that RSEI-based environmental racial inequality levels vary greatly across the 61 largest metropolitan areas in the continental US. In some of these metropolitan areas, Hispanics are the most highly burdened group included in the study; in other metropolitan areas, Blacks are the most highly burdened group included in the study; and in still other metropolitan areas, Whites are the most highly burdened group included in the study. Moreover, the degree to which these groups are overburdened or underburdened varies greatly across the 61 metropolitan areas.

This study also demonstrates that the residential segregation and racial income inequality hypotheses do a poor job of explaining metropolitan-area variation in environmental inequality outcomes, either in the 61 largest metropolitan areas in the continental US or in all 329 metropolitan areas in the continental US. As noted earlier, this finding is quite at odds with the prominence of these explanations in the literature (Downey, 2005; Pastor *et al.*, 2001). This finding also contrasts quite strongly with Morello-Frosch and Jesdale's (2006, p. 5) recent conclusion that "racial disparities in [cancer] risk burdens [associated with ambient air toxics] widen with increasing levels of segregation".

However, a close examination of Morello-Frosch and Jesdale's findings shows that the explanatory power of their reduced regression models (which include a single segregation measure as an independent variable) is virtually identical to the explanatory power of the reduced regression models presented in this article, suggesting that, just as in this study, segregation levels predict very little of the variation found in their dependent variable.

So, why do the residential segregation and income inequality hypotheses do such a poor job of predicting environmental inequality outcomes? As noted earlier, one possible explanation for this is that these hypotheses ignore the spatial distribution of environmental hazards within metropolitan areas, assuming that poor people and minorities will be drawn into environmentally hazardous neighbourhoods regardless of where these neighbourhoods are located. However, as the maps presented in the previous section suggest, residential segregation may decrease minority proximity to environmental hazards in some metropolitan areas and increase it in others. In other words, although environmental racial inequality cannot exist without at least some level of residential segregation, residential segregation does not necessarily produce environmental racial inequality and may in some cases place minorities further than Whites from environmental hazards. (The fact that residential segregation is a necessary but insufficient condition for the existence of environmental racial inequality may explain why segregation scores explain some, but only some, of the variation in environmental racial inequality levels found in this study and in Morello-Frosch and Jesdale's study.)

Although these conclusions may seem surprising, they are consistent with Boone's (2002) findings regarding Baltimore and Downey's (2005) findings regarding Detroit, suggesting that factors such as residential segregation and racial income inequality cannot be treated as simple predictors that will behave in a similar fashion in all metropolitan areas. Instead, it seems likely that the role these factors play in shaping environmental inequality is highly contingent on local conditions which, in turn, are likely to be the product of historical forces that vary from one metropolitan area to another and are poorly captured by simple explanatory models. Thus, researchers will probably have to conduct historical case studies of *multiple* metropolitan areas before they can fully understand how residential segregation and racial income inequality interact with other factors to produce variation in environmental inequality outcomes across metropolitan areas.

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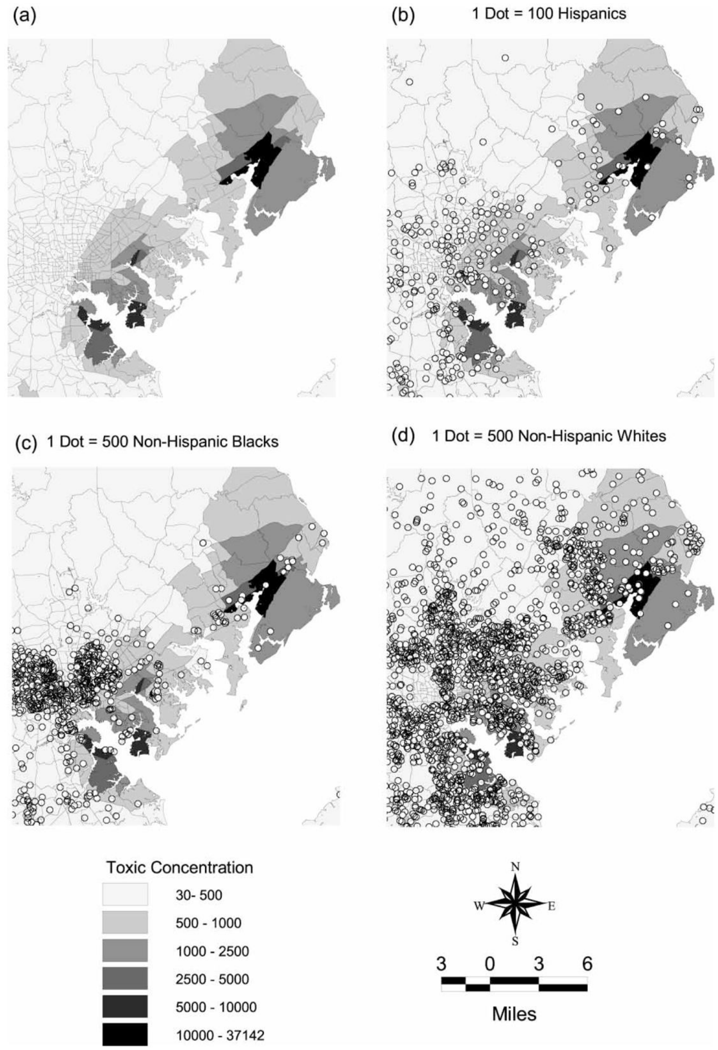

Figure 1.
Hispanics, Blacks, Whites and toxic emissions in the Baltimore metropolitan area.

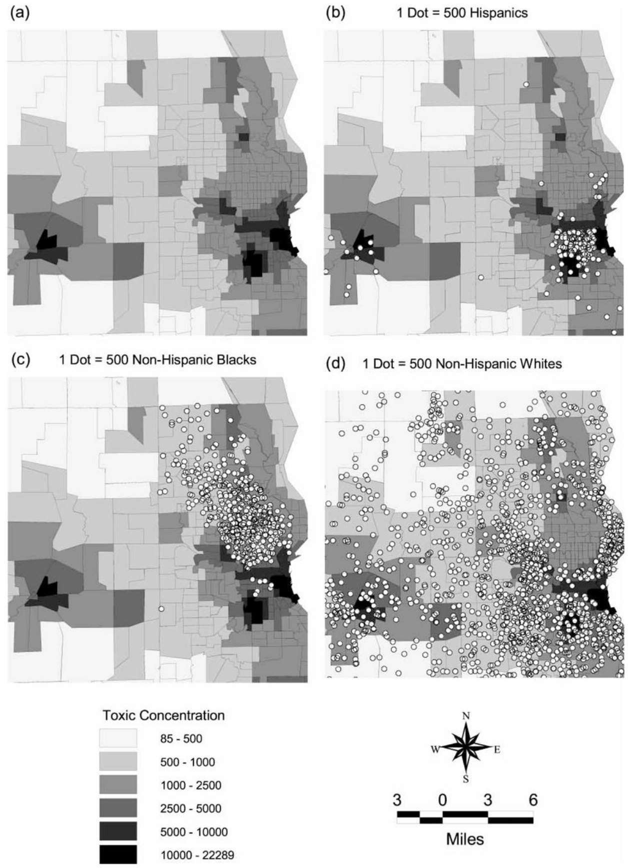

Figure 2.
Hispanics, Blacks, Whites and toxic emissions in the Milwaukee metropolitan area.

Table 1

Metropolitan-area segregation and income inequality indices, 2000

Black/White				Hispanic/Non-Hispanic White				Black/Hispanic	
Metropolitan area (1)	**Dissimilarity (2)**	**Metropolitan area (3)**	**Black/ White income ratios (4)**	**Metropolitan area (5)**	**Dissimilarity (6)**	**Metropolitan area (7)**	**Hispanic/ Non-Hispanic White income ratios (8)**	**Metropolitan area (9)**	**Black/ Hispanic income ratios (10)**
Detroit	84.7	Minneapolis	0.500	Providence	67.6	Rochester	0.474	San Francisco	0.682
Milwaukee	82.2	Milwaukee	0.500	New York	66.7	Hartford	0.500	Pittsburgh	0.692
New York	81.8	Memphis	0.500	Newark	65.0	New York	0.500	New Orleans	0.692
Chicago	80.8	New Orleans	0.529	Hartford	63.8	Philadelphia	0.500	Minneapolis	0.733
Newark	80.4	Providence	0.529	Los Angeles	63.2	Buffalo	0.529	Saint Louis	0.733
Cleveland	77.3	Buffalo	0.529	Chicago	62.1	Providence	0.529	Kansas City	0.733
Buffalo	76.7	Oakland	0.556	Philadelphia	60.2	Boston	0.591	Cincinnati	0.733
Cincinnati	74.8	Newark	0.556	Milwaukee	59.6	Houston	0.591	Memphis	0.733
Nassau	74.4	San Francisco	0.556	Boston	58.8	Milwaukee	0.591	Grand Rapids	0.733
Saint Louis	74.3	Saint Louis	0.579	Cleveland	58.1	San Diego	0.591	Chicago	0.765
Miami	73.6	Cleveland	0.579	Bergen	57.8	San Jose	0.629	Detroit	0.765
Bergen	73.2	Kansas City	0.579	Buffalo	56.2	Bergen	0.630	Baltimore	0.765
Philadelphia	72.3	Cincinnati	0.579	Orange County	56.0	Newark	0.630	Fort Lauderdale	0.765
Indianapolis	70.7	Rochester	0.579	Houston	55.7	Orange County	0.630	Oakland	0.789
New Orleans	69.3	Grand Rapids	0.579	Dallas	54.1	Austin	0.682	Monmouth	0.789
Kansas City	69.1	New York	0.591	Rochester	54.0	Charlotte	0.682	Tampa	0.846
Memphis	68.7	Chicago	0.591	San Francisco	53.9	Dallas	0.682	Miami	0.846
Baltimore	67.9	Philadelphia	0.591	Phoenix	52.5	Denver	0.682	Cleveland	0.846
Los Angeles	67.5	Detroit	0.591	Atlanta	52.5	Memphis	0.682	Milwaukee	0.846
Houston	67.5	Houston	0.591	Middlesex	52.2	Minneapolis	0.682	Greensboro	0.846
Pittsburgh	67.3	Dallas	0.591	Grand Rapids	51.6	Raleigh	0.682	Louisville	0.846
Grand Rapids	67.2	Boston	0.591	San Jose	51.6	Cleveland	0.684	Dallas	0.867
W. Palm Beach	66.7	Baltimore	0.591	Greensboro	51.1	Los Angeles	0.684	Portland	0.867
Rochester	66.3	Charlotte	0.591	San Antonio	51.0	Nashville	0.684	Fort Worth	0.867
Boston	65.7	Raleigh	0.591	San Diego	51.0	Phoenix	0.684	Sacramento	0.867

Black/White				Hispanic/Non-Hispanic White				Black/Hispanic	
Metropolitan area (1)	Dissimilarity (2)	Metropolitan area (3)	Black/ White income ratios (4)	Metropolitan area (5)	Dissimilarity (6)	Metropolitan area (7)	Hispanic/ Non-Hispanic White income ratios (8)	Metropolitan area (9)	Black/ Hispanic income ratios (10)
Atlanta	65.6	Hartford	0.591	Charlotte	50.4	Middlesex	0.704	Indianapolis	0.867
Hartford	65.1	Pittsburgh	0.600	Denver	50.2	Oakland	0.704	Norfolk	0.867
Louisville	64.5	San Jose	0.629	Washington, DC	48.4	Washington, DC	0.704	Las Vegas	0.867
Tampa	64.5	Bergen	0.630	Fort Worth	48.4	Oklahoma City	0.733	Columbus	0.867
Monmouth	63.3	Greensboro	0.647	Memphis	47.9	Greensboro	0.765	Charlotte	0.867
Washington, DC	63.1	Louisville	0.647	Oakland	47.3	Louisville	0.765	Raleigh	0.867
Columbus	63.1	Atlanta	0.682	Nassau	47.2	New Orleans	0.765	W. Palm Beach	0.867
Oakland	62.8	San Diego	0.682	Minneapolis	46.6	Orlando	0.765	Jacksonville	0.867
Fort Lauderdale	62.2	Seattle	0.682	Austin	46.5	San Antonio	0.765	Atlanta	0.882
Denver	61.8	Denver	0.682	Nashville	46.3	Atlanta	0.773	Seattle	0.882
San Francisco	60.9	Austin	0.682	Kansas City	45.7	Baltimore	0.773	Newark	0.882
Fort Worth	60.3	Monmouth	0.682	Detroit	45.7	Chicago	0.773	Los Angeles	1.000
Dallas	59.4	Los Angeles	0.684	Tampa	45.1	Detroit	0.773	Washington, DC	1.000
Greensboro	59.0	Portland	0.684	Oklahoma City	44.4	Seattle	0.773	Houston	1.000
Providence	58.7	Fort Worth	0.684	Miami	44.4	Cincinnati	0.789	Boston	1.000
Minneapolis	57.8	Sacramento	0.684	Indianapolis	43.8	Columbus	0.789	Riverside	1.000
Nashville	57.0	Indianapolis	0.684	W. Palm Beach	43.2	Fort Worth	0.789	Nassau	1.000
Orlando	57.0	Norfolk	0.684	Raleigh	43.0	Grand Rapids	0.789	Denver	1.000
Sacramento	56.0	Columbus	0.684	Riverside	43.0	Indianapolis	0.789	San Jose	1.000
Charlotte	55.2	Nashville	0.684	Las Vegas	42.7	Jacksonville	0.789	Orlando	1.000
Oklahoma City	54.4	W. Palm Beach	0.684	Salt Lake City	42.5	Kansas City	0.789	San Antonio	1.000
San Diego	54.1	Jacksonville	0.684	Orlando	40.7	Norfolk	0.789	Bergen	1.000
Jacksonville	53.9	Washington, DC	0.704	Sacramento	39.8	Portland	0.789	Salt Lake City	1.000
Austin	52.3	Orange County	0.704	Monmouth	38.2	Sacramento	0.789	Austin	1.000
Middlesex	52.0	Tampa	0.733	Columbus	37.7	Salt Lake City	0.789	Nashville	1.000
San Antonio	50.4	Miami	0.733	Baltimore	36.2	Saint Louis	0.789	Providence	1.000
Seattle	49.6	Oklahoma City	0.733	New Orleans	36.1	W. Palm Beach	0.789	Buffalo	1.000

	Black/White				Hispanic/Non-Hispanic White			Black/Hispanic	
Metropolitan area (1)	**Dissimilarity (2)**	**Metropolitan area (3)**	**Black/ White income ratios (4)**	**Metropolitan area (5)**	**Dissimilarity (6)**	**Metropolitan area (7)**	**Hispanic/ Non-Hispanic White income ratios (8)**	**Metropolitan area (9)**	**Black/ Hispanic income ratios (10)**
Portland	48.1	Orlando	0.765	Louisville	35.8	Nassau	0.815	Oklahoma City	1.000
Riverside	46.3	Fort Lauderdale	0.765	Portland	35.4	San Francisco	0.815	Orange County	1.118
Norfolk	46.2	San Antonio	0.765	Fort Lauderdale	31.6	Monmouth	0.864	Phoenix	1.154
Raleigh	46.2	Las Vegas	0.765	Norfolk	31.5	Miami	0.867	San Diego	1.154
Phoenix	43.7	Phoenix	0.789	Seattle	31.1	Pittsburgh	0.867	Middlesex	1.158
Las Vegas	43.3	Salt Lake City	0.789	Cincinnati	29.8	Tampa	0.867	New York	1.182
San Jose	40.5	Nassau	0.815	Pittsburgh	29.5	Las Vegas	0.882	Philadelphia	1.182
Salt Lake City	36.9	Middlesex	0.815	Saint Louis	29.0	Riverside	0.882	Hartford	1.182
Orange County	36.8	Riverside	0.882	Jacksonville	26.4	Fort Lauderdale	1.000	Rochester	1.222

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Table 2

Black, Hispanic and White toxic concentration levels, 2000

Metropolitan area	Population	Average toxic concentration	Non-Hispanic black toxic concentration	Hispanic toxic concentration	Non-Hispanic white toxic concentration
Louisville	1 025 598	3 416.18	7 340.86	4 140.70	2 720.66
Pittsburgh	2 358 695	2 199.49	2 245.35	2 570.75	2 196.23
Rochester	1 098 201	1 888.04	3 509.20	3 854.47	1 571.90
Saint Louis	2 603 607	1 839.42	2 643.87	2 025.09	1 641.04
Milwaukee/Waukesha	1 500 741	1 652.63	1 703.11	4 240.15	1 400.90
Grand Rapids/Muskegon/Holland	1 088 514	1 595.46	2 837.60	2 054.87	1 438.39
Cleveland/Lorain/Elyria	2 250 871	1 577.59	2 181.53	1 732.62	1 422.81
Portland/Vancouver	1 918 009	1 261.67	3 058.12	1 315.81	1 187.77
Cincinnati	1 646 395	1 085.38	1 754.47	1 232.90	975.78
Columbus	1 540 157	1 064.85	1 647.22	1 009.01	972.44
New Orleans	1 337 726	1 050.91	1 043.06	1 054.22	1 066.78
Hartford	1 183 110	954.30	866.82	1 040.12	945.02
Indianapolis	1 607 486	925.45	1 445.31	1 378.91	822.27
Norfolk/Virginia Beach/Newport News	1 569 541	874.33	1 612.70	626.49	538.89
Buffalo/Niagara Falls	1 170 111	790.14	945.10	814.69	765.89
Chicago	8 272 768	728.59	1 092.97	1 331.23	453.69
Denver	2 109 282	703.26	572.92	1 061.22	626.63
Salt Lake City/Ogden	1 333 914	671.86	675.73	768.72	656.16
Memphis	1 135 614	649.45	713.58	583.53	604.46
Houston	4 177 646	596.44	474.07	843.73	512.09
Philadelphia	5 100 931	498.16	678.73	1886.63	353.29
Charlotte/Gastonia/Rock Hill	1 499 293	487.41	560.14	437.55	471.92
Greensboro/Winston-Salem/High Point	1 251 509	463.14	499.43	615.80	446.61
Detroit	4 441 551	451.19	768.20	638.93	338.56
Kansas City	1 776 062	432.98	568.35	1086.37	362.60
Tampa/StPetersburg/Clearwater	2 395 997	431.18	677.57	536.58	382.47
Baltimore	2 552 994	418.99	331.03	421.48	459.98
Nashville	1 231 311	415.68	355.01	439.77	428.03

Metropolitan area	Population	Average toxic concentration	Non-Hispanic black toxic concentration	Hispanic toxic concentration	Non-Hispanic white toxic concentration
Oklahoma City	1 083 346	336.03	401.82	331.92	329.86
Orlando	1 644 561	321.79	836.43	271.97	220.02
Orange County	2 846 289	300.73	438.28	285.62	321.63
Riverside/San Bernardino	3 254 821	279.87	323.08	325.29	238.91
Jacksonville	1 100 491	248.45	299.18	235.35	234.05
Minneapolis/StPaul	2 968 806	226.05	302.88	353.24	211.82
Las Vegas	1 563 282	209.40	167.35	183.11	234.23
Dallas	3 519 176	186.75	195.91	352.06	123.66
Los Angeles/Long Beach	9 519 338	183.32	253.12	216.79	114.31
Miami	2 253 362	176.41	217.60	192.76	100.32
Atlanta	4 112 198	167.68	175.96	155.35	167.21
Providence/Fall River/Warwick	1 188 613	167.33	212.09	222.20	158.64
Fort Worth/Arlington	1 702 625	166.11	184.30	238.82	141.48
Raleigh/Durham/Chapel Hill	1 187 941	165.19	221.95	188.12	144.20
Phoenix/Mesa	3 251 876	163.45	223.35	299.30	109.48
Oakland	2 392 557	152.73	149.47	217.32	120.53
San Antonio	1 592 383	150.82	175.20	124.15	179.46
Newark	2 032 989	148.83	125.40	245.61	136.03
Middlesex/Somerset Hunterdon	1 169 641	143.90	154.98	162.78	139.21
Seattle/Bellevue/Everett	2 414 616	142.34	164.40	157.50	138.82
Bergen/Passaic	1 373 167	117.61	100.44	132.98	116.21
New York	9 314 235	83.10	87.29	86.34	80.46
Boston	3 405 985	82.39	53.95	86.01	85.95
Austin/San Marcos	1 249 763	81.75	134.85	112.92	61.66
Washington, DC	4 923 153	71.22	70.22	53.26	77.94
San Jose	1 682 585	61.51	68.16	77.50	51.85
Fort Lauderdale	1 623 018	48.23	53.55	53.53	45.15
Nassau/Suffolk	2 753 913	47.09	26.17	36.96	50.84
San Diego	2 813 833	37.84	49.38	51.93	31.72
West Palm Beach/Boca Raton	1 131 184	21.29	40.71	23.96	17.10
San Francisco	1 731 183	20.40	27.60	23.03	18.68

Metropolitan area	Population	Average toxic concentration	Non-Hispanic black toxic concentration	Hispanic toxic concentration	Non-Hispanic white toxic concentration
Sacramento	1 628 197	19.57	21.70	23.06	18.30
Monmouth/Ocean	1 126 217	15.62	13.69	15.91	15.49

Table 3

Black/White toxic concentration, dissimilarity and income inequality comparison

Metropolitan area	Toxic concentration ratio	Dissimilarity index	Rank[a]	Income ratio	Rank[b]
Orlando	3.80***	57.04	(43)	0.76	(53)
Norfolk/Virginia Beach/Newport News	2.99***	46.20	(55)	0.68	(43)
Louisville	2.70***	64.49	(28)	0.65	(31)
Portland/Vancouver	2.57***	48.07	(53)	0.68	(39)
Chicago	2.41***	80.85	(4)	0.59	(17)
West Palm Beach/Boca Raton	2.38***	66.68	(23)	0.68	(46)
Detroit	2.27***	84.72	(1)	0.59	(19)
Rochester	2.23***	66.32	(24)	0.58	(14)
Los Angeles/Long Beach	2.21***	67.55	(19)	0.68	(38)
Austin/San Marcos	2.19***	52.28	(49)	0.68	(36)
Miami	2.17***	73.57	(11)	0.73	(51)
Phoenix/Mesa	2.04***	43.72	(57)	0.79	(57)
Grand Rapids/Muskegon/Holland	1.97***	67.18	(22)	0.58	(15)
Philadelphia	1.92***	72.33	(13)	0.59	(18)
Cincinnati	1.80***	74.84	(8)	0.58	(13)
Tampa/St Petersburg/Clearwater	1.77***	64.47	(29)	0.73	(50)
Indianapolis	1.76***	70.66	(14)	0.68	(42)
Columbus	1.69***	63.10	(32)	0.68	(44)
Saint Louis	1.61***	74.35	(10)	0.58	(10)
Dallas	1.58***	59.36	(38)	0.59	(21)
Kansas City	1.57***	69.12	(16)	0.58	(12)
San Diego	1.56***	54.15	(47)	0.68	(33)
Raleigh/Durham/Chapel Hill	1.54***	46.17	(56)	0.59	(25)
Cleveland/Lorain/Elyria	1.53***	77.32	(6)	0.58	(11)

Metropolitan area	Toxic concentration ratio	Dissimilarity index	Rank[a]	Income ratio	Rank[b]
San Francisco	1.48***	60.87	(36)	0.56	(9)
Minneapolis/StPaul	1.43***	57.83	(41)	0.50	(1)
Orange County	1.36***	36.80	(61)	0.70	(49)
Riverside/San Bernardino	1.35***	46.28	(54)	0.88	(61)
Providence/Fall River/Warwick	1.34***	58.69	(40)	0.53	(5)
San Jose	1.31***	40.51	(59)	0.63	(28)
Fort Worth/Arlington	1.30***	60.33	(37)	0.68	(40)
Jacksonville	1.28***	53.94	(48)	0.68	(47)
Oakland	1.24***	62.81	(33)	0.56	(7)
Buffalo/Niagara Falls	1.23***	76.74	(7)	0.53	(6)
Oklahoma City	1.22***	54.45	(46)	0.73	(52)
Milwaukee/Waukesha	1.22***	82.16	(2)	0.50	(2)
Charlotte/Gastonia/Rock Hill	1.19***	55.16	(45)	0.59	(24)
Fort Lauderdale	1.19***	62.25	(34)	0.76	(54)
Sacramento	1.19***	55.97	(44)	0.68	(41)
Seattle/Bellevue/Everett	1.18***	49.62	(52)	0.68	(34)
Memphis	1.18***	68.72	(17)	0.50	(3)
Greensboro/Winston-Salem/High Point	1.12***	59.01	(39)	0.65	(30)
Middlesex/Somerset/Hunterdon	1.11***	51.97	(50)	0.81	(60)
New York	1.08***	81.82	(3)	0.59	(16)
Atlanta	1.05***	65.61	(26)	0.68	(32)
Salt Lake City/Ogden	1.03	36.91	(60)	0.79	(58)
Pittsburgh	1.02***	67.27	(21)	0.60	(27)
New Orleans	0.98***	69.25	(15)	0.53	(4)
San Antonio	0.98 *	50.40	(51)	0.76	(55)
Houston	0.93***	67.49	(20)	0.59	(20)
Newark	0.92***	80.42	(5)	0.56	(8)

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Metropolitan area	Toxic concentration ratio	Dissimilarity index	Rank[a]	Income ratio	Rank[b]
Hartford	0.92***	65.05	(27)	0.59	(26)
Denver	0.91***	61.76	(35)	0.68	(35)
Washington, DC	0.90***	63.12	(31)	0.70	(48)
Monmouth/Ocean	0.88***	63.35	(30)	0.68	(37)
Bergen/Passaic	0.86***	73.24	(12)	0.63	(29)
Nashville	0.83***	57.05	(42)	0.68	(45)
Baltimore	0.72***	67.93	(18)	0.59	(23)
Las Vegas	0.71***	43.32	(58)	0.76	(56)
Boston	0.63***	65.68	(25)	0.59	(22)
Nassau/Suffolk	0.51***	74.38	(9)	0.81	(59)

[a] Dissimilarity index rank from Table 1.

[b] Income ratio rank from Table 1.

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

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Table 4

Hispanic/White toxic concentration, dissimilarity and income inequality comparison

Metropolitan area	Toxic concentration ratio	Dissimilarity index	Rank[a]	Income ratio	Rank[b]
Philadelphia	5.34***	60.15	(7)	0.50	(2)
Milwaukee/Waukesha	3.03***	59.57	(8)	0.59	(7)
Kansas City	3.00***	45.73	(36)	0.79	(40)
Chicago	2.93***	62.09	(6)	0.77	(35)
Dallas	2.85***	54.10	(15)	0.68	(15)
Phoenix/Mesa	2.73***	52.50	(18)	0.68	(22)
Rochester	2.45***	54.02	(16)	0.47	(1)
Miami	1.92***	44.41	(40)	0.87	(56)
Los Angeles/Long Beach	1.90***	63.16	(5)	0.68	(23)
Detroit	1.89***	45.65	(37)	0.77	(36)
Austin/San Marcos	1.83***	46.49	(34)	0.68	(16)
Newark	1.81***	65.01	(3)	0.63	(12)
Oakland	1.80***	47.30	(31)	0.70	(26)
Denver	1.69***	50.21	(27)	0.68	(17)
Fort Worth/Arlington	1.69***	48.37	(29)	0.79	(41)
Indianapolis	1.68***	43.76	(41)	0.79	(42)
Minneapolis/StPaul	1.67***	46.64	(33)	0.68	(18)
Houston	1.65***	55.67	(14)	0.59	(8)
San Diego	1.64***	50.97	(25)	0.59	(9)
Louisville	1.52***	35.82	(53)	0.76	(30)
San Jose	1.49***	51.58	(22)	0.63	(11)
Grand Rapids/Muskegon/Holland	1.43***	51.63	(21)	0.79	(43)
Tampa/St Petersburg/Clearwater	1.40***	45.06	(38)	0.87	(57)
West Palm Beach/Boca Raton	1.40***	43.21	(42)	0.79	(44)

Metropolitan area	Toxic concentration ratio	Dissimilarity index	Rank[a]	Income ratio	Rank[b]
Providence/Fall River/Warwick	1.40***	67.58	(1)	0.53	(5)
Greensboro/Winston-Salem/High Point	1.38***	51.06	(23)	0.76	(31)
Riverside/San Bernardino	1.36***	43.02	(44)	0.88	(59)
Raleigh/Durham/Chapel Hill	1.30***	43.03	(43)	0.68	(19)
Cincinnati	1.26***	29.80	(58)	0.79	(45)
Sacramento	1.26***	39.79	(48)	0.79	(46)
Orlando	1.24***	40.71	(47)	0.76	(32)
Saint Louis	1.23***	29.01	(60)	0.79	(47)
San Francisco	1.23***	53.87	(17)	0.81	(53)
Cleveland/Lorain/Elyria	1.22***	58.07	(10)	0.68	(24)
Fort Lauderdale	1.19***	31.65	(55)	1.00	(61)
Salt Lake City/Ogden	1.17***	42.52	(46)	0.79	(48)
Pittsburgh	1.17***	29.51	(59)	0.87	(58)
Middlesex/Somerset/Hunterdon	1.17***	52.24	(20)	0.70	(27)
Norfolk/Virginia Beach/Newport News	1.16***	31.55	(56)	0.79	(49)
Bergen/Passaic	1.14***	57.79	(11)	0.63	(13)
Seattle/Bellevue/Everett	1.13***	31.15	(57)	0.77	(37)
Portland/Vancouver	1.11***	35.36	(54)	0.79	(50)
Hartford	1.10***	63.79	(4)	0.50	(3)
New York	1.07***	66.68	(2)	0.50	(4)
Buffalo/Niagara Falls	1.06***	56.22	(12)	0.53	(6)
Columbus	1.04	37.65	(50)	0.79	(51)
Nashville	1.03	46.32	(35)	0.68	(25)
Monmouth/Ocean	1.03***	38.17	(49)	0.86	(55)
Oklahoma City	1.01	44.44	(39)	0.73	(29)
Jacksonville	1.01	26.41	(61)	0.79	(52)
Boston	1.00	58.80	(9)	0.59	(10)

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Metropolitan area	Toxic concentration ratio	Dissimilarity index	Rank[a]	Income ratio	Rank[b]
New Orleans	0.99	36.06	(52)	0.76	(33)
Memphis	0.97†	47.90	(30)	0.68	(20)
Atlanta	0.93***	52.49	(19)	0.77	(38)
Charlotte/Gastonia/Rock Hill	0.93***	50.37	(26)	0.68	(21)
Baltimore	0.92 **	36.19	(51)	0.77	(39)
Orange County	0.89***	56.01	(13)	0.63	(14)
Las Vegas	0.78***	42.75	(45)	0.88	(60)
Nassau/Suffolk	0.73***	47.18	(32)	0.81	(54)
San Antonio	0.69***	50.98	(24)	0.76	(34)
Washington, DC	0.68***	48.41	(28)	0.70	(28)

[a] Dissimilarity index rank from Table 1.

[b] Income ratio rank from Table 1.

† $p < 0.1$;

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

Table 5

Black/Hispanic toxic concentration and income inequality comparison

Metropolitan area	Toxic concentration ratio	Income ratio	Rank[a]
Orlando	3.08***	1.00	(37)
Norfolk/Virginia Beach/Newport News	2.57***	0.87	(22)
Portland/Vancouver	2.32***	0.87	(23)
Louisville	1.77***	0.85	(16)
West Palm Beach/Boca Raton	1.70***	0.87	(24)
Columbus	1.63***	0.87	(25)
Orange County	1.53***	1.12	(54)
Cincinnati	1.42***	0.73	(4)
San Antonio	1.41***	1.00	(38)
Grand Rapids/Muskegon/Holland	1.38***	0.73	(5)
Washington, DC	1.32***	1.00	(39)
Saint Louis	1.31***	0.73	(6)
Charlotte/Gastonia/Rock Hill	1.28***	0.87	(26)
Jacksonville	1.27***	0.87	(27)
Tampa/St Petersburg/Clearwater	1.26***	0.85	(17)
Cleveland/Lorain/Elyria	1.26***	0.85	(18)
Memphis	1.22***	0.73	(7)
Oklahoma City	1.21***	1.00	(40)
Detroit	1.20***	0.76	(10)
San Francisco	1.20***	0.68	(1)
Austin/San Marcos	1.19***	1.00	(41)
Raleigh/Durham/Chapel Hill	1.18***	0.87	(28)
Los Angeles/Long Beach	1.17***	1.00	(42)
Buffalo/Niagara Falls	1.16***	1.00	(43)
Atlanta	1.13***	0.88	(34)
Miami	1.13***	0.85	(19)
Indianapolis	1.05***	0.87	(29)
Seattle/Bellevue/Everett	1.04***	0.88	(35)
New York	1.01***	1.18	(58)
Fort Lauderdale	1.00	0.76	(11)
Riverside/San Bernardino	0.99	1.00	(44)
New Orleans	0.99	0.69	(2)
Providence/Fall River/Warwick	0.95***	1.00	(45)
Middlesex/Somerset/Hunterdon	0.95***	1.16	(57)

Metropolitan area	**Toxic concentration ratio**	**Income ratio**	**Rank[a]**
San Diego	0.95***	1.15	(55)
Sacramento	0.94***	0.87	(30)
Las Vegas	0.91	0.87	(31)
Rochester	0.91***	1.22	(61)
San Jose	0.88***	1.00	(46)
Salt Lake City/Ogden	0.88***	1.00	(47)
Pittsburgh	0.87***	0.69	(3)
Monmouth/Ocean	0.86***	0.79	(14)
Minneapolis/StPaul	0.86***	0.73	(8)
Hartford	0.83***	1.18	(59)
Chicago	0.82***	0.76	(12)
Greensboro/Winston-Salem/High Point	0.81***	0.85	(20)
Nashville	0.81***	1.00	(48)
Baltimore	0.79***	0.76	(13)
Fort Worth/Arlington	0.77***	0.87	(32)
Bergen/Passaic	0.76***	1.00	(49)
Phoenix/Mesa	0.75***	1.15	(56)
Nassau/Suffolk	0.71***	1.00	(50)
Oakland	0.69***	0.79	(15)
Boston	0.63***	1.00	(51)
Houston	0.56***	1.00	(52)
Dallas	0.56***	0.87	(33)
Denver	0.54***	1.00	(53)
Kansas City	0.52***	0.73	(9)
Newark	0.51***	0.88	(36)
Milwaukee/Waukesha	0.40***	0.85	(21)
Philadelphia	0.36***	1.18	(60)

[a]Income ratio rank from Table 1.

*p < 0.05;

**p < 0.01;

***p < 0.001.

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Table 6

OLS models regressing metropolitan-area toxic concentration ratios on dissimilarity scores, household income ratios, and other covariates (*N* = 329)

	Model 1 (Black/White)	Model 2 (Black/White)	Model 3 (Hispanic/White)	Model 4 (Hispanic/White)	Model 5 (Black/Hispanic)	Model 6 (Black/Hispanic)
Dissimilarity	0.0130***	0.0160**	0.0138**	0.0147*	0.0001	−0.0058
Median household income ratio	−0.0347	0.0859	−0.2242	−0.3817	−0.3119*	−0.1417
Percentage non-Hispanic Black		−0.0040		0.0036		0.0012
Percentage Hispanic		−0.0020		0.0082†		0.0020
Average toxic concentration		−0.0001		0.0000		−0.0001
Population size						
>1 000 000		−0.2035		−0.1794		0.0230
500 000–1 000 000		−0.0856		−0.2389		0.1234
250 000–500 000		0.0189		−0.1157		0.0516
Regions						
Mid-Atlantic		0.0794		0.1991		0.1058
East North Central		0.4228*		0.3702		0.3761*
West North Central		0.2413		0.3061		0.1833
South Atlantic		0.3691		0.1660		0.3994*
East South Central		0.5141*		0.1267		0.6275**
West South Central		0.1720		−0.0031		0.1384
Mountain		0.1339		0.6652*		−0.0711
Pacific		0.2901		0.0828		0.0746
Constant	0.8151**	0.4590	0.9980**	0.8131*	1.3330***	1.1516***
R^2	0.0453	0.0835	0.0462	0.0970	0.0165	0.0694

† $p < 0.1$;

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.