Spatial Variability in Toxicity Indicators Used to Rank Chemical Risks

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Objectives. This study used 6 different measures of toxicity to explore spatial and statistical variations in relative risk indicators of Toxic Release Inventory emissions.

Methods. Statistical and spatial correlations between the 6 indices were computed for individual South Carolina facilities.

Results. Although the 6 toxicity indices are not highly correlated in theory, they have more commonality in practice. There was significant spatial variation in the indices by individual facility level.

Conclusions. Environmental justice researchers must be cognizant of differences in toxicity indices because the choice of the toxicity measure can alter (statistically and spatially) the results of equity analyses and lead to erroneous conclusions. (*Am J Public Health.* 2002;92:420-422)

Current risk policies lack an adequate way of characterizing risks that the public can understand. Under community right-to-know provisions and pollution prevention efforts, the demand for this type of information—especially by environmental justice advocates and community-based organizations—is increasing. There are many different toxicity indices to choose from. Which one best represents the potential risk of nearby facilities?

Only a handful of studies incorporate toxicity measures into equity analyses, thus providing a quantitative measure of potential exposure.[1–7] Although each of these studies uses the same basic toxics database (the US Environmental Protection Agency's Toxic Release Inventory [TRI]) for quantity and type of chemical released, they use different measures of toxicity. As a result, comparing findings across studies and developing generalizations about levels of relative risk to low-income and minority populations is difficult, if not impossible. In this report, we compare 6 toxicity indices that were used to characterize airborne releases from individual facilities and examine the statistical and spatial correlation between these indices, using South Carolina as a test case.

METHODS

We used data from the 1992 TRI in this analysis because of their availability, reasonable estimate of quantities of released chemicals by individual facilities, and widespread use in environmental justice analyses. In 1992, 67.9 million pounds of toxic chemicals were released in South Carolina—placing the state 13th nationally in quantity of toxic releases.[8] South Carolina had 426 facilities reporting to the TRI; 142 different chemicals were released. The locations of these facilities have been verified to ensure their correct positions (longitude/latitude) according to the methodology reported by Scott et al.[9]

We chose 6 different toxicity indicators for this analysis, based on their general availability and prior use in environmental justice studies.[10] A brief summary of each toxicity indicator appears in Table 1. Working from the Environmental Defense Scorecard—which includes 40 different chemical indexing systems—we computed a simple index for each chemical, based on the number of times the chemical was ranked above the 50th percentile (more hazardous than most substances) across all applicable indices; we labeled this scheme the "Modified Scorecard." For example, formaldehyde scores higher than the 50th percentile on 6 of 12 indices listed in Scorecard, for a value of 0.5. Benzene exceeds the 50th percentile on 5 of 12 indices on Scorecard, so we assigned it a value of 0.36; mercury exceeds the 50th percentile on 8 of 10 indices, so we gave it a value of 0.8 on the Modified Scorecard. Although using such a simple indicator glosses over uncertainties in measuring and summarizing information about these complex interactions, it does provide a basis for comparison.

RESULTS

Toxicity Indices and Potential Risk Scores

The correlations between indices are statistically significant but relatively weak except for 3 pairs: Total UTN and Modified Scorecard (R=.70, P>.001); USEPA PCL and Modified Scorecard (R=.77, P>.001); and TLV and EDF TEP (R=.74, P>.001). Overall, the weak correlations demonstrate statistical independence among the indices, suggesting that they are not entirely duplicative of each other and do indeed provide slightly different indicators of toxicity. This result is what we expected.

We calculated a potential risk exposure score for each facility, using the following equation, to determine the statistical and spatial manifestations of each index as applied to specific facilities.

$$RPRS_f = \sum_i^n C_i x T_i$$

where $RPRS_f$ is the relative potential risk score for a given facility f; n is the number of chemicals released by facility f; C_i is the amount of chemical i, in pounds; T_i is the toxicity measure of chemical i, in pounds; note T_i will be $1/T_i$ for concentration-based toxicity measures such as TLV.

Potential risk scores by facility are highly correlated among the Pratt, USEPA PCL, Total UTN, and Modified Scorecard indices (R=.77 to .96, P>.001). Some interesting associations appear in comparisons of theoretical statistical correlations with an application involving specific releases from individual facilities. For example, the Modified Scorecard and USEPA PCL have the highest correlation

TABLE 1—Comparison of Toxicity Indices

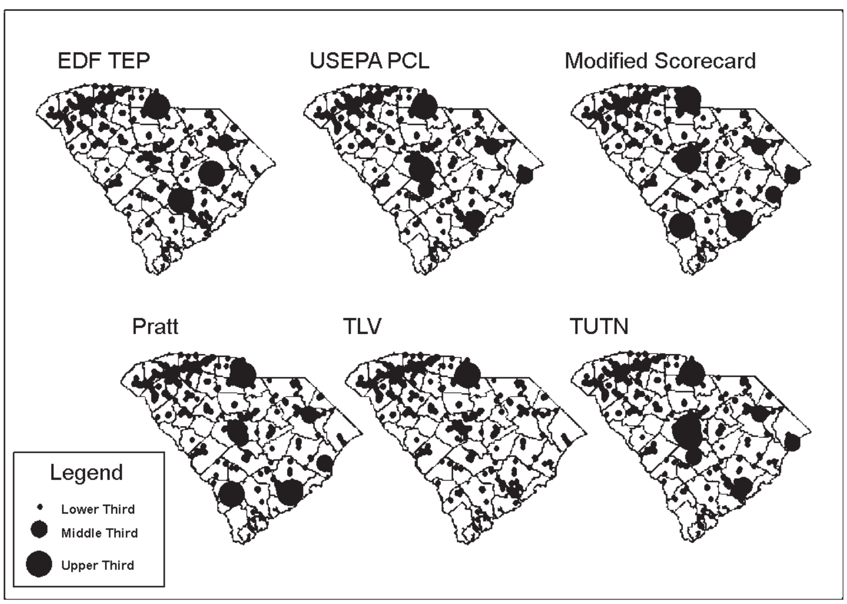
Index	No. Chemicals Indexed	Value Range	South Carolina TRI Example: % TRI Chemicals Not Indexed	South Carolina TRI Example: Value Range	South Carolina TRI Example: Mean	Reference(s)
Threshold Limit Values (TLV)	634	.0005–9000	26.1	0–100	3.97	11
Pratt Index (Pratt)	182	0–21.09	38.7	0–16.1	10.3	12
US EPA Priority Chemical List (USEPA PCL)	879	6–18	28.9	6–17	9.8	13, 14
University of Tennessee Total Hazard Value (Total UTN)	Unknown	0–200	28.2	4.4–120	52.2	14, 15
Environmental Defense Fund (EDF) Toxicity Equivalent Potential (EDF TEP)	159	0–900	21.8	0–470	13.7	16
EDF Modified Scorecard (Modified Scorecard)	650	0–100	2.1	0–100	54.0	14

Note. TRI = Toxic Release Inventory (US Environmental Protection Agency).

(R=.77, P>.001); when they are examined by individual facility, however, the correlation drops (R=.65, P>.001). The same is true for the association between TLV and EDF Toxic Equivalent Potential. Indices that do not appear to be highly correlated in theory (Pratt and USEPA PCL, Pratt and Total UTN) turn out to be in practice. In all but 3 instances (USEPA PCL and TLV, USEPA PCL and Modified Scorecard, TLV and EDF Toxic Equivalent Potential), correlation coefficients improved from the theoretical case to the application. Determining whether this outcome is an artifact of statistics or reflects subtle differences in the indicators when applied to individual emissions requires further research.

Spatial Variability in Toxicity Indices

We divided the relative risk scores calculated on a facility-by-facility basis into 3 equal classes (tertiles) for each index and then mapped them. As Figure 1 shows, there is considerable geographic variability among the indices at the facility level, especially among those in the upper tertile. This variability is a function of the specific types of chemicals and quantities released by each individual facility. Depending on which toxicity index is used, facilities may migrate between classes (even though the quantity stays constant), thereby portraying a very different geography of the relative risk of facilities. In all 6 maps, 1 facility in the northern portion of the state stands out. The Bowater facility is not the largest emitter in the state, yet the combination of a large quantity and higher toxicity of those releases pushes Bowater into the top position in the state on all indices.



Note. EDF TEP = Environmental Defense Fund Toxicity Equivalent Potential[16]; USEPA PCL = US Environmental Protection Agency Priority Chemical List[13,14]; Modified Scorecard = Environmental Defense Fund Modified Scorecard[14]; Pratt = Pratt Index[12]; TLV = Threshold Limit Values[11]; T UTN = University of Tennessee Total Hazard Value.[14,15]

FIGURE 1—Spatial distribution of relative risk of South Carolina's Toxic Release Inventory facilities, based on quantity and toxicity of emissions, showing geographic variability in relative hazardousness of facilities depending on which toxicity indicator is used.

DISCUSSION

Researchers may choose among several toxicity indicators to estimate the risk posed to a community by an industrial facility. As this study demonstrates, the results of that choice can result in statistical and spatial variations in the results. This variability has important implications for communities or governmental agencies that base policy or equity actions on such studies. Incorporation of a toxicity measure into an equity analysis could lead to differing conclusions about environmental inequities and injustices, depending on which index were used. Therefore, careful selection and justification of toxicity indices is warranted, and caution must be exercised in interpreting the results. ■

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Contributors

S.L. Cutter designed the original study and wrote the report. M.S. Scott did the statistical analysis and contributed to the writing. A.A. Hill assisted in the statistical analysis, prepared the final graphics, and helped write the report.

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