RESEARCH REPORT

# Environmental justice: frequency and severity of US chemical industry accidents and the socioeconomic status of surrounding communities

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**Study objectives:** The Clean Air Act Amendments of 1990 requires that chemical facilities in the US with specified quantities of certain toxic or flammable chemicals file a five year history of accidents. This study considers the relation between the reported accidents and surrounding community characteristics.
**Design:** This study is a retrospective analysis of the association between the demographics of counties in which facilities are located and the risk of accidental chemical release and resulting injuries at those facilities. The ''location risk'' (the risk that a facility having large volumes of hazardous chemicals is located in a community) and ''operations risk'' (the risk of an accident itself) are investigated.
**Setting:** 1994–2000 accident history data from 15 083 US industrial facilities using one or more of 140 flammable or toxic substances above a threshold level. Demographic makeup of 2333 counties surrounding these facilities was determined from the 1990 US census.
**Main results:** Larger and more chemical intensive facilities tend to be located in counties with larger African-American populations and in counties with both higher median incomes and high levels of income inequality. Even after adjusting for location risk there is greater risk of accidents for facilities in heavily African-American counties (OR of accident = 1.9, 95% CI = 1.5 to 2.4).
**Conclusions:** Further research and policy interventions are required to reduce the probability of locating facilities in an inequitable fashion, as well as health surveillance, and regulatory monitoring and enforcement activities to ensure that hazardous facilities in minority communities prepare and prevent accidental chemical releases to the same standards as elsewhere.

''Environmental justice'' addresses whether health risks or environmental impacts from industrial activities are distributed in a manner that comports with basic cultural and social notions of fairness.[1–5] An extensive body of research in political economics, public policy, and public health has noted associations between environmental and health risks arising from industrial facilities and the socioeconomic status (SES) of host communities.[6 7] These associations could be caused by firms anticipating lower levels of collective action and monitoring from communities with lower SES, and therefore preferring to locate hazardous facilities there. These could also result from migration of groups of lower SES to sites where such facilities have located, as property values may be lower there. Whatever the reason, a finding that certain communities are at significantly greater risk than others raises fundamental questions for environmental and health authorities.

Empirical findings regarding the details of these associations, and their underlying causes, have been mixed. Brown[1] found that African-Americans and lower SES Americans are disproportionately likely to live near hazardous waste sites, to be exposed to air pollution or other toxic releases, and not to receive relief from regulatory decision or toxic cleanups. Perlin *et al*[2] found that African-Americans lived closer than white people to the nearest industrial emission source, that African-Americans were more likely than the white population to live within two miles of multiple emission sources, and that African-American children 5 and younger were substantially more likely than white children to live near one or more sources of industrial air pollution. Brooks and Sethi[8] found in their study of US zip codes that lower SES zip codes suffered higher levels of air toxins than their higher SES counterparts, with public pressure an important element in explaining changes in the level of these environmental impacts over time. Mitchell *et al*[9] found significant negative correlations between the SES of host counties and the risk imposed by South Carolina chemical facilities, but that these risk differences across counties are primarily the result of migration patterns of lower SES individuals to the vicinity of the facilities and not the result of the original location decisions of facility owners.

The debate continues both as to the existence and significance of environmental injustice. But the matter has grown well beyond debate to policy and action. In the US, terms such as NIMBY (not in my backyard), LULU (locally undesirable land use), and dumping in Dixie capture the widespread sense that geography and social status have been significant factors in determining which communities end up bearing the environmental risk of manufacturing and waste disposal facilities. Fuelled by public concern and a growing list of reported environmental disasters in the hazardous waste arena,[7–9] political action by environmental and socially oriented NGOs gave rise to national pressure in the US in the late 1980s to integrate environmental justice into governmental policies. The resulting establishment of the EPA Office of Environmental Justice in 1992 was followed by President Clinton's Executive Order 12898, issued on 11 February 1994, which directed all federal agencies to develop an environmental justice strategy to identify and address adverse health and environmental effects of programmes,

**Abbreviations:** SES, socioeconomic status; MARS, major accident reporting system; RMP, risk management programme; FTE, full time employees

**Key points**

- Facilities with hazardous characteristics were more likely to be located in counties with higher median incomes, with greater income inequality, and with higher proportions of African-Americans.
- This pattern of increased risk of facilities in heavily African-American counties persists with several different measures of risk, even after adjusting for confounding variables pertaining to demographics and facility characteristics.

policies, and activities on minority and low income populations. These policies have also given rise to fundamental changes in company strategies, extending traditional internal monitoring and assessment procedures to encompass community exposure limits and environmental justice concerns.[10]

Concern about the geographical distribution of risk from chemicals and toxic emissions is not isolated to the US. Similar activities have been very much in evidence in Europe and Asia, after the disasters in Seveso, Bhopal, and Chernobyl. Citizen activism is also on the rise in emerging economies such as India and China.[11 12] In the European Union, environmental health monitoring and surveillance systems[13 14] and regulatory programmes have been developed[15] and data are slowly becoming available to assess the geographical distribution of risk. In particular, the major accident reporting system (MARS), set up in 1984 under the SEVESO II directive, has the potential to provide data for the EU that would allow a comparable study to that reported here. Kirchsteiger[16] indicates, however, that the regulation of reporting in the EU is weak and the threshold for reporting so high that the MARS data are presently very incomplete.

This manuscript is based on the first detailed assessment of the countrywide accident history data assembled under section 112(r) of the Clean Air Act Amendments of 1990 by the US Environmental Protection Agency. The data, covering the period 1994–2000, present a comparatively complete picture of the accident histories of chemical facilities in the United States using one or more of 140 toxic or flammable substances. (See Kleindorfer *et al*[17] for a detailed description of the data, the chemicals involved, and types of accidents.) This allows us to provide a nationwide assessment of the geographical pattern of risks from these chemicals and their relation to the SES and racial makeup of the counties in which facilities are located.

We considered two potential impacts of community characteristics that reflect two essential sources of risk to surrounding populations: (1) risks associated with the decision about where to locate hazardous facilities, which we term ''location risk''; and (2) risks associated with the methods of operation and standards of care that are used in existing facilities, which we term ''operations risk''. Our analysis proceeds by first considering the statistical association between community characteristics and ''location risk''—the risk of an intrinsically hazardous facility, as reflected by the quantity of chemicals stored there and their potential for harm, conditional on the surrounding community demographics. We then consider ''operations risk''—the risk of an accident and resulting bad outcomes, including injuries and property damage, conditional on the surrounding community demographics. Two questions can be asked about operations risk: (1) whether the demographics of the communities surrounding facilities are associated with risk of an accident; and (2) whether these community demographics are associated with accident risk *after adjusting for location risk*. This second question addresses the issue of whether facilities in low SES or African-American communities, or both, may exercise less caution in operations, even if they have the same amount of hazardous chemicals on site.

## METHODS

### Data sources

The information about facility risk has been obtained from the RMP*Info database. The RMP*Info database is set forth under Section 112(r) of the 1990 Clean Air Act Amendments. With certain exceptions, all facilities storing on site at least one of 77 toxic or one of 63 flammable substances above a threshold quantity are required to develop a risk management programme (RMP). (For details on the RMP, see the Environmental Protection Agency web site http://www.epa.gov/swercepp/pubs/potw/part6899.pdf). In addition to developing an RMP, each covered facility must also file assessments of hazards present at the facility together with a five year accident history with the US Environmental Protection Agency (US EPA). The regulation implementing 112(r) set a final deadline of 21 June 2001, for the filing of the RMP data, which then covered the preceding five year period. As filing under 112(r) is mandated by law, and carries significant penalties for non-compliance, the resulting data may be viewed as a reasonably complete and exhaustive picture of the hazards represented by the US chemical industry during 1994–2000.

The information contained in this RMP*Info database is extensive and includes details about on site chemicals and processes; regulatory programme coverage; geographical location; and number of full time employees (FTE). For each regulated chemical, the EPA determined a ''threshold quantity'' by a consideration of its potential toxicity, its potential for dispersion in the event of an unintentional release, and its flammability. Regulated substances were grouped into hazard levels, with thresholds set to values of 227, 455, 1136, 2273, 4545, 6818, and 9091 kg (500, 1000, 2500, 5000, 10000, 15000, and 20000 lb). The accident related information includes date and time of accident; number of associated injuries or deaths among workers, public responders, and the public at large; and other consequences such as property damage (on site, offsite), evacuations, confinement indoors of nearby residents, and environmental damage. In this analysis we focus on the total number of accidents and the total number of injuries, as they are the most common outcomes and may be the most consistently reported.

More than 97% of RMP*Info filings were submitted electronically, permitting consistency and range checks during the submission process. These filings followed an intensive multi-year public review process of the data requested under 112(r), and a series of pilot runs for the data submission process to determine and eliminate problem areas for respondents. The data obtained were screened for accuracy and consistency by the research team via interviews with plant level and corporate managers responsible for submitting RMP data and via examination for outliers and internal inconsistency in the data. Managers generally exhibited a clear understanding of the RMP process and devoted considerable effort toward its completion, suggesting data quality was likely to be high.[14] The data received a final review by facilities before their release; a review of the data by the researchers revealed no major remaining outliers or inconsistencies. The total number of filers in this initial implementation of 112(r) was 15 219. We restrict attention in this paper to the subset of 15 083 facilities in RMP*Info located in the 50 US states and the District of Columbia (''US facilities''), omitting facilities located in Puerto Rico and other US territories.

**Table 1** Characteristics of RMP reporting facilities in the 50 states and the District of Columbia and county level data associated with facilities

| | Mean | Median | SD | Min | Max |
|---|---|---|---|---|---|
| Total number of facilities = 15083 | | | | | |
| Number of chemicals | 1.38 | 1 | 1.65 | 1 | 59 |
| Toxic | 1.08 | 1 | 0.95 | 0 | 28 |
| Flammable | 0.31 | 0 | 1.14 | 0 | 31 |
| Total hazard* | 9.59 | 7.09 | 13.22 | −3.5 | 443.3 |
| Total number of counties = 2333 | | | | | |
| Total population in county (1000s) | 101 | 31 | 303 | 1 | 8863 |
| Percentage of adults 25 and older with less than high school education | 28.6 | 27.2 | 9.1 | 5.2 | 68.4 |
| Percentage of adults 25 and older with four or more years of college | 14.1 | 12.3 | 6.4 | 4.2 | 49.9 |
| Percentage of population in surrounding county white | 87.8 | 94.1 | 14.5 | 23.0 | 100.0 |
| Percentage of population African-American | 8.0 | 1.6 | 13.1 | 0.0 | 74.7 |
| Median county household income ($1000s) | 24.9 | 23.6 | 6.4 | 10.2 | 59.2 |
| Percentage of households below poverty | 11.3 | 10.3 | 5.1 | 1.7 | 46.0 |
| Gini index of income inequality | 0.457 | 0.452 | 0.042 | 0.345 | 0.649 |
| Percentage of labour force employed in manufacturing | 18.3 | 17.3 | 10.0 | 0.4 | 53.7 |

*''Total hazard'' is calculated as defined in the Methods section.

The US Census Bureau's Summary Tape File 3A (STF-3A) from the 1990 decennial census contains detailed county level information, including total population, education, race, and income data.[18] Ecological predictors used in this analysis include, for each county, percentage of population age 25 and older with less than 12 grades of education; percentage of population 25 and older with 16 or more grades of education; percentage of total population white; percentage of total population African-American; median household income; percentage of population living in households with income below poverty (''poor''); and percentage of the labour force employed in manufacturing jobs (in contrast with employment in other sectors such as financial or service). In addition, we constructed an approximation to the Gini index of income inequality[16] for each county by using midpoint information on 25 household income category bins (from $5000/y to greater than $150 000/y).

## Data analysis

As a summary measure of facility hazardousness, we constructed a ''total hazard'' measure, calculated as the sum over all regulated chemicals at the facility of $\log_2$(maximum quantity of inventory on site/threshold). Hence a total hazard measure of 0 indicates that only threshold levels of chemicals are kept in inventory, a total hazard measure of 1 means 1 chemical is kept at up to twice threshold level, 2 means 2 chemicals kept at up to twice threshold level or 1 chemical at up to four times threshold level, and so forth; unit changes in this measure can thus be interpreted as either a doubling of volume inventoried of a single chemical or an addition of another twice-threshold chemical on site. Note that threshold levels are inversely proportional to the per weight hazardousness of the chemical.

For the outcome of location risk, we consider the Spearman rank correlations[20] between hazard measures of FTEs, number of chemicals used, and total hazard measure and the surrounding county's median household income, percentage of population white, percentage of population African-American, percentage of population in poverty, percentage of labour force in manufacturing, and income inequality. Partial Spearman correlations were used to determine the residual correlation between the location risk outcome measures and a given demographic characteristic, after adjusting for all other county demographic measures.

For the outcome of operations risk, we consider expected number of accident and injury counts as a function of the surrounding county's demographic makeup, both unadjusted

**Table 2** Spearman correlations among demographic variables for counties with RMP reporting facilities

| | Median household income | % Poverty | Income inequality | % Manufacturing | % No high school | % College or more | Total population |
|---|---|---|---|---|---|---|---|
| % African-American | **0.07** | **0.25** | **0.38** | **0.27** | **0.30** | **0.07** | **0.48** |
| Median household income | 1.00 | −**0.81** | −**0.62** | **0.12** | −**0.63** | **0.56** | **0.56** |
| % Poverty | | 1.00 | **0.78** | −**0.13** | **0.65** | −**0.37** | −**0.27** |
| Income inequality* | | | 1.00 | −**0.16** | **0.51** | −**0.14** | −**0.07** |
| %Manufacturing | | | | 1.00 | **0.27** | −**0.33** | **0.24** |
| % No high school | | | | | 1.00 | −**0.71** | −**0.26** |
| % College or more | | | | | | 1.00 | **0.47** |

*Gini index of income inequality. Values in bold significant at $p \leq 0.05$.

**Table 3** Location risk: Spearman rank correlations between county demographic variables and three measures of hazardousness

| | Number of full time employees | Number of chemicals* | Total hazard |
|---|---|---|---|
| % African-American | **0.34** | **0.19** | −**0.05** |
| Median household income | **0.25** | **0.08** | −**0.04** |
| % Poverty | 0.00 | **0.08** | **0.02** |
| Income inequality† | **0.10** | **0.09** | −**0.03** |
| % No high school | **0.04** | **0.03** | −**0.02** |
| % College | **0.20** | **0.10** | −**0.04** |
| %Manufacturing | **0.19** | **0.04** | −**0.03** |
| Total population | **0.39** | **0.16** | −**0.09** |
| **Adjusted** | | | |
| % African-American | **0.06** | **0.06** | −**0.02** |
| Median household income | **0.04** | **0.05** | **0.05** |
| % Poverty | **0.02** | **0.08** | **0.07** |
| Income inequality† | −0.00 | −0.02 | −**0.02** |
| % No high school | **0.08** | 0.00 | **-0.06** |
| % College | **0.06** | **0.02** | −0.02 |
| %Manufacturing | **0.12** | **0.03** | 0.00 |
| Total population | **0.13** | 0.01 | −**0.09** |

*Number of chemical used at facility above RMP*Info reporting threshold. †Gini index of income inequality. Values in bold type significant at $p \leqslant 0.05$. (Adjusted = partial correlations after adjusting for all other demographic variables.)

and adjusted for the facility's intrinsic hazardousness. We generated these two different models because of our conceptual framework. The model that is not adjusted for facility hazardousness examines the association between county demographic characteristics and overall risk of an accident occurring. The model that is adjusted for facility hazardousness examines the association between demographic characteristics and risk of an accident occurring, adjusting for the number of hazardous chemicals and their quantities. The adjusted model may test more directly the association between demographic characteristics and ''operations risk,'' the facility management's level of precaution in operating the facility.

We related the expected number of accidents and injuries per facility to the predictors of interest via generalised linear models,[21] in particular negative binomial regression. The interpretation of the regression parameters is that of a log relative risk, similar to that of Poisson regression. Confidence intervals for these odds ratios are constructed from the profile log-likelihood. Likelihood ratio tests are used to compare nested models. Potential outlier facilities were determined using Pearson deviance residuals and the regression models re-run with these outliers removed: little change was observed in the reported regression parameters. Linear and negative binomial regression models are fit using the SAS system for Windows version 8 (Cary, NC, SAS Institute).

Continuous covariates were grouped into categories to allow for non-linear effects and to better highlight their effect over their range in the data; the groupings were chosen by considering a reasonably broad set of cut off points sufficiently separated to consider the full range of the data yet still containing a reasonably large sample size. Percentage African-American was selected as the key ethnic predictor, because it was a more powerful predictor of accident risk than alternatives such as Hispanicity or non-white.

## RESULTS

Of the 15 083 US facilities, 1183 (7.8%) reported at least one accident and 669 (4.4%) reported accidents with associated worker or public injuries during the calendar years 1994 to 1999. Among the 1183 US facilities with accidents, 70% (5.5% of all reporting facilities) reported exactly one accident, while 30% (2.3% of all) reported two or more; 30% (2.3% of all) reported exactly one injury, while 27% (2.1% of all) reported two or more persons injured. The total number of accidents across all reporting facilities was 1946. The most common chemicals involved in accidents were chlorine (696), ammonia (594), and flammable mixture (100). Table 1 summarises important facility and community variables.

Because many of the community predictors are interrelated, some of the associations between risk and a particular community demographic measure may be the result of some underlying relation among the community demographics. Table 2 reports Spearman correlations among the community level demographics for the 2333 US counties with at least one reporting facility. Counties with greater proportions of African-Americans tend to have slightly higher average incomes and substantially higher poverty rates, that is, to be counties with higher degrees of income inequality. More populated counties tend to have higher proportions of minority (that is, non-white) populations as well as higher levels of education and income. We note in passing that the average area of a US county is 3066 $km^2$.

We first consider ''location risk.'' Table 3 considers the effect of ''location risk'' as the Spearman correlations between demographic characteristics of the county in which each reporting facility is sited and hazardousness of the facility. Facilities with more employees and facilities using a larger number of regulated chemicals are more likely to be located in more heavily populated and more heavily African-American counties, and to a lesser extent in counties with a greater proportion of the labour force employed in manufacturing, in counties with high median incomes, in counties with a larger percentage of college graduates (but not with a corresponding lower percentage without high school), and in counties with a higher degree of income inequality. When location risk is measured in terms of the summary hazard measure of the facility, the associations with the surrounding community demographics are generally weak, and tend to be in the opposite direction of the association with size and number of chemicals. When we simultaneously adjust for all county demographic factors, we find that larger facilities are found in more populated counties with large manufacturing labour forces, in counties with greater extremes of education, and in more heavily African-American counties. Facilities using larger numbers of chemicals are found in counties with greater extremes of income and in more heavily African-American counties. Facility hazard was positively associated with greater extremes of income but negatively associated with county population.

**Table 4** Operations risk: adjusted relative risk (RR) for facility accidents or injuries in 1995–2000)

| | Bivariate analyses | | | | | Model 1 | Model 2 |
|---|---|---|---|---|---|---|---|
| **Accidents** | | | | | | | |
| 1–10% African-American (v <1%) | **1.92(1.63 to 2.28)** | | | | | **1.60(1.33 to 1.91)** | 1.21(0.99 to 1.47) |
| 10–20% African-American | **2.44(1.97 to 3.01)** | | | | | **1.79(1.41 to 2.29)** | 1.19(0.92 to 1.54) |
| >20% African-American | **3.79(3.10 to 4.66)** | | | | | **3.03(2.40 to 3.83)** | **1.85(1.45 to 2.37)** |
| Median income $20–30K (v <$20K) | | **1.43(1.10 to 1.87)** | | | | **1.58(1.16 to 2.16)** | 0.92(0.67 to 1.28) |
| Median income $30–40K | | **1.85(1.39 to 2.46)** | | | | **2.05(1.44 to 2.94)** | 0.99(0.68 to 1.44) |
| Median income $40K+ | | **1.83(1.23 to 2.73)** | | | | **2.34(1.42 to 3.89)** | 1.00(0.60 to 1.67) |
| 5–10% income below poverty (v <5%) | | | 0.76(0.57 to 1.01) | | | 0.91(0.64 to 1.30) | 0.80(0.57 to 1.13) |
| 10–20% income below poverty | | | 1.07(0.81 to 1.43) | | | 1.01(0.68 to 1.49) | 0.79(0.52 to 1.13) |
| | | | 0.77(0.47 to 1.28) | | | 0.82(0.42 to 1.61) | 0.54(0.28 to 1.04) |
| Income inequality 0.4–0.45 (v <0.4)* | | | | 1.21(0.87 to 1.67) | | 1.24(.88 to 1.76) | 1.21(.86 to 1.71) |
| Income inequality 0.45–0.55 | | | | **1.70(1.23 to 2.35)** | | **1.46(1.00 to 2.14)** | 1.44(0.99 to 2.10) |
| Income inequality >0.55 | | | | **2.36(1.28 to 4.42)** | | **2.08(1.05 to 4.24)** | 1.84(0.93 to 3.65) |
| 10+% Manufacturing (v <10%) | | | | | **1.98(1.64 to 2.39)** | **1.57(1.29 to 1.91)** | **1.30(1.06 to 1.59)** |
| 10–50K Total population (v <10K) | | | | | | | **1.61(1.16 to 2.26)** |
| 50K+ population | | | | | | | **2.30(1.64 to 3.28)** |
| Number of FTEs (1000s) | | | | | | | **1.68(1.44 to 1.99)** |
| Total hazard measure† | | | | | | | **1.05(1.05 to 1.06)** |
| **Injuries** | | | | | | | |
| 1–10% African-American(v <1%) | **2.12(1.63 to 2.77)** | | | | | **1.52(1.13 to 2.05)** | 1.01(0.74 to 1.36) |
| 10–20% African-American | **3.01(2.14 to 4.28)** | | | | | **1.74(1.16 to 2.62)** | 1.19(0.80 to 1.78) |
| >20% African-American | **3.90(2.77 to 5.58)** | | | | | **2.46(1.64 to 3.71)** | 1.41(0.95 to 2.10) |
| Median income $20–30K (v <$20K) | | **1.64(1.07 to 2.46)** | | | | **2.13(1.29 to 3.45)** | 0.83(0.50 to 1.35) |
| Median income $30–40K | | **1.79(1.19 to 2.80)** | | | | **2.70(1.50 to 4.81)** | 1.04(0.58 to 1.84) |
| Median income >$40K | | 1.90(0.99 to 3.76) | | | | **4.77(2.12 to 10.98)** | 1.29(0.58 to 2.90) |
| 5–10% income below poverty (v <5%) | | | 1.05(0.63 to 1.68) | | | 1.43(0.77 to 2.61) | 1.04(0.58 to 1.82) |
| 10–20% income below poverty | | | **1.68(1.01 to 2.70)** | | | 1.62(0.82 to 3.14) | 1.02(0.54 to 1.89) |
| >20% income below poverty | | | 1.12(0.50 to 2.66) | | | 1.94(0.65 to 6.04) | 0.97(0.36 to 2.65) |
| Income inequality 0.4–0.45 (v <0.4)* | | | | 1.27(0.74 to 2.10) | | 1.16(0.63 to 2.09) | 1.17(0.67 to 2.02) |
| Income inequality 0.45–0.55 | | | | **2.41(1.41 to 3.98)** | | 1.87(0.96 to 3.59) | 1.60(0.87 to 2.93) |
| Income inequality >0.55 | | | | 1.82(0.66 to 5.94) | | 1.47(0.42 to 5.74) | 1.35(0.45 to 4.26) |
| >10% Manufacturing (v <10%) | | | | | **2.69(1.99 to 3.60)** | **2.36(1.72 to 3.20)** | **1.47(1.07 to 2.01)** |
| 10–50K Total population (v <10K) | | | | | | | **1.69(1.05 to 2.74)** |
| 50K+population | | | | | | | **2.98(1.79 to 4.99)** |
| Number of FTEs (1000s) | | | | | | | **6.32(4.57 to 9.00)** |
| Total hazard measure† | | | | | | | **1.06(1.05 to 1.07)** |

95% confidence intervals in parentheses; values in bold type significant at p<0.05. *Gini index of income inequality. †Total hazard is calculated as defined in the Methods section.

Table 4 considers "operations risk," the risk of actual accidents at a facility, with and without adjustments for "location risk". (In this analysis we have dropped the educational level of the county as a covariate, as little explanatory power remained for education after adjusting for race and income.) Facilities were at greater risk of accident and injury in more heavily African-American counties, in counties with higher median incomes, in counties with a larger degree of income inequality (accident only), and in counties with a larger percentage of the labour force involved

**Table 5** Illustrative Midwestern county zip code containing one facility with a major accident (eight injuries, $12 857 000 property damage) compared with 12 other county zip codes containing reporting facilities with no accidents and with the county as a whole

| | Major accident zip code | Mean of other facility zip codes (range) | All county |
|---|---|---|---|
| % African-American | 23.1 | 16.9 (2.0–74.2) | 15.9 |
| % Poor | 17.6 | 14.8 (2.8–30.8) | 10.1 |
| Median household income (1000s) | 24.4 | 27.1 (16.3–45.2) | 30.4 |
| % Employed in manufacturing | 17.9 | 13.1 (7.0–16.4) | 12.2 |
| % No high school | 42.9 | 25.3 (8.5–43.5) | 19.0 |
| % College | 4.1 | 19.6 (6.6–36.6) | 26.6 |

in manufacturing. Even after adjusting for location risk, the effect of race remains significant, however, with the RR of accidents 1.9 times as great (95% CI = 1.5 to 2.4) in facilities in counties that were 20% or more African-American compared with <1% African-American. In other words, facilities with the same number of hazardous chemicals, the same hazard score for number and quantity of chemicals, and the same number of employees were more likely to have accidents when they were sited in counties with more African-Americans, even after adjusting for other demographic factors and facility characteristics.

## DISCUSSION

The relation between chemical facility risk and the demographics of the surrounding community is complex. This study found evidence that heavily African-American counties experience greater location risk and greater operations risk. Greater location risk means more employees and higher number of chemicals in use at facilities in these counties. Greater operations risk means that facilities in these counties had greater risks of an accidental chemical release, and of having injuries associated with the chemical release. The operations risk for the most heavily African-American counties persists even after accounting for location risk.

The impact of income and poverty is more complex. Larger facilities were more likely to be located in counties with higher median incomes and higher levels of income inequality, although part of the median income association is explained by the fact that larger facilities tend to also be located in counties with large populations. Similarly, facilities in higher income counties with higher levels of poverty, or at least without corresponding low poverty levels—again, high income inequality counties—were at greater operational risk as well. However, after adjusting for ''total hazardousness'', income and income inequality were no longer associated with operations risk.

Thus, higher risk facilities are more likely to be found in counties with sizeable poor and/or minority populations that disproportionately bear the collateral environmental, property, and health risks. An alternative, though related, perspective is that communities burdened by low SES and past or present discrimination may be willing to accept these risks to obtain the economic benefits of facility location, or that residents not willing to accept this risk move away.[22] For facilities of a similar hazard level, those operated in more heavily African-American counties seem to pose greater risk of accident and injury than those in counties with fewer African-Americans.

As an example to illustrate how these mechanisms might work on a smaller scale, we consider a single Midwestern county as a case study (see table 5). This county contained 19 facilities but only one facility that reported accidents—a single accident resulting in eight injuries (four to workers and four to public responders) and over $12 000 000 in property damage (including $87 000 off site). In addition to this facility, there were 18 other reporting facilities in this county, none of which reported accidents. If we consider the zip code associated with this facility, we see that it has much lower income and education measures and a higher minority proportion than the county as a whole. If we restrict our attention to just the 12 zip codes in this county containing reporting facilities, we see that the worst case zip code has the third highest proportion of African-Americans, the second highest proportion without a high school education, and the lowest proportion with college education. These associations between race and education are in line with our national data. However, we also note that the zip code in which the accident occurred exhibited the highest proportion employed in manufacturing, only the fifth highest rate of poverty, and a rank of 6 out of 12 in median income, contrasting with the associations in our national data. The county had an overall income inequality measure of 0.4510, which was somewhat below the national average.

In summary, a disproportionate burden of location risk for counties with specific demographic characteristics supports an increased focus on assessments of total ''regional load'' from all facilities in such counties as part of siting and permitting of new or expanded facilities. The findings on operations risk are more disturbing as they suggest that there may be aspects of county administration, regulatory enforcement, management procedures or community facility interactions in counties with heavier African-American populations that engender higher risks from chemical facilities located in those counties, even after controlling for the hazardousness of these facilities. At the very least, this finding would suggest prioritising regulatory oversight and audit of facilities in counties with characteristics identified as being at increased risk. As the majority of the most hazardous facilities are covered by the Emergency Preparedness and Community Right to Know Act (EPCRA), and all facilities analysed here are covered by the informational requirements of 112(r) of the Clean Air Act Amendments, there are in place already significant levers for informing and involving the community concerning the operations of hazardous facilities located nearby. This paper suggests that these levers may need to be reinforced, by both governmental and non-governmental organisations, in jurisdictions whose characteristics point to higher risk levels.

### Limitations of the study and future research directions

There were several limitations to our study. Firstly, the methodology used may not have completely separated location risk from operations risk. When adjusting for location risk or facility hazardousness in the model to study predictors of operations risk, comparatively simple measures

## Policy implications

- These findings suggest the need for further research and for policy interventions designed to reduce the probability of locating facilities in an inequitable fashion, as well as health surveillance, and regulatory monitoring and enforcement activities to ensure that hazardous facilities in minority communities operate according to the same standards as elsewhere in respect to preparedness and prevention of chemical accidents and releases.

of hazardousness were used. Therefore, residual confounding by location risk remains a possibility. For example, there may be interactions between certain chemicals or between chemicals or processes that may increase or decrease risk in a manner that the count of chemicals or total hazard measure does not capture. Even were residual confounding substantial, it would not detract from our primary finding that location risk and operation risk are greater in counties with more African-Americans.

Selection bias remains a possibility, in that the sampling frame containing the RMP*Info facilities may not include all required facilities. This issue is discussed in detail in Kleindorfer *et al*,[17] who conclude that the data assembled under RMP*Info are rather complete, especially among larger firms and in industry segments like propane, chlorine, and ammonia, where strong trade associations exist. Considerable effort was undertaken over the period 1996–1999 to advertise the requirements of the Rule. Moreover, there are significant penalties for non-compliance, especially for larger firms with reputations at risk if allegations of environmental impairment are raised against them. County level and regional organisations in areas with high concentrations of chemical facilities also pushed hard to have every covered facility file so that a complete picture of risks from chemical accidents in their region could be obtained.

Analyses could be conducted at different geographical levels. A postal zip code level analysis is problematic because zip codes are not necessarily contiguous, authoritative maps do not exist, and 8% of facilities did not have zip codes that could be linked to census zip code records. We are pursing analyses at the census track level, though ambiguous and erroneous address data present problems here as well.

A further important extension would consider the public health effects of these accidents.[23 24] Accidents can have both acute and chronic health effects. For example, integrating the Center for Disease Control Hazardous Substances Emergency Events Surveillance (HSEES) database with the RMP*Info database could yield estimates of the acute and chronic consequences of such accidents, which may differ considerably across chemicals.

Finally, because the EPA plans to repeat the RMP*Info data collection in 2004 and at regular intervals thereafter, the current analysis serves as an important initial benchmark for future trends in US accident history. As the RMP process is repeated in 2004 and beyond, we should begin to develop a much better understanding of the differential sources of risk by chemical and process, of their effects on the communities in which they are located, and on the needed regulatory and policy developments to mitigate these, both in total and for specific population segments that may currently face an inequitable portion of the overall risks from economic activity.

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