GEOGRAPHIC PATTERNS OF RURAL TOXIC AIRBORNE RELEASES

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This paper examines the spatial distribution of airborne releases of acute toxins in nonmetropolitan areas of the United States. It is often thought that releases of acute toxic substances into the air occur only in major industrial areas of the country. Such incidents also occur in rural areas and are more likely to occur in certain types of rural locations than others. This study describes the location patterns and frequency of toxic chemical releases and explains how they are associated with rural industrialization, hazardous material transportation corridors, and other aspects of hazardous chemical use in nonmetropolitan areas.

It is difficult for communities to manage for accidental releases of hazardous substances. Airborne toxins are particularly insidious because they can spread unchecked in the atmosphere and be inhaled unwittingly. Unplanned releases are frequently sudden and can occur almost anywhere and anytime. Virtually all United States municipalities view accidental releases of hazardous substances with grave concern.[1] Tens of thousands of accidents involving hazardous materials occur yearly.[2] Since 1980 138 people have been killed, 4,717 injured, and more than 200,000 evacuated from their homes because of accidents involving the airborne release of acute toxic substances. The cost of resulting damages and emergency responses ranges in the billions of dollars.[3]

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[1]U.S. Department of Transportation/National Response Team, *Hazardous Materials Emergency Planning Guide* (Washington, D.C.: National Response Team, 1979), p. 1.

[2]U.S. Department of Transportation/National Response Center, *Hazardous Material Spills Data Records; 1982-1986* (Boston, MA: U.S. Department of Transportation/National Response Center), Annual Data; U.S. Office of Technology Assessment, *Transportation of Hazardous Materials: State and Local Activities* (Washington, D.C.: Government Printing Office, 1986), p. 4.

[3]Industrial Economics Incorporated, *Acute Hazardous Events Data Base*, Interim Final Report for the Office of Toxic Substances, EPA 560-5-85-029 (Cambridge, MA: Industrial Economics Incorporated, 1985), pp. iii-iv.

Airborne releases pose particular problems for rural communities.[4] Frequently these communities are poorly prepared, because local agencies lack the experience, equipment or personnel to respond to toxic-release emergencies. Indeed, many rural communities have been unable to meet the requirements set forth in the Superfund Amendment Reauthorization Act, which mandates that all communities in the United States develop emergency response plans and identify acute chemical hazards within their jurisdictions.[5]

In research on the national pattern of airborne toxic releases, Cutter and Solecki[6] found that of the 571 incidents reported during 1982-86, roughly 20 percent occurred in non-metropolitan areas of the United States. The problem in rural areas is even more serious because the frequency of rural incidents has increased at a rate faster than that of urban incidents. Nevertheless, little research has been done on the geographic distribution of rural airborne toxic releases. In light of these facts, further analysis of rural risks and hazards is warranted.

Risk, hazard and hazardousness of place are important concepts in this paper. Risk is defined as the mathematical probability that an unexpected or unintentional airborne release of a toxic chemical from a containment facility will occur. A hazard is defined as the actual release of materials from storage. The hazardousness of a place refers to the hazard potential of a location. In the case of airborne toxic substances, hazards are often associated with chemical production plants, chemical warehouses, and routes along which hazardous materials are transported.

It is important to recognize that the risk and potential hazard of an event can vary greatly depending on location. Hazardousness of place is the qualitative summary of all the hazards present at a

[4]Rebecca Hessel Garten and Eugene R. Russell, "Integration of Hazardous Materials Emergency Planning into Small-Town Planning," in *Recent Advances in Hazardous Materials Transportation Research, an International Exchange Process* (Washington, D.C.: Transportation Research Board, National Research Council, 1985), pp. 74-78.

[5]Charles E. Faupel and Conner Bailey, "Contingencies affecting emergency preparedness for hazardous wastes," *International Journal of Mass Emergencies and Disasters 1989*. In Press.

[6]Susan L. Cutter and William D. Solecki, "The National Pattern of Airborne Toxic Releases," *Professional Geographer* 41 (May 1989): 149-61.

particular location or in a region.[7] Cutter and Solecki[8] found that there is great spatial variation in the level of risk and hazard present in the United States. They found that the number of chemical firms and railroad mileage were the most useful factors for distinguishing between high- and low-hazard areas. This paper furthers the geographic analysis of the hazardousness of place in two ways. Firstly, it classifies and describes the types of airborne toxic hazards that characterize rural landscapes. Secondly, it summarizes the spatial distribution of these hazard types in the United States.

METHODS

One hundred and thirty-five accidental releases of acute toxins, occurring in counties outside of a Standard Metropolitan

Statistical Area, were analyzed in the study. The data set is a subset of information compiled by Cutter and Solecki.[9] The data set includes twenty-five variables and represents a conservative sample of the total number of incidents that occurred during the 1982-1986 period.

The location of each incident was mapped. Descriptive statistics and multivariate analysis were used to analyze the source and magnitude of potential hazards. Statistics were tabulated for twelve accident-specific variables (Table 1). Five county-specific and eight state-specific variables, representing contextual risk and potential hazard measures, also were included in the analysis. All three sets of variables were combined in a principal components analysis to detect the strength of association among the incidents and classify groups of similar incidents. Four main groups of incidents were identified; each is an expression of a different airborne chemical hazard.

RESULTS

Accidental airborne releases occurred throughout the United States during the study period (Figure 1). Slightly more than one-half of the incidents happened east of the Mississippi River, with a

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[7]Kenneth Hewitt and Ian Burton, *The Hazardousness of Place: A Regional Ecology of Damaging Events* (Toronto: University of Toronto Press, 1971), pp. 24-27.

[8]Cutter and Solecki, op. cit., footnote 6.

[9]Cutter and Solecki, op. cit., footnote 6.

Table 1: Variables

Variable	Value	Source--Table Note Number:
Accident-specific		
Accident type (acctype)	0 = transportation; 1 = fixed	1
Carrier (carrier)	0 = rail; 1 = road	1
Injuries and Deaths (injury)	number of people	1
Location (location)	0 = transfer point; 1 = transit	1
Material released		
* - type	name of material	1
* - amount	0 = known; 1 = not known	
- toxicity	0 = may be poisonous; 1 = poisonous	2
Season		
winter (winter)	0 = no; 1 = yes	1
spring (spring)	0 = no; 1 = yes	
summer (summer)	0 = no; 1 = yes	
fall (fall)	0 = no; 1 = yes	
Time (time)	0 night; 1 = day	1
Year (year)	1982-1986	1
Week (week)	0 = Friday-Monday 1 = Tuesday-Thursday	1
County-specific		
Agricultural chemicals, including fertilizer (agrisum)	number of acres of application	3
Chemical firms (chemestb)	number of firms	4
Manufacturing firms (indsestb)	number of firms	4
Manufacturing employment (xlarge)	number of firms with > 200 workers	4
Borders a metropolitan area	0 = no; 1 = yes	5
State-specific		
Chemical firms (chemfirm)	number of firms	4
Hazardous material regulation		6
-Right to know (rttoknow)	0 = no; 1 = yes	
-Transport fee (hazmtfee)	0 = no; 1 = yes	
-Notification requirement (hmnotif)	0 = no; 1 = yes	
Hazardous waste facilities (hwfacil)	number operating	7
Non-metropolitan wholesalers	number of wholesalers	8
-chemical products (chemwhl)		
-farm supplies (farmwhl)		
Value of chemical products shipments (shipment)	millions of dollars	4

* - Variable not used in the principal components analysis.

Table 1 (continued):

Table Notes:

(1) U.S. Department of Transportation/National Response Center, *Hazardous Material Spills Data Records; 1982-1986* (Boston, MA: U.S. Department of Transportation/National Response Center), Annual Data; U.S. Office of Technology Assessment, *Transportation of Hazardous Materials: State and Local Activities* (Washington, D.C.: Government Printing Office, 1986), p. 4.
(2) U.S. Department of Transportation, *Emergency Response Guidebook for Hazardous Materials Incidents* (Washington, D.C.: Government Printing Office, DOT P 5800.3, 1984).
(3) U.S. Department of Commerce, Bureau of Census, *U.S. Census of Agriculture: 1982* Volume 1, *State Data* (Washington, D.C.: Government Printing Office, 1984), Table 7, various state volumes.
(4) U.S. Department of Commerce, Bureau of Census *U.S. Census of Manufacturing: 1982* (Washington, D.C.: Government Printing Office, 1984), Table 9, various state volumes.
(5) *Rand McNally Commercial Atlas & Marketing Guide, 1988* (New York: Rand McNally and Company, 1988).
(6) Industrial Economics Incorporated, *Acute Hazardous Events Data Base*, Interim Final Report for the Office of Toxic Substances, EPA 560-5-85-029 (Cambridge, MA: Industrial Economics Incorporated, 1985), pp. iii-iv.
(7) U.S. Congress, Legislative Commission on Toxic Substance and Hazardous Wastes, *Hazardous Waste Facility Siting A National Survey; June, 1987* (Washington, D.C.: Government Printing Office, 1984), pp. 14-15.
(8) U.S. Department of Commerce, Bureau of Census, *U.S. Census of Wholesalers: 1982* (Washington, D.C.: Government Printing Office, 1984), Table 5, various state volumes.

pronounced cluster appearing in the central Midwest. California and Illinois were the only states with more than ten releases. Forty-two percent of the releases were concentrated in only six states: California, Illinois, Indiana, Iowa, Kentucky and Texas. No releases occurred in thirteen states. Few incidents occurred in the Southeast, northern Great Plains and the Southwest. There were no incidents in New Jersey because all of the counties in that state are classified as metropolitan. The low count in New England could be due to the fact that most of its counties also have this classification.

Frequencies of thirteen accident-specific variables were calculated. A great variation among the frequencies was found, but the total number of rural releases increased each year and nearly doubled for the study period.

Anhydrous ammonia was involved in about 20 percent of the accidents. Airborne releases of more than fifty other chemicals were responsible for the remaining 80 percent. Most of the materials were defined as poisonous and likely poisonous and very few were found to be likely fatal, although the releases did cause 197 injuries and one fatality.

Wide temporal variations existed among the incidents; more than 66 percent occurred during the spring and summer. Relatively few took place during the remainder of the year. Overall, a slightly higher number of incidents occurred during the daytime, but weekday nights and weekend periods also showed slight concentrations.

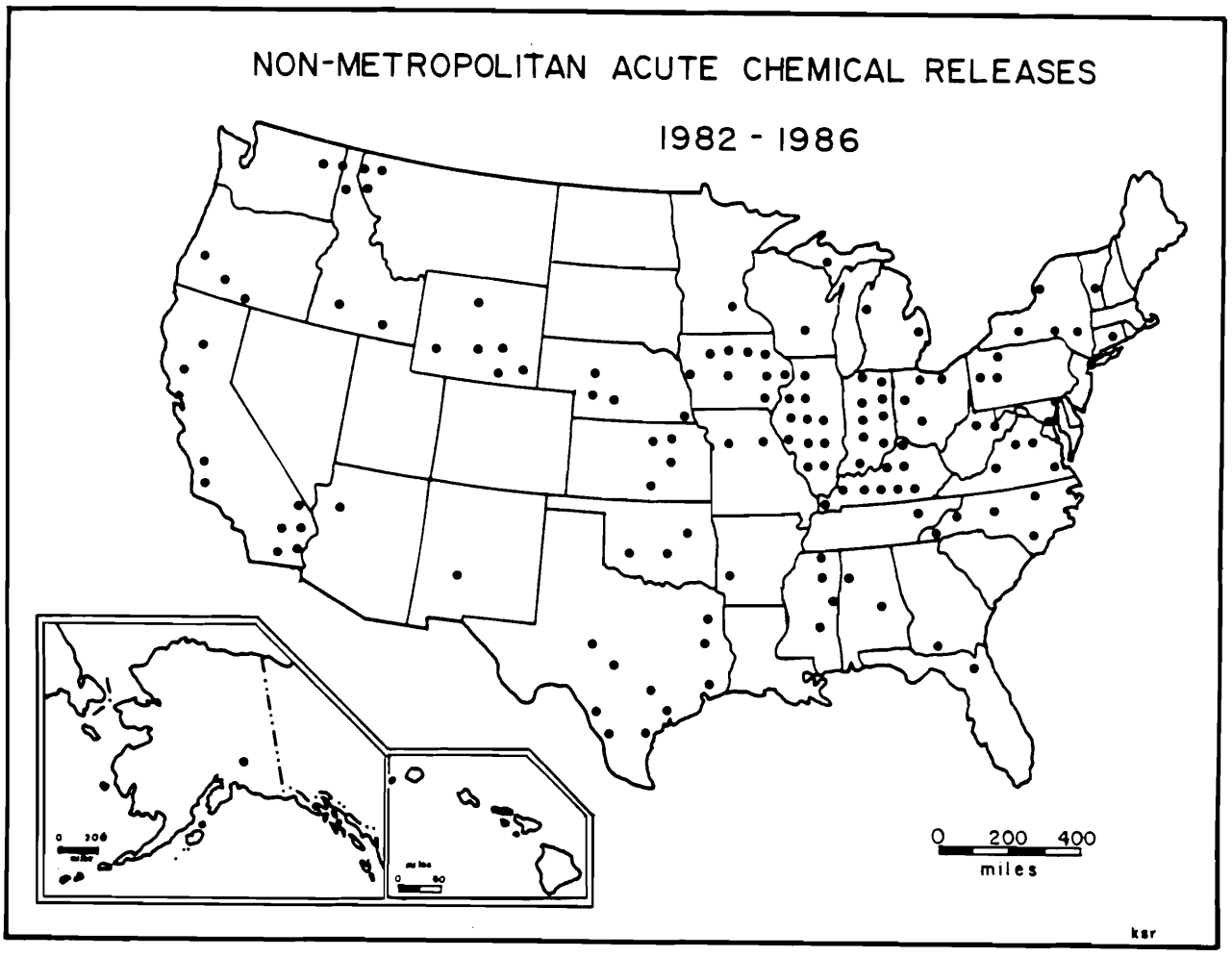

Figure 1

Almost all of the releases were the result of accidents during transportation of hazardous materials. Trains were involved more than twice as often as trucks. The vast majority of incidents occurred during the transport of the materials rather than at shipping and receiving points.

Different groups of airborne releases were identified through principal components analysis. The eleven components with eigenvalues greater than 1.00 accounted for 76 percent of the association among the variables (Table 2). Because of the low predictive value of the nominal variables, all component loadings above .400 were deemed significant.

The first component identifies accidents which occurred in states where a relatively large amount of hazardous material is generated, used and stored. Nonmetropolitan counties with a concentration of manufacturing firms, particularly chemical facilities, are identified by the second component. Many of these counties have large populations and are adjacent to metropolitan areas. The next three components define groups of accidents that happened in agricultural counties, where large amounts of chemical fertilizers are used. Many of these incidents occurred during the spring and summer.

The last six components distinguish toxic releases related to transportation. As a group, these incidents are somewhat weaker than the other components. No single group has an eigenvalue greater

TABLE 2. Component Loadings

Variable Name	1	2	3	4	5	6	7	8	9	10	11
indsestb		.786									
chemestb		.664	-.471								
xlarge		.560	-.453								
adjacent											-.527
chemwhl	.666	-.463									
farmwhl	.467	-.513		.452							
winter				-.506			.671				
spring			.410		.733						
summer			-.430	.426		-.531		.400			
fall					-.499	.596					
hwfacil	.846										
time								.512			
location											.605
carrier			.412					.483	.450		
injury					.416				.471		
death						.488					
rttoknow				.582				.447			
hmnotif			.637								
hazmtfee	.417				-.632						
chemfirm	.749		.427								
shipment	.922										
hazchem							.525			-.615	
acctype										.670	
agrisum			.521			-.409					
Eigen-value	3.66	3.18	2.13	1.92	1.70	1.46	1.29	1.22	1.16	1.04	1.00
Percent Variation	14.1	12.2	8.2	7.4	6.5	5.6	5.0	4.7	4.5	4.0	3.9

than 1.50. Truck accidents during weekday daylight hours exhibit some importance and many occurred on isolated local highways and involved injuries. Another relatively important group of incidents involved weekend, nighttime train accidents.

DISCUSSION

Based on the analysis, four factors associated with rural, airborne toxic hazards can be identified. The first factor indicates that rural airborne releases will occur in states where large volumes of hazardous materials are handled. Even if most of these activities tend to be concentrated in urban areas of major industrial states, the data clearly indicate that some releases happen in rural locales, particularly on transportation corridors.

The second factor relates to rural industrialization. Many of the incidents occurred in counties with relatively large amounts of industrial development, particularly chemical manufacturing. Rural industrialization has increased dramatically since the end of World War II.[10] Manufacturing employment in non-metropolitan areas gained 1.8 million jobs from 1962 to 1978, an increase of more than 50 percent, while employment in metropolitan areas only increased ten percent over the same period.[11] A more recent phenomenon is that some of the evolving "high tech" industries are locating in rural areas.[12] The growing presence of these industries is obviously increasing the likelihood of accidental airborne releases of toxic materials.

The third factor represents releases which occurred in heavily agricultural counties. During the past forty years, American farmers have become increasingly dependent on commercial fertilizer and pesticides to maintain and increase their harvest yields. It can be assumed that many of these releases

[10]Gene F. Summers et al., *Industrial Invasion of Nonmetropolitan America, A Quarter Century of Experience* (New York: Praeger Publishers, 1976), p. 7-12; Richard E. Lonsdale and H.L. Seyler, eds., *Non-Metropolitan Industrialization* (New York: John Wiley and Sons, 1979), p. 15.

[11]Claude C. Haren and Ronald W. Holling, "Industrial development in nonmetropolitan America: a locational perspective," in *Nonmetropolitan Industrialization*, eds. Richard E. Lonsdale and H.L. Seyler (New York: John Wiley and Sons, 1979), pp. 13-46.

[12]Ann Markunsen et al., *High Tech America, The What, How, Where, and Why of the Sunrise Industries* (Boston, MA: Allen and Urwin, 1986). David L. Barkley, "The Decentralization of High-Technology Manufacturing to Nonmetropolitan Areas," *Growth and Change* 19 (Winter 1988): 13-30.

were related to the use of hazardous chemicals in agriculture. In fact, many of the incidents in agricultural counties involved anhydrous ammonia, a chemical which is a primary component of many commercial fertilizers. Inhalation of anhydrous ammonia in sufficient quantities can be fatal. Most agriculture related incidents do not involve the more spectacular chemicals, for instance methylisocyanate which killed or injured hundreds of thousands in Bhopal, India in 1984. Another characteristic of these incidents is that many occurred during the growing season, the spring and summer, logically the period when agricultural chemicals are used the most.

The fourth hazard factor is associated with the transport of hazardous materials. The unpredictability and suddenness of transportation accidents are especially troublesome for emergency response managers. Two distinct types of transport related releases are evident in the data. Many releases were caused by weekday, daytime truck accidents. It can be assumed that these trucks were either making local deliveries to rural towns or traveling through rural areas on major highways.

A second type of transport hazard is the long-distance rail transport of hazardous materials. Large volumes of these materials are shipped by this method through rural areas. Train derailments and the rupture of tank cars have been the cause of many major chemical releases. Many of the rail transport accidents happened on weekends, during nighttime hours.

It is unclear what effect government regulation has had on the probability of accidental hazardous material releases. Regulation is an important variable in several of the components. No single component, however, has more than one regulation variable with a loading greater than .400. Many of the incidents in heavily agricultural counties occurred in states which maintain "right to know" and hazardous-material notification requirements yet lack hazardous-material transport fees.

The geographic distribution of accidents observed in Figure 1 can be explained largely in terms of the hazard factors identified in the components analysis. The Midwest, the region with the highest concentration of accidents, experiences the influence of all four factors. Large amounts of hazardous materials are present in the region, because the rural Midwest is heavily agricultural and industrial.

Large amounts of chemical pesticides and fertilizers are used on corn, the most important crop of the Midwest.[13] In addition, several major transportation corridors, using Chicago and northern Indiana as the main hub, are present in the area. Towards the Northeast, through Ohio, Pennsylvania and New York, many of the accidents seem to correspond with the location of industries and their associated hazardous waste transport. Agricultural chemicals appear to be less important toward the highly industrialized metropolitan northeast coast.

Incidents in the central and southern Great Plains states can be divided into two groups: the local truck delivery of agricultural chemicals, and the long-distance rail transport of hazardous materials. Anhydrous ammonia was released in many of the incidents. The releases frequently occurred when the material was being transferred, either at a rail yard or other loading area. Rural industrialization does not appear to play much of a role in the pattern of releases in these areas.

Many of the incidents in the more isolated areas of the northwestern United States, particularly in Wyoming, Idaho and Oregon, involve mainly the truck transport of gases, such as propane, used by households or commercial establishments. This type of accident also was evident in the isolated regions of the southern Midwest and South, particularly in Kentucky and Mississippi. Other accidents in the South reflect a broad range of hazard factors. Incidents related to long-distance rail transport of hazardous materials, the use of agricultural chemicals, and rural industrialization are present. Few incidents, however, were recorded in this region.

The nature and distribution of incidents in California and Texas are similar to those found in the Midwest, particularly in Illinois. Large volumes of hazardous materials are handled in each state. The large size of each state further enhances the likelihood many rural accidents might occur. Many of the incidents in Texas, which involved the release of liquefied petroleum gas, seem to be related to the state's petro-chemical industry.

[13]Pierre R. Crosson and Sterling Brubaker, *Resource and Environmental Effects of U.S. Agriculture* (Washington, D.C.: Resources for the Future, 1982), pp. 70-74.

An examination of the nature and spatial distribution of incidents in Indiana should help to further clarify the various types of rural airborne toxic hazards and their spatial distribution (Figure 2). Single incidents in seven counties are mapped. The incidents in the northern part of the state are nighttime, weekend train accidents. Rail lines heading toward the Chicago, Illinois and Gary, Indiana area pass through the three most northerly counties: Kosciusko, La Porte and Marshall.[14] The three counties also

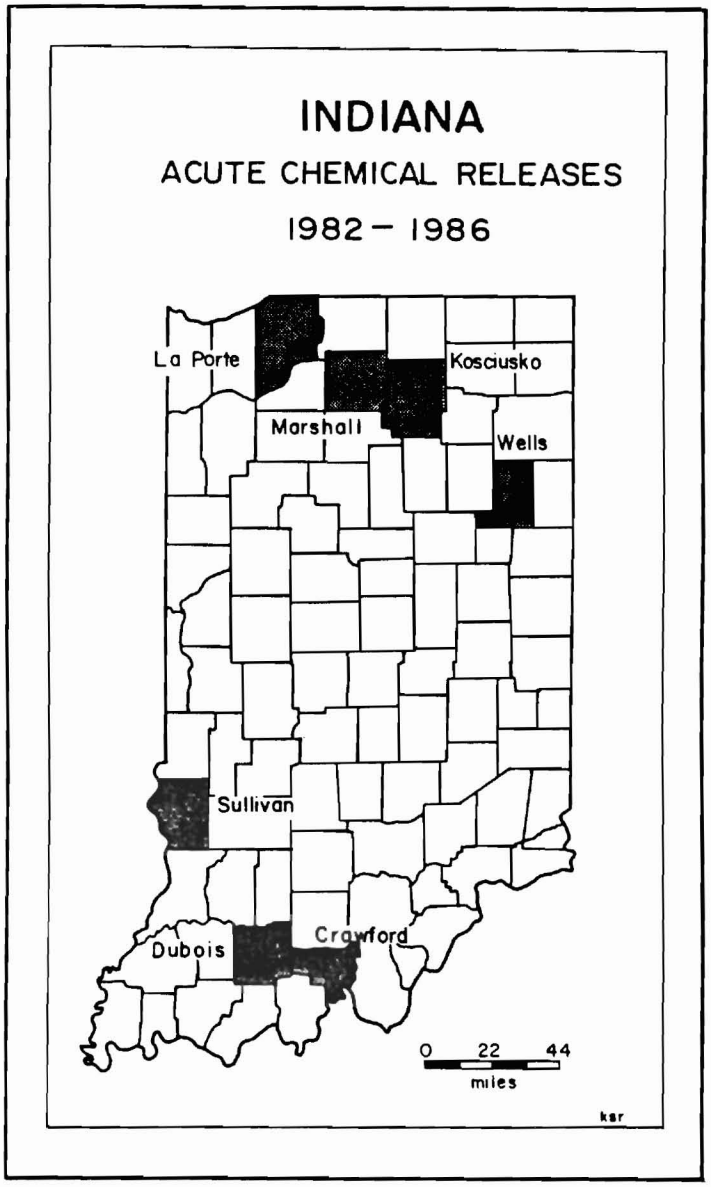

Figure 2

[14]*Rand McNally Commercial Atlas & Marketing Guide, 1988* (New York: Rand McNally and Company, 1988).

are relatively industrialized. More than one hundred manufacturing firms are found in each county. LaPorte and Kosciusko counties each have five chemical firms.[15] Wells county, the fourth northern county, is largely agricultural with more than ninety percent of the land in farmland.[16] Anhydrous ammonia, a major constituent of fertilizer, was released from a rail tank car. The three southern incidents are quite distinct. The incident in Crawford county was a weekend accident at a rail yard in which liquefied petroleum gas was released. Crawford is a poor, isolated, largely non-agricultural and non-industrial county. Only eleven industrial firms are present and just 42.5 percent of its area is used as farmland.[17] The incident in Dubois county involved a fixed facility from which a cloud of anhydrous ammonia was discharged. In Dubois county, over 77 percent of the land is farmland and 107 industrial firms are present, two of which are chemical facilities.[18] In Sullivan county, anhydrous ammonia was released from a truck on a local highway during a weekend evening. Sullivan is another relatively poor county with little industry and limited agriculture.[19]

CONCLUSIONS

This paper adds to a limited body of knowledge about important acute toxic hazards in nonmetropolitan areas. The analysis demonstrates that accidental airborne releases of toxic chemicals in rural areas have pronounced regional patterns. The regions can be defined by either the presence of a single type of toxic airborne hazard or a composite of several types. A complex composite of hazards are present in the Midwest, California and Texas. Incidents in the Great Plains states and the Northeast largely are representative of only one type of hazard; material transport and rural industrialization,

[15]U.S. Department of Commerce, Bureau of the Census, *U.S. Census of Manufacturing, Indiana: 1982* (Washington, D.C.: Government Printing Office, 1985, p. 75; U.S. Department of Commerce, Bureau of the Census, *County and City Data Book* (Washington D.C.: Government Printing Office, 1983), p. 186.

[16]U.S. Department of Commerce, Bureau of the Census, *County and City Data Book* (Washington, D.C.: Government Printing Office, 1983), p. 182, 185.

[17]Ibid., p. 168.

[18]U.S. Department of Commerce, Bureau of Census, op. cit., footnote 15, p. 72; U.S. Department of Commerce, op. cit., footnote 15, p. 168, 171.

[19]U.S. Department of Commerce, Bureau of the Census, op. cit., footnote 15, p. 182, 185.

respectively.

The results suggest several areas of future research. Data on more incidents must be collected to improve the representative sample of toxic releases. Such information should allow for a more comprehensive spatial analysis and correspondent refinement of the regional classification of rural airborne hazards in the United States. In addition, a state-level analysis is needed to understand why some states have fewer incidents or more incidents than expected. It is unclear why Iowa, Kentucky and Wyoming have relatively high numbers of incidents, whereas Alabama, South Dakota and North Dakota have so few. More information from the county and state levels could help explain these discrepancies.