Hazardous Substances Releases Causing Fatalities and/or People Transported to Hospitals: Rural/Agricultural vs. Other Areas

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Abbreviations:
CI = confidence interval
EMT = emergency medical technician
FEMA = Federal Emergency Management Agency
HazMat = hazardous materials
HSEES = Hazardous Substances Emergency Events Surveillance
NRC = National Response Center
PPE = personal protective equipment
PR = proportional ratio
US = United States

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Abstract

Introduction: Mass-casualty and hospital preparedness has been analyzed widely. However, information regarding the types of areas where these events occur is limited. Therefore, the characteristics of acute hazardous substances releases resulting in death/multiple-victim events occuring in rural/agricultural areas and in all other areas were studied and compared.

Methods: Data reported to the Hazardous Substances Emergency Events Surveillance (HSEES) system from 16 state health departments during 1993–2000 were used to examine factors associated with events with death/multiple victims involving acute release of hazardous substances. A death/multiple-victim event is defined as any event resulting in a death and/or at least five people being transported to a hospital.

Results: Of a total of 43,133 events, 6,661 occurred in rural/agricultural areas. Of these, 107 were death/multiple-victim events with 632 victims, of whom 91 died and 77 were hospitalized. All other areas had 472 death/multiple-victim events with 7,981 victims, of whom 116 died and 413 were hospitalized. Death/multiple-victim events in rural/agricultural areas were more likely to be associated with transportation (Proportional Ratio (PR) = 4.1, 95% CI = 3.1–5.4) and fires and/or explosions (PR = 1.4, 95% CI = 0.95–2.0) than were death/multiple-victim events in all other areas. Among transportation-related events in rural/agricultural areas, 19 were associated with air transport—mainly crop dusters—and resulted in 18 deaths. Responders were three times more likely to be injured in rural/agricultural areas. Of responders, volunteer firefighters constituted 52% compared with 6.7% in all other areas. The most frequently released chemicals in rural/agricultural areas were ammonia, chlorine, and pesticides. In all other areas, ammonia, chlorine, hydrochloric acid, carbon monoxide, and 0-chlorobenzylidene malononitrile, a tearing agent often associated with an illegal or unauthorized act, were released most frequently.

Conclusions: Findings from this analysis suggest that remedial actions should address safety measures in both transportation and fixed facilities containing acute hazardous substances. These include regular maintenance of equipment, education of workers about the substances used in their facility, rigorous training and licensing of drivers and crop duster operators, and education and training of employees and first responders in the use of protective equipment. These activities may reduce the number of events, casualties, and costs associated with hazardous substance events.

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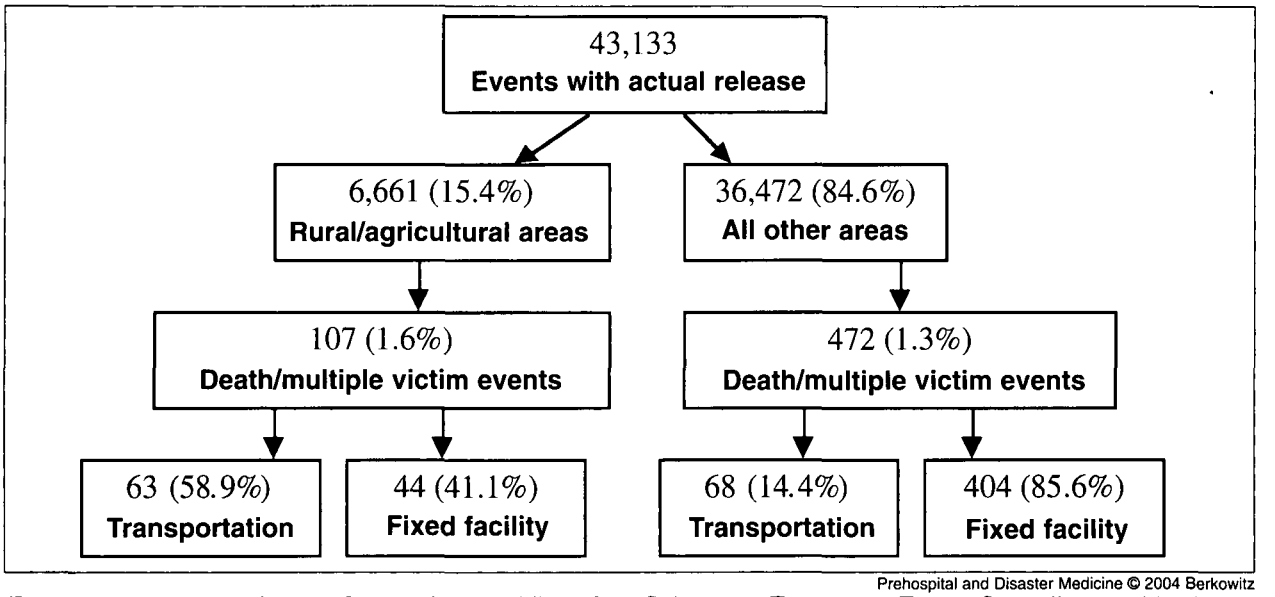

Figure 1—Number and type of events by area, Hazardous Substances Emergency Events Surveillance, 1993-2000

Introduction

Reports from the National Response Center (NRC) show that the annual number of incidents involving acute releases of hazardous substances in the United States increased from 27,776 in 1997 to 32,185 in 2002.[1] These releases, which are mostly accidental, frequently occur during ground, air, or rail transport, for example, and in fixed facilities such as factories, storage areas, farms, schools, and households. Some result in both a large number of people being transported to a hospital and in fatalities. The subject of mass-casualty and hospital preparedness has been analyzed widely.[2–5] However, there is little information documenting the specific area types (i.e., rural or agricultural, residential, industrial) in which events involving fatalities and a large number of casualties occur from the release of hazardous materials (HazMat).

This analysis uses data from 1993 through 2000 to examine the factors and characteristics associated with death/multiple-victim events, defined as events in which any death and/or at least five casualties transported to a hospital occurred, and compares the findings between rural/agricultural areas (rural and/or agricultural) and all other areas.

Methods

This analysis uses data reported to the Hazardous Substances Emergency Events Surveillance (HSEES) system from 1993 through 2000 by 16 state health departments located in four geographic areas of the United States (US) (South: Alabama, Mississippi, and Texas; Midwest: Iowa, Missouri, Minnesota, and Wisconsin; East: New York, New Jersey, Rhode Island, New Hampshire, and North Carolina; West: Colorado, Oregon, Washington, and Utah). Ten of these states participated during the whole period of the analysis. These states represent more than one-third of the population of the US.

Hazardous substances events were defined as uncontrolled or illegal acute releases of substances that may result in adverse public health effects and which must be cleaned up, removed, or neutralized according to federal, state, or local law. Events involving petroleum exclusively were excluded.

State health department coordinators collected information from various sources. These included, but were not limited to, federal and state agencies, local emergency planning committees, fire and police departments, industry, and the media.

Rural/agricultural events were defined as events for which the location of the release was coded as *rural/agricultural* only, or *rural/agricultural* and another type of area, such as rural/agricultural and industrial. Other areas included *industrial, commercial, residential, forest, wetland or coastal, surface water, and other*. Events for which the location was not known were excluded from the analysis.

Transportation events were defined as those occurring during surface, air, or water transport of hazardous materials, and could have been associated with industries other than the transportation industry. For example, transportation of fertilizer might be classified as agricultural and not transportation industry. Fixed-facility events were those occurring at a permanent facility located in an industrial, commercial, residential, or other site.

This analysis includes only events that had at least one substance released into the environment in gas or liquid form, or by fire, explosion, or other type of release. The substances involved in the events were categorized into 12 groups. An event involving a release of multiple substances from the same group (e.g., acids) was counted once in one of the single category groups. An event involving a release of substances from different groups (e.g., acids and chlorine) was counted once in the multiple substance category. The decision to define death/multiple-victim events as

Substance category	Rural/agricultural Areas			All Other Geographical Areas			Total		
	Events (%)	Victims	Evacuees	Events (%)	Victims	Evacuees	Events	Victims	Evacuees
Ammonia	8 (7.5)	48	351	41 (8.7)	1,201	6,357	49	1,249	6,708
Chlorine	7 (6.5)	90	888	41 (8.7)	490	3,048	48	580	3,936
Volatile organic substances	5 (4.7)	40	0	38 (8.0)	539	3,397	43	562	3,397
Other inorganic substances†	14 (13.1)	128	738	94 (19.9)	1,376	20,244	108	1,520	20,982
Acids	3 (2.8)	14	317	33 (7.0)	345	6,816	36	359	7,133
Mixtures	9 (8.4)	37	15	44 (9.3)	725	7,063	53	786	7,078
Pesticides	15 (14.0)	41	14	16 (3.4)	312	5,725	31	353	5,739
Bases	2 (1.9)	3	0	8 (1.7)	341	213	10	344	213
Paints & dyes	2 (1.9)	2	0	6 (1.3)	42	110	8	44	110
Polychlorinated biphenyls	1 (0.9)	2	0	0 (0.0)	0	0	1	2	0
Other‡	21 (19.6)	123	1,025	90 (19.1)	1,745	36,882	111	1,868	37,907
Unknown	0 (0.0)	0	0	2 (0.4)	31	200	2	31	200
Multiple substance categories	20 (18.7)	104	86	59 (12.5)	834	11,551	79	915	11,637
Total	**107 (100.0)**	**632**	**3,614**	**472 (100.0)**	**7,981**	**101,606**	**579**	**8,613**	**105,220**

Table 1—Number of victims and evacuees in each substance category by area type (†Except for acids, bases, ammonia, and chlorine; ‡Chemicals that were not included in all other categories)

those events resulting in any death and/or at least five injured persons being transported to a hospital was based on an earlier analysis requested by the [US] Federal Emergency Management Agency (FEMA). In addition, death/multiple-victim events could include, but were not defined by, additional victims who were not transported to a hospital, but were treated at the scene, seen by a physician within 24 hours, or whose injuries were reported to the state health department by an official.

Results

The number and type of events by area is shown in Figure 1. A total of 43,133 events having at least one substance released was reported to the HSEES system from 1993–2000. Of these, 6,661 (15.4%) occurred in rural/agricultural areas.

There were 579 death/multiple-victim events, 107 (18.5%) in rural/agricultural areas and 472 (81.5%) in all other areas. Among all participating states, Washington had the largest number of events (n = 154), followed by Texas (n = 98), and New York (n = 65). The annual number of all events did not show an increasing trend over the first seven years (range: 67–73 events). However, the year 2000 had a total of 91 events, 27.5% of which occurred in New York. Rural/agricultural areas proportionally had more transportation-related events than did all other areas (PR = 4.09, 95% CI = 3.1–5.4). Events in rural/agricultural areas more often were associated with the agriculture, forestry, and fisheries industry (n = 28, 26.2%), and the manufacturing industry (n = 24, 22.4%). The main industries involved in all other areas, in addition to transportation, were manufacturing (n = 146, 30.9%) and professional services (n = 76, 16.1%). Professional services in all other areas consisted mainly of elementary and secondary schools (n = 37), hospitals (n = 11), and nursing and personal care services (n = 10), which are categories associated with vulnerable populations.

Data describing primary factors responsible for the release in fixed-facility events have been collected since 1996. The most common primary factors reported in both area types were, in decreasing order of frequency, operator error, equipment failure, and improper mixing of chemicals. However, it is important to note that 23 events were associated with illegal activity, one of which occurred in a rural/agricultural area, and 22 that occurred in all other areas. This number likely is underestimated because factors for numerous events involving tearing agents in schools and other public areas were entered as unknown prior to 1996. Many of these probably were intentional.

Substances

Death/multiple-victim events involving fire and/or explosions were more likely to have occurred in rural/agricultural areas (n = 27, 25.2%) than in all other areas (n = 86, 18.2%) (PR = 1.38, 95% CI = 0.95–2.02). Death/multiple-victim events in rural/agricultural areas were also more likely to have had more than one substance involved in the release than were death/multiple-victim events in all other

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Category	Areas			
	Rural/agricultural		Other	
	Victims	(%)	Victims	(%)
Employees	331	(52.4)	3,774	(47.3)
Responders (total)‡	146	(23.1)	584	(7.3)
Volunteer firefighter	76	(12.0)	39	(0.5)
Professional firefighter	8	(1.3)	45	(0.6)
Firefighter, unknown type	0	(0.0)	14	(0.2)
EMT personnel	8	(1.3)	46	(0.6)
Hospital personnel	0	(0.0)	18	(0.2)
Employee responder	0	(0.0)	20	(0.2)
Police officer	4	(0.6)	100	(1.2)
Responder, unknown type*	50	(7.9)	302	(3.8)
General public	154	(24.4)	3,573	(44.8)
Unknown	1	(0.1)	50	(0.6)
Total	**632**	**(100.0)**	**7,981**	**(100.0)**

Table 2—Number of victims in each category by area type (*Most of the information reported was from 1993–1995; EMT = emergency medical technician; ‡Total of responders shown in shaded area)

areas (n = 23, 21.5% versus n = 73, 15.5%, respectively). A large proportion of these events had fire and/or explosions (n = 11, 47.8% and n = 33, 45.2%, respectively). The category of substances released in each event according to area type is shown in Table 1. Hydrochloric and sulfuric acids were among the most frequently released substances (n = 26 and 20, respectively), mostly in all other areas. These substances often were released in events involving multiple substances. Among events having only one substance released, carbon monoxide was the third most frequent substance released, following ammonia and chlorine. There were 31 carbon-monoxide releases, comprising 29% of the category *other inorganic substances*. Two of these releases occurred in rural/agricultural areas and 29 occurred in all other areas. Following carbon monoxide in frequency were 0-chlorobenzylidene malononitrile (n = 21) and 2-chloroacetophenone (n = 5), both tearing agents that comprised 29% of the category other in all other areas. None of these events occurred in rural/agricultural areas.

Victims and Injuries

A total of 8,613 persons were injured in death/multiple-victim events, comprising 55.9% of all victims in events with actual releases. Six-hundred thirty-two persons were injured in rural/agricultural areas (range 1–46 victims per event, median = 2), and 7,981 in all other areas (range 1–583 victims, median = 9). The largest proportion of victims among all single substance releases was attributed to ammonia releases (15%), mostly in all other areas (Table 1).

The categories of victims according to area type are listed in Table 2. Employees constituted the largest proportion of injured persons in rural/agricultural areas. The victim population in all other areas comprised of employees and the general public in similar proportions. The proportion of victims who were responders in rural/agricultural areas (n = 146, 23.1%) was three times larger than was the respective proportion in all other areas (n = 584, 7.3%). Of the responders injured in rural/agricultural areas, the majority were volunteer firefighters. Almost all injured firefighters were wearing some type of personal protective equipment (PPE). Of known PPE, the most commonly used was firefighter turn-out gear (99% and 74% of firefighters in rural/agricultural and all other areas, respectively). A larger proportion (56%) of injured firefighters in rural/agricultural areas were known to have received HazMat training compared with firefighters in all other areas (41%). However, information concerning the HazMat training for 35% and 41% of firefighters in rural/agricultural and all other areas respectively was missing. Sixty-five percent of responders of unknown type in rural/agricultural areas wore firefighter turn-out gear. The rest used no PPE. Fifty-six percent of responders of unknown type in all other areas had some kind of PPE, of which 72% wore firefighter turn-out gear. Most of these responders reported not to have received HazMat training. Few police officers wore protective clothing. Among emergency medical technicians (EMTs), only two were known to have worn level 'D' protection, which includes coveralls, gloves, boots/shoes, safety glasses or chemical splash goggles, and a hard hat, and one was wearing firefighter turn-out gear. Only three hospital personnel were wearing gloves and eye protection.

The numbers of victims according to outcome of injury by victim's category and area type are listed in Table 3. One-hundred fifty-one death/multiple-victim events were associated with 207 fatalities. Almost half of the fatalities occurred in events involving fire and/or explosion (n = 99, 47.8%). Victims in rural/agricultural areas proportionally were much more likely to die (PR = 9.9, 95% CI = 7.6–12.9) and to be admitted to a hospital (PR = 2.35, 95% CI = 1.87–2.96) than those in all other areas. A large number of fatalities were associated with transportation-related events (n = 66 and 49 in rural/agricultural and all other areas, respectively), and of these, 27.3% and 32.6%, respectively, were involved in events involving fire and/or explosions. Although most of the fatalities were among employees,

Severity of outcome	Victim category	Rural/agricultural areas		All other areas	
		n	(%)	n	(%)
Death	Employees	66	(72.5)	76	(65.5)
	Responders	0	(0)	5	(4.3)
	General public	24	(26.4)	35	(30.2)
	Unknown	1	(1.1)	0	(0)
	Total	**91**	**(14.4)**	**116**	**(1.45)**
Admitted to hospital	Employees	46	(59.7)	264	(63.9)
	Responders	19	(24.7)	47	(11.4)
	General public	12	(15.6)	101	(24.5)
	Unknown	0	(0)	1	(0.2)
	Total	**77**	**(12.2)**	**413**	**(5.2)**
Observed at hospital	Employees	22	(46.8)	396	(69.1)
	Responders	5	(10.6)	32	(5.6)
	General public	20	(42.6)	140	(24.4)
	Unknown	0	(0)	5	(0.9)
	Total	**47**	**(7.4)**	**573**	**(7.2)**
Treated at hospital, but not admitted	Employees	194	(49.9)	2,569	(42.8)
	Responders	99	(25.4)	490	(8.2)
	General public	96	(24.7)	2,934	(48.9)
	Unknown	0	(0)	11	(0.2)
	Total	**389**	**(61.6)**	**6,004**	**(75.2)**
Treated at the scene	Employees	0	(0)	314	(46.9)
	Responders	21	(95.5)	8	(1.2)
	General public	1	(4.5)	315	(47.0)
	Unknown	0	(0)	33	(4.9)
	Total	**22**	**(3.5)**	**670**	**(8.4)**
Seen by physician within 24 hours	Employees	3	(100)	142	(85.5)
	Responders	0	(0)	2	(1.2)
	General public	0	(0)	22	(13.3)
	Total	**3**	**(0.5)**	**166**	**(2.1)**
Injuries reported by an official within 24 hours	Employees	0	(0)	12	(31.6)
	Responders	2	(66.7)	0	(0)
	General public	1	(33.3)	26	(68.4)
	Total	**3**	**(0.5)**	**38**	**(0.5)**
Total		**632**	**(100)**	**7,980***	**(100)**

Table 3—Number of victims by category and area type (n = number; *There was one employee with an unknown severity of outcome)

members of the general public comprised a relatively large proportion (26.4% and 30.2% in rural/agricultural and all other areas, respectively). Among victims admitted to a hospital, responders in rural/agricultural areas (24.7%) were more likely to have been admitted than were those in all other areas (11.4%).

Of note were injuries which resulted from the following circumstances:

1. Nineteen events occurring in rural/agricultural areas were related to air transportation, and most were accidents occurring during aerial spraying of pesticides by crop dusters. These resulted in 31 injured persons. Seventeen of these events resulted in 19 victims, of which 18 died. None of the fatalities in all other areas was associated with air transportation.
2. Carbon monoxide, a colorless and odorless substance, was released in 31 events, two of which occurred in rural/agricultural areas. These two events had produced 30 victims and resulted from releases in the agricultural services industry due to equipment failure. All other areas had 29 events, which resulted in 613 victims. These events were more likely to occur in public areas, such as wholesale premises, entertainment and recreational areas, and schools. The events were mostly attributed to equipment failure (n = 11) and operator error (n = 7). The factors for the remaining events were not reported or not known. The number of known evacuees associated with these events was 1,541.
3. The tearing agents 0-chlorobenzylidene malononitrile and 2-chloroacetophenone, better known as pepper spray or mace, were released in 27 events in all other areas (this total includes an event involving a release of smoke grenades in addition to pepper spray) resulting in 664 victims (range 5–180). Nine of these events occurred in schools and had 261 victims. Ninety-eight victims were injured in public areas such as eating and drinking places, merchandise stores, and hardware stores. Among those events in which the cause was known, almost all were associated with illegal or unauthorized acts. These releases, which were not reported in the rural/agricultural areas, resulted in 16,285 evacuees.
4. Thirteen events were associated with illegal drug laboratories. The most frequently involved substances were ammonia, acetone, and hydrochloric acid. Two events occurred in rural/agricultural areas and 11 in all other

Injury/ symptom	Rural/agricultural areas		All other areas	
	Number	(%)	Number	(%)
Trauma only	81	(12.8)	235	(2.9)
Trauma with other injuries	23	(3.6)	74	(0.9)
Respiratory	186	(29.4)	2,126	(26.6)
Gastrointestinal	13	(2.1)	202	(2.5)
Thermal burns	12	(1.9)	32	(0.4)
Chemical burns	8	(1.3)	116	(1.5)
Heat stress	0	(0.0)	31	(0.4)
Headache	8	(1.3)	152	(1.9)
Eye	5	(0.8)	150	(1.9)
Skin	2	(0.3)	187	(2.3)
Dizziness/ other CNS symptoms	2	(0.3)	125	(1.6)
Chest pain	2	(0.3)	31	(0.4)
Shortness of breath*	0	(0.0)	51	(0.6)
Other injuries	6	(0.9)	103	(1.3)
Multiple injuries without trauma	284	(44.9)	4,366	(54.7)
Total	**632**	**(100.0)**	**7,981**	**(100.0)**

Table 4—Distribution of injuries/symptoms associated with death/multiple-victim events by area type (*Cause unknown)

areas, resulting in 85 victims of whom seven died. Seven of these events involved fire and/or explosion. Thirty-seven of the victims (43.5%) were responders. These responders included seven hospital personnel and nine EMTs, all of whom were injured in all other areas. In addition, 21 police officers were involved in six events, one of whom was injured in an event in a rural/agricultural area. No police officer was known to have worn PPE. The number of known evacuees associated with these events was 464.

The distribution of injuries according to area type is listed in Table 4. Sixty-three of all 91 deaths in rural/agricultural areas were associated with trauma. Additionally, 12 had a combination of traumatic and other injuries. Of victims who were admitted to hospitals in rural/agricultural areas, the majority sustained respiratory tract symptoms that often were accompanied by gastrointestinal symptoms, eye irritation, headache, shortness of breath, or other symptoms. Among all deaths (n = 116) in all other areas, 42 resulted from trauma, and an additional 26 were associated with a combination of traumatic and other injuries, including thermal burns. Other causes of death were thermal burns alone, chemical burns, and asphyxiation. The majority of victims who were admitted to a hospital in all other areas suffered from respiratory tract symptoms, as did victims in rural/agricultural areas.

Among firefighter victims, at least half (56% in rural/agricultural and 51% and all other areas) suffered from respiratory tract symptoms. In addition, a large proportion of firefighters sustaining respiratory symptoms in rural/agricultural areas also had headache, dizziness, and gastrointestinal symptoms. Heat stress in firefighters was more prevalent in rural/agricultural areas (41.7%) than in all other areas (12.2%) (PR = 3.8, 95% CI = 2.1–6.9). In rural/agricultural areas, this symptom occurred mostly in combination with high blood pressure and headache.

Evacuations

Rural/agricultural areas had a much lower proportion of events with evacuation, and a lower number of evacuees than all other areas (Table 1). Thirty-nine of 107 events (36.8%) involved evacuations in rural/agricultural areas. Of these events, 36 had a known number of people evacuated, and the total number of evacuees was 3,614 (range 1–680, median = 41). Of 472 events in all other areas, evacuation was ordered at 350 events (74.1%). Of these, 297 events had a known number of evacuees totaling 101,606, and ranging from 1 to 11,000, with a median value of 55 people.

Decontamination

The numbers of events and population types according to type of area are listed in Table 5. Decontamination was administered in 48% of the events. The largest proportion of decontaminations occurred at the scene.

An additional analysis comparing events with death/multiple-victims (Group 1), with all other events with injuries (Group 2), and events with no injuries (Group 3) revealed that the main factors and characteristics associated with Group 1 were less strongly associated with Group 2 and Group 3. Groups 2 and 3 had lower proportions of events involving fire and/or explosion, especially in rural/agricultural areas, lower proportions of transportation events among events in rural/agricultural areas, and lower proportions of ordered evacuations than Group 1.

Discussion

This analysis was conducted to describe the factors and characteristics associated with chemical releases resulting in death/multiple victims in both rural/agricultural and all other areas. These events accounted for more than half of all injured persons in the HSEES system during 1993–2000. Transportation-related events, fire and/or explosion, and emission of toxic substances—often in the form of gas—were shown to be the most likely factors associated with these events. Fires and/or explosions comprised a large proportion of events that had more than one substance released. These events were more prevalent in rural/agricultural areas than in all other areas. Previous analyses of HSEES data indicated that events involving fire and/or explosion or releases of more than one chemical from the same or different substance categories more likely were to result in personal injuries that also were more severe.[6,7] These events also have a potential for causing major property damage.

Rural/agricultural areas had a much larger proportion of transportation-related fatalities than all other areas. These

	Area							
	Rural/agricultural				Other			
At scene	**Events**	**n**	**Range**	**Median**	**Events**	**n**	**Range**	**Median**
Employees	10	40	1–11	2	69	663	1–88	3
Responders	19	215	2–35	5	69	543	1–47	5
General public	3	6	1–4	1	16	824	1–750	3
Total	**32**	**261**			**154**	**2,030**		
At facility								
Employees	3	12	1–10	1	37	342	1–78	5
Responders	4	29	1–19	4–5	25	170	1–21	4
General public	3	11	1–6	4	20	377	1–225	8–9
Total	**10**	**52**			**82**	**889**		
Total Decon	**42**	**313**			**236**	**2,919**		

Table 5—Events with decontamination site and population type by type of area (Decon = decontamination; n = number of people affected)

fatalities often were associated with both ground and air transportation. Aircraft accidents mostly involved crop dusters applying pesticides. The outcomes of transportation-related accidents were reflected by the large number of traumatic injuries among these victims. Although each of these events had chemicals spilled, it was not clear from the reports whether the injuries resulted from an impact due to an accident, or due to victim contact with hazardous materials, or both.

Victims injured in events in rural/agricultural areas were more than twice as likely to be admitted to a hospital as those in all other areas. The greater likelihood of admission to a hospital in rural/agricultural areas might have been related to the types of injury (a large proportion of traumatic, respiratory, burns, and multiple injuries). The distance of the care facility from the victim's residence might have been an additional factor.

A striking difference between death/multiple-victim events in rural/agricultural areas and those in all other areas was related to victim types. Overall, responders in rural/agricultural areas were three times more likely to be injured than were those in all other areas, and of these, volunteer firefighters were at particularly high risk. This might be due to the fact that volunteer firefighters comprise a large number of first responders in rural/agricultural areas, and that a large proportion of these events involved fire and/or explosions. Although firefighters in both areas were equipped with protective clothing, the injuries they sustained suggest that some might not have had sufficient protection against inhalation and heat stress. Most firefighters were wearing turn-out gear that does not provide any better protection than do firefighter uniforms if a positive-pressure, self-contained breathing apparatus is not worn.[8] Volunteer firefighters also might perform their duties over large areas in rural/agricultural communities, and there might be problems of communication both in contacting the responders, and between the responders and members of the community. The fire might have spread and become very hot by the time responders arrived. In addition, the responders might not have been informed of the presence of hazardous materials until they were well into their firefighting efforts. Because information from the HSEES data on HazMat training among firefighters is not complete, it is not possible to draw conclusions related to the level of the firefighters' training. However, reports published by the Federal Emergency Management Agency (FEMA) indicate that rural/agricultural areas have less financial resources to purchase appropriate PPE, and their volunteer firefighters receive less training than do those in all other areas.[9]

Of note was the large proportion of victims who were responders, mainly police officers and EMTs, in events involving drug laboratories. More than half of these events involved fire and/or explosion, and almost all injured police officers and EMTs did not wear personal protective clothes. These circumstances indicate that responders typically are very vulnerable to hazardous exposures. They often enter the event area with little knowledge of the chemicals involved, and they do not have the proper protection that may prevent contact with these chemicals.[10]

Members of the general public were less likely to be injured in rural/agricultural areas than in all other areas. This is most likely due to the lower population density in rural/agricultural areas compared with that in all other areas. In addition, more than half of the events in rural/agricultural areas were transportation related, and many of these resulted in a low number of injured persons, although the injuries often were more severe or fatal. Aside from ammonia releases, a large number of injured persons in all other areas resulted from releases of carbon monoxide

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and tearing agents, which often were emitted in areas containing large numbers of people. Tearing agents often were associated with an unauthorized or illegal activity.

The limitations of this report stem from the fact that the chemicals released in participating states might not be representative of releases in non-participating states. In addition, the HSEES system records health effects resulting from acute releases and does not follow injured persons and exposed populations for chronic ill effects. Another limitation concerns the definition of rural and/or agricultural areas. This definition might not be homogenous among the participating states and among the reporting sources on which the HSEES system depends.

Conclusion and Recommendations

Findings from this analysis suggest that remedial actions should address safety measures both in transportation and fixed facilities, education of workers and their supervisors about substances used within each facility and their compatibilities, and education about the use of protective clothing by employees and first responders.

Industries associated with transportation should take more care in selecting and training drivers to help reduce fatalities and traumatic injuries from impact, and potentially improve safety awareness in local and short haul operations.[11] Kuncyté *et al* suggested that drivers transporting dangerous goods should have training in regulations associated with these materials, and in measures to contain the amount of the chemical spilled and its effects on the population exposed to it if a release occurs.[12] Drivers in rural/agricultural areas, who often are self-employed, should attend to the maintenance and safety of their vehicles, the equipment they carry, the process of loading and unloading material, and reduce their driving speed. Crop duster operators, who often own and maintain their equipment, should undergo rigorous training and licensing. Their equipment and maintenance records also should be inspected regularly.

Operators of facilities housing or transporting hazardous substances should enforce regular and rigorous maintenance of equipment and regularly inspect production processes to reduce the chance of explosion and fire, install smoke and carbon monoxide detectors and check their function regularly,[13] and install and periodically maintain ventilation systems.

Responders should receive updated information on hazardous materials, particularly those known to be used most frequently in their area of operation, and regularly practice prevention activities associated with these materials. They also should be equipped to respond to events with releases of unknown substances. Hospital personnel should be educated about the importance of protective clothing and trained in methods utilized to prevent secondary contamination from injured persons who transport themselves to the hospital or a clinic.[14]

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