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Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Acute Chemical Incidents Surveillance — Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: Although they are infrequent, acute chemical incidents (i.e., uncontrolled or illegal release or threatened release of hazardous substances lasting <72 hours) with mass casualties or extraordinary levels of damage or disruption severely affecting the population, infrastructure, environment, and economy occur, and thousands of less damaging chemical incidents occur annually. Surveillance data enable public health and safety professionals to better understand the patterns and causes of these incidents, which can improve prevention efforts and preparation for future incidents.

Reporting Period: 1999–2008.

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry (ATSDR) during January 1991–September 2009 to describe the public health consequences of chemical releases and to develop activities aimed at reducing the harm. This report provides a historical overview of HSEES and summarizes incidents from the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: During 1999–2008, a total of 57,975 chemical incidents occurred: 41,993 (72%) occurred at fixed facilities, and 15,981 (28%) were transportation related. Chemical manufacturing (NAICS 325) (23%) was the industry with the most incidents; however, the number of chemical incidents in chemical manufacturing decreased substantially over time (R^2 = 0.78), whereas the educational services category (R^2 = 0.65) and crop production category (R^2 = 0.61) had a consistently increasing trend. The most common contributing factors for an incident were equipment failure (n = 22,535, 48% of incidents) and human error (n = 16,534, 36%). The most frequently released chemical was ammonia 3,366 (6%). Almost 60% of all incidents occurred in two states, Texas and New York. A decreasing trend occurred in the number of incidents in Texas, Wisconsin, and Colorado, and an increasing trend occurred in Minnesota.

Interpretation: Although chemical manufacturing accounted for the largest percentage of incidents in HSEES, the number of chemical incidents over time decreased substantially for this industry while heightened awareness and prevention measures were being implemented. However, incidents in educational services and crop production settings increased. Trends in incidents and number of incidents varied by state. Only a certain few chemicals, sectors, and areas were found to be related to the majority of incidents and injured persons. Equipment failure and human error, both common casual factors, are preventable.

Public Health Implications: The findings in this collection of surveillance summaries underscore the need for educational institutions and the general public to receive more focused outreach. In addition, the select few chemicals and industries that result in numerous incidents can be the focus of prevention activities. The data in these surveillance summaries show that equipment maintenance, as well as training to prevent human error, could alleviate many of the incidents; NTSIP has begun work in these areas. State surveillance allows a state to identify its problem areas and industries and chemicals for prevention and preparedness. Beginning in 2010, ATSDR replaced HSEES with the National Toxic Substance Incidents Program (NTSIP) to expand on the work of HSEES. NTSIP helps states to collect surveillance data and to promote cost-effective, proactive measures such as converting to an inherently safer design, developing geographic mapping of chemically vulnerable areas, and adopting the principles of green chemistry (design of chemical products and processes that reduce or eliminate the generation of hazardous substances). Because the more populous states such as New York and Texas had the most incidents, areas with high population density should be carefully assessed for preparedness and prevention measures. NTSIP develops estimated incident numbers for states that do not collect data to help with state and national planning. NTSIP also collects more detailed data on chemical incidents with mass casualties. HSEES and NTSIP data can be used by public and environmental health and safety practitioners, worker

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representatives, emergency planners, preparedness coordinators, industries, emergency responders, and others to prepare for and prevent chemical incidents and injuries.

Introduction

In spite of efforts to improve chemical safety, chemical incidents continue to occur, and educational efforts and interventions are needed. The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) reported the results of an investigation involving several large incidents and found recurring causes, including inadequate process hazards analysis, use of inappropriate or poorly designed equipment, and inadequate indications of process conditions (*1*). In addition, other incidents were preceded by a series of similar incidents, incidents that narrowly avoided causing mass casualties, or low-level failures, indicating the need for more attention to implementation of lessons and more thorough company investigation of low-level failures and incidents that could have caused numerous injuries and deaths (*1*).

In 2007, an explosion at the British Petroleum (BP) refinery in Texas City, Texas, resulted in 15 deaths and injured 170 people. This incident spurred the U.S. Chemical Safety Board (CSB) to recommend an independent review panel, the findings of which are commonly referred to as the Baker Panel Report. The panel urged companies to regularly and thoroughly evaluate their safety culture, the performance of their process safety management systems, and their corporate safety oversight for possible improvements. The panel noted that complacency results in chemical incidents with injuries and deaths (*2*). In 2009, OSHA announced $87,430,000 in proposed penalties for BP Products, North America, for its failure to correct potential hazards faced by employees (*3*). A similar explosion involving ammonium nitrate occurred 6 years later and approximately 250 miles away in West, Texas, at the West Fertilizer Company. Fifteen people died, and hundreds were injured. On June 27, 2013, the CSB chairperson testified to the U.S. Senate Committee on Environment and Public Works that current U.S. standards have safety gaps. Despite what is known about the dangers of ammonium nitrate, no federal, state, or local rules restrict the storage of large amounts of ammonium nitrate near homes, schools, or hospitals (*4*).

Other incidents could have caused mass casualties, such as the 2008 incident at the Bayer Crop Science facility in Institute, West Virginia. During that incident, an out-of-control chemical reaction occurred inside a 4,500-gallon pressure vessel, causing it to explode and resulting in a fire that burned for approximately 4 hours. Although two deaths and eight injuries occurred, the potential for hundreds or thousands of additional deaths and injuries existed. According to the CSB incident report, methyl isocyanate (MIC) could have been released during that incident. MIC is the same chemical that killed thousands and permanently injured many more in the worst industrial incident in history, which occurred in Bhopal, India, in 1984 (*5*). Because of the potential for a similar incident in the United States, the U.S. Congress provided funding for CSB to commission a study by the National Academy of Science (NAS) on the feasibility of implementing safer alternative chemicals to MIC and processes at this plant.

Bayer no longer produces MIC at the plant. However, as a result of the NAS study, CSB found that the chemical industry could benefit from incorporating the principles of inherently safer design to effectively eliminate or reduce hazards, prevent accidents, and protect nearby communities (*6*). Inherently safer design and green chemistry (design of chemical products and processes that reduce or eliminate the generation of hazardous substances) have become increasingly accepted as preventive measures by industry organizations. The Presidential Green Chemistry Challenge Awards recognize chemical technologies that incorporate the principles of green chemistry into chemical design, manufacture, and use. EPA sponsors the Presidential Green Chemistry Challenge Awards in partnership with the American Chemical Society Green Chemistry Institute and other members of the chemical community, including industry, trade associations, academic institutions, and other government agencies (*7*).

Several different agencies provide oversight for chemical incidents in the United States, including EPA, OSHA, CSB, and the National Transportation Safety Board (NTSB). The National Institute of Environmental Health Sciences Worker Training Program supports training of thousands of workers in hazardous waste operations and emergency response (*8*). The Agency for Toxic Substances and Disease Registry (ATSDR) is a nonregulatory agency that serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances (*9*). During 1990–2009, ATSDR funded surveillance of hazardous substance releases in up to 17 states and two other countries (India and Poland) through the Hazardous Substances Emergency Events Surveillance (HSEES) system (*10*), an active, state-based surveillance system to systematically collect data on thousands of incidents for evidence-based preparedness and prevention efforts. Although HSEES collected the most complete information on the public health impacts of chemical releases, including worksite, transportation, and private property incidents, not all states were included.

This report summarizes the incidents occurring in selected states participating in HSEES during 1999–2008 and is a part of a comprehensive collection of surveillance summaries (*11*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industries, emergency responders, and others who prepare for or respond to chemical incidents can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES by health departments in nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 complete calendar years of data collection, 1999–2008. Data from 2009 were not included because several states ended data collection mid-year.

Description of Data System

Since 1991, ATSDR and CDC have supported state health departments with actively gathering information about chemical incidents. Funded states negotiated formal or informal data sharing agreements with the federal, state, and local agencies that are routinely notified when hazardous substances emergencies occur. Data sources included but were not limited to the National Response Center (NRC), the U.S. Department of Transportation (DOT) Hazardous Materials Incident Reporting System (HMIRS), police and fire departments, environmental health agencies, poison control centers, various emergency response agencies. The media also served as a resource for identifying incidents. For each incident, information was collected about the location, industry, substances released, contributing factors, injured persons, injuries, and evacuations. States entered the data into a standardized ATSDR-provided online system from which the HSEES database was constructed (*10*).

HSEES Case Definition

During the surveillance period, a hazardous substances emergency incident was defined as an acute uncontrolled or illegal release or threatened release of hazardous substances lasting <72 hours. Threatened releases were defined as imminent releases that did not occur but led to an action (e.g., an evacuation) that could have affected the health of employees, emergency responders, or members of the general public. In accordance with the Comprehensive Environmental Response, Compensation, and Liability Act, commonly known as Superfund (*12*) (the authorizing legislation for ATSDR), incidents in which the only substance released was petroleum (e.g. crude oil, gasoline, or mineral spirits) were excluded. Incidents involving petroleum and another qualifying hazardous substance were included.

Case Definition Changes

Beginning in 2006, ATSDR changed the inclusion and exclusion criteria for an HSEES incident to improve the uniformity of reporting among states and reduce investigation of incidents that had minimal public health impact. Before 2006, the case definition included any release of a hazardous substance in an amount that was required by federal, state, or local law to be cleaned up. State and local laws could vary and could be more stringent than federal laws. In 2006, the definition was changed to fixed amounts for all states. Beginning in 2006, an incident qualified for inclusion if the amount released was >10 lbs or 1 gallon or any amount of a substance on the HSEES mandatory reporting list (*13*). The HSEES mandatory list was compiled from the highly hazardous substance lists from other agencies, such as those of EPA and the U.S. Department of Homeland Security (DHS), with additions of substances shown to be hazardous in HSEES. Also in 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, or nitrogen oxides were excluded because they rarely resulted in a substantial public health incident and because of the sheer number of incidents.

Variable Definitions

An incident was considered to be related to transportation if it occurred during surface, air, pipeline, or water transport of hazardous substances or before the substance was totally unloaded from a vehicle or vessel. All other incidents were considered fixed-facility incidents.

HSEES defined an injured person as a person who experienced at least one documented acute (i.e., occurring in <24 hours) adverse health effect or who died as a consequence of the incident; injured persons must have had at least one injury type or symptom, and up to seven could be listed (*10*).

Contributing factors consisted of primary (root) causes and secondary (contributing) causes. Each incident could have one of each (i.e., up to two) factors.

Analyses

Descriptive data analysis on incidents by industry, factor, chemical, and state were performed. The data were then plotted to look for trends over time. The coefficient of determination

(R^2) value was used to determine goodness of fit for trend. Ranging from 0 to 1, a higher R^2 value denotes that the variable of interest was increasing or decreasing at a steady rate over time. A perfectly linear trend would have an R^2 value of 1. The statistical analyses were performed using statistical software.

Businesses were categorized using the U.S. Census Bureau's 3-digit North American Industry Classification System (NAICS) for 2002 (*14*). For the chemical-specific analysis, only incidents in which one substance was released were included (n = 54,989, 94.8% of incidents). The top 10 substances released were examined. To determine whether the 2006 reporting guidelines had an effect on the top 10 substances, the totals for the 3 years before (2003–2005) and after (2006–2008) the changes for each substance were measured as a percent change. Contributing factors were examined for the last 8 years only, corresponding to the dates the list of factors was expanded.

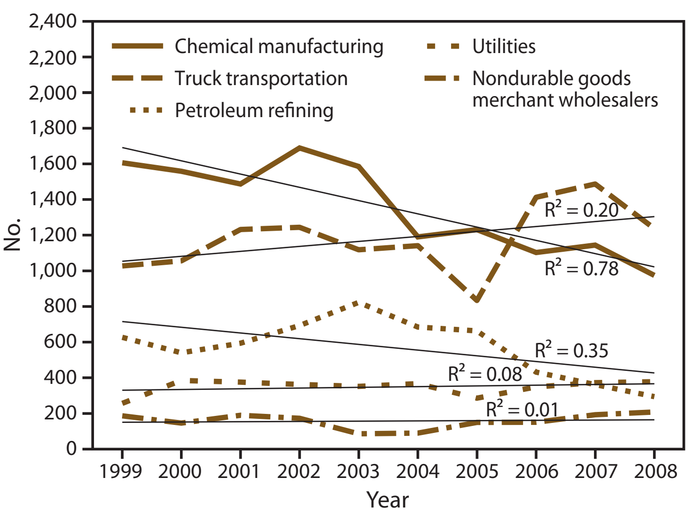
Results

During 1999–2008, a total of 57,975 chemical incidents occurred. A total of 41,993 (72%) were fixed-facility incidents and 15,981 (28%) were transportation related.

Industries

Of the 57,975 incidents that occurred in the 10-year period, 61% were reported from five industries: chemical manufacturing (NAICS 325) (23%), truck transportation (NAICS 484) (20%), petroleum and coal products manufacturing (NAICS 324) (10%), utilities (NAICS 221) (6%), and nondurable good merchant wholesalers (NAICS 424) (2%) (Figure) (Table 1). Although the chemical manufacturing category accounted for the largest percentage of incidents in HSEES, the number of chemical incidents decreased substantially over time for this industry (R^2 = 0.78). Certain industry groups had an increasing number of chemical incidents over time. The educational services category (R^2 = 0.65) and crop production (R^2 = 0.61) category had a consistently increasing trend (Table 1).

FIGURE. Trends in the number of chemical incidents, by top five industries — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008



Abbreviation: R^2 = coefficient of determination.
* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

Contributing Factors

Each incident could have up to two contributing factors listed. Of the 64,270 reported contributing factors for 46,489 incidents, the most common contributing factors associated with a chemical incident reported in HSEES were equipment failure (n = 22,535, 48% of incidents) and human error (n = 16,534, 36%). Other commonly cited factors included improper filling, loading, or packaging (n = 6,551, 14%) and system or process upset (any glitch in the system that upsets the process; the problem has to be specific to the facility) (n = 4,092, 9%) (Table 2).

Contributing factors that could cause smokestack emissions, such as system or process upset, system startup or shutdown, performing maintenance, and power failure or other electrical problems, decreased in 2006 when the reporting change went into effect that excluded smokestack emissions of carbon monoxide, sulfur oxides, or nitrogen oxides. Fires also decreased (Table 2).

Chemicals

A total of 54,989 (95%) incidents occurred that involved release of one substance. Ammonia was the chemical most often involved in HSEES single-substance incidents, with ammonia released in 3,366 (6%) incidents. Other frequently released chemicals included paint not otherwise specified; alkaline hydroxides (sodium hydroxide and potassium hydroxide), sulfuric acid, mercury, hydrochloric acid, carbon monoxide, ethylene glycol (antifreeze), nitrogen oxide, and sulfur dioxide (Table 3). These top 10 substances involved 28% of all single-substance incidents.

A comparison of the 3-year period before and after the change to the inclusion criteria took place in 2006 (2003–2005 vs. 2006–2008) indicates that incidents involving the substances that became subject to mandatory reporting, regardless of the amount released, increased (i.e., ammonia, alkaline hydroxide, sulfuric acid, mercury, and carbon monoxide >50 parts per million [ppm]) (Table 3). Some decreases occurred among the substances that were newly excluded: smokestack emissions

TABLE 1. Number of chemical incidents, by 10 industries with most incidents — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Industry (NAICS code)†	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	R^2
Chemical manufacturing (325)	1,606	1,558	1,487	1,689	1,585	1,190	1,231	1,103	1,144	974	0.78
Truck transportation (484)	1,027	1,056	1,232	1,244	1,118	1,141	834	1,412	1,487	1,237	0.20
Petroleum refining (324)	627	540	594	693	823	685	663	432	362	294	0.35
Utilities (221)	257	375	376	363	352	367	286	349	373	378	0.10
Nondurable goods merchant wholesalers (424)	187	146	190	173	86	90	150	151	193	208	0.01
Food manufacturing (311)	124	114	141	106	107	114	114	103	107	148	0.00
Rail transportation (482)	98	120	129	132	123	98	122	123	111	110	0.00
Oil and gas extraction (211)	63	64	106	113	165	126	120	56	28	46	0.08
Educational services (611)	59	65	81	83	71	82	68	99	95	100	0.65
Crop production (111)	70	66	74	79	56	77	84	99	101	94	0.61
Total	**4,118**	**4,104**	**4,410**	**4,675**	**4,486**	**3,970**	**3,672**	**3,927**	**4,001**	**3,589**	—

Abbreviations: NAICS = North American Industry Classification System; R^2 = coefficient of determination.
* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† 2007 NAICS codes. Additional information available at http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007Census.

TABLE 2. Factors contributing to chemical incidents — Hazardous Substances Emergency Events Surveillance system, nine states,* 2001†–2008

Factor	2001	2002	2003	2004	2005	2006	2007	2008	Total	R^2
Equipment failure	2,654	3,060	3,378	2,858	2,647	2,575	2,691	2,672	**22,535**	0.21
Human error	2,053	2,137	1,996	1,941	1,656	2,250	2,310	2,191	**16,534**	0.10
Improper filling, loading or packaging	538	831	859	847	681	1,013	930	852	**6,551**	0.35
System or process upset	672	793	729	653	483	286	235	241	**4,092**	0.85
System start up or shut down	496	486	579	409	513	239	300	190	**3,212**	0.67
Performing maintenance	381	398	413	334	350	358	324	233	**2,791**	0.66
Vehicle or vessel incident	224	196	232	234	246	219	241	236	**1,828**	0.27
Unauthorized or improper dumping	266	204	232	288	202	216	196	171	**1,775**	0.40
Fire	217	236	252	225	211	201	199	188	**1,729**	0.59
Bad weather conditions or natural disasters	121	161	161	137	240	134	125	184	**1,263**	0.04
Power failure or other electrical problems	194	150	163	136	119	80	107	77	**1,026**	0.87
Improper mixing	68	111	65	53	44	48	53	57	**499**	0.34
Explosion	39	64	72	68	44	50	45	53	**435**	0.04

Abbreviation: R^2 = coefficient of determination.
* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† N= 46,489; data for 1999 and 2000 were omitted because of the limited number of factor choices during those years.

TABLE 3. Number of single-chemical incidents, by 10 most commonly released chemicals — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Chemical name	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total		3-year difference†	%
											No.	(%)		
Ammonia	340	261	361	354	339	331	309	355	336	380	**3,366**	**(6)**	92	4.5
Paint (not otherwise specified)	98	112	93	60	112	112	221	422	403	356	**1,989**	**(4)**	736	45.3
Alkaline (sodium and potassium) hydroxide	152	168	214	174	150	117	116	206	232	197	**1,726**	**(3)**	252	24.8
Sulfuric acid	179	170	136	144	139	119	127	178	154	169	**1,515**	**(3)**	116	13.1
Mercury	104	117	147	120	130	118	75	138	175	171	**1,295**	**(2)**	161	20.0
Hydrochloric acid	119	99	109	110	121	116	75	123	144	169	**1,185**	**(2)**	124	16.6
Carbon monoxide	44	90	87	74	122	156	138	164	146	140	**1,161**	**(2)**	34	3.9
Ethylene glycol	77	121	142	99	88	114	107	102	117	155	**1,122**	**(2)**	65	9.5
Nitrogen oxide	34	140	151	194	182	136	136	8	4	1	**986**	**(2)**	-441	-94.4
Sulfur dioxide	292	153	82	75	94	99	50	17	11	17	**890**	**(2)**	-198	-68.8

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† 2003–2005 versus 2006–2008.

of nitrogen oxide (441 fewer cases, a 94% decrease) and sulfur dioxide (198 fewer cases, a 69% decrease). Conversely, the frequency of incidents involving paint (not otherwise specified), and ethylene glycol increased, presumably because their reportable quantities were decreased to 10 lbs or 1 gallon after the 2006 change in reporting guidelines.

Distribution by State

Almost 60% of all incidents occurred in two states, Texas and New York (Table 4). A decreasing trend occurred in the number of incidents in Texas, Wisconsin, and Colorado, and an increasing trend occurred in Minnesota. However, no trends were associated with the case definition changes in 2006.

Discussion

The change in the case definition in 2006 appears to have had expected effects on the data. Contributing factors that would be expected to cause smokestack emissions of carbon monoxide, sulfur oxides, or nitrogen oxides such as system or process upset, system startup or shutdown, performing maintenance, and power failure or other electrical problems, decreased in 2006. Incidents increased involving the substances that became subject to mandatory reporting (i.e., ammonia, alkaline hydroxide, sulfuric acid, mercury, and carbon monoxide >50 ppm). Substantial decreases occurred in the newly excluded substances: smokestack emissions of nitrogen oxide (441 fewer cases, a 94% decrease) and sulfur dioxide (198 fewer cases, a 69% decrease). Conversely, the frequency of incidents involving paint (not otherwise specified) and ethylene glycol increased, presumably because their reportable quantities were higher than 10 lbs or 1 gallon previously. However, no trends in state distribution were associated with the case definition changes.

A slight decreasing trend (R^2 = 0.30) in incidents over the 10 years has been reported in another analysis in this collection of surveillance summaries (*15*). Incidents in the industry with the highest number of incidents, chemical manufacturing, decreased substantially over the period, possibly as a result of HSEES and others agencies such as OSHA and CSB and industry group outreach. However, the lack of an overall decrease in HSEES injuries and an increase in deaths reported (*16*) suggest a need to continue to evaluate trends and direct outreach. Five industries accounted for almost one third of all injured persons: truck transportation, educational services, chemical manufacturing, utilities, and food manufacturing (*17*). The injuries of many persons injured in truck transportation incidents were unrelated to the chemical release. The numerous injuries that occurred in educational institutions were surprising, and the finding is concerning because children are more susceptible to environmental hazards (*17*).

The five most commonly released chemicals associated with injured persons (carbon monoxide, ammonia, chlorine, hydrochloric acid, and sulfuric acid) were the five chemicals most commonly released by the five industries with the most chemical incidents resulting in injuries (*18*). This is not an unexpected finding because these are extremely hazardous, fairly ubiquitous chemicals. Chlorine, although not one of the 10 most commonly released chemicals, was one of the five chemicals most commonly associated with injury because of its hazardous properties. Given this finding, outreach that focuses on these chemicals is likely to have a substantial effect on reducing morbidity and mortality.

States varied in their number of incidents, with highly populous Texas and New York having the most. This might be a result of the increased number of incidents that occur in population centers. In addition, the top chemicals and industries varied by state (*19*). This finding highlights the importance of using a state-based surveillance system, which provides important data for each state to prioritize planning and prevention strategies.

As reported in another analysis, approximately one fourth (26%) of all incidents resulted in at least one public health action (e.g., evacuation, decontamination, shelter-in-place order, road or area closure, or environmental sampling) (*20*). Although necessary, these actions can be stressful, disruptive,

TABLE 4. Number of chemical incidents, by state — Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008

State	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	R^2
Texas	2,691	2,486	2,514	2,771	2,754	2,298	2,297	2,061	2,083	1,877	**23,832**	0.71
New York	599	1,064	1,244	1,106	1,125	1,086	1,003	1,108	1,075	1,065	**10,475**	0.12
Minnesota	348	419	414	356	438	468	407	546	595	600	**4,591**	0.75
Wisconsin	507	478	508	537	410	428	346	367	324	298	**4,203**	0.83
Washington	423	439	522	625	580	375	181	327	237	270	**3,979**	0.43
North Carolina	318	301	311	311	374	382	314	344	332	287	**3,274**	0.00
Iowa	288	290	328	315	327	349	302	273	406	393	**3,271**	0.37
Oregon	105	270	275	282	256	230	183	239	265	272	**2,377**	0.10
Colorado	250	210	225	196	188	179	161	204	194	166	**1,973**	0.55
Total	**5,529**	**5,957**	**6,341**	**6,499**	**6,452**	**5,795**	**5,194**	**5,469**	**5,511**	**5,228**	**57,975**	—

Abbreviation: R^2 = coefficient of determination.

and costly. Therefore, ATSDR and participating states formed partnerships to link agencies responsible for responding to these incidents (e.g., state environmental departments, state health departments, and other state and local agencies emergency agencies) to increase situational awareness and state emergency notification for chemical emergencies.

Every year, participating states submitted outreach plans with logic models to ATSDR with several planned activities that were substantiated by their data and had measurable effects. Details on these activities were published previously (*21*). HSEES data were used by local and state emergency planners (EPA regional response teams, regional hazardous materials teams, state emergency management offices, local emergency planning committees, DHS, law enforcement, and chemical incident response teams) to identify chemicals, industries, and locations at high risk for involvement in a chemical release. HSEES data were used as a source of data for case scenario drills. HSEES data were used to support documentation for legislation, particularly for illegal methamphetamine laboratories and mercury bans in schools. Minnesota passed legislation banning the sale of mercury thermometers in 2001 and passed methamphetamine laboratory ordinances in many counties, which substantially reduced the number of illegal laboratories. New York provided data on methamphetamine laboratories for a governor's program bill that became law in 2005. In 2004, a law banning use of elemental mercury in all primary and secondary schools in New York required the development and dissemination of informational materials, which were developed in partnership with HSEES staff in New York. Iowa methamphetamine data were used by the governor to promote a new law restricting the sale of pseudoephedrine in 2005. Reports show a reduction of as much as 90% in methamphetamine laboratory incidences after the Iowa law was enacted. In Oregon, HSEES data were used to support state legislation to decrease the availability of precursor chemicals used in methamphetamine laboratories, which resulted in a 95% reduction in the number of laboratories during 2003–2007. In Wisconsin, HSEES data were used to demonstrate the large percentage of incidents that resulted in injuries but involved less than the state-reportable quantities, when the state legislature had a proposal to raise the state-reportable quantities. In addition, ATSDR and the state health departments have collaborated on numerous journal articles and presentations, which can be found on the ATSDR HSEES website (available at http://www.atsdr.cdc.gov/HS/HSEES).

The chemical incidents and injury prevention stakeholders include persons in areas such as labor, industry, academia, public safety, other state and federal agencies, and nongovernmental organizations. ATSDR convened stakeholders during 2004–2007 to gather input on making improvements to HSEES. As a result, in 2010, NTSIP replaced HSEES (*22*). NTSIP has a streamlined incident database as suggested by participating states and added petroleum incidents as suggested by stakeholders. In addition, NTSIP takes a multifaceted approach to incident surveillance and response. Specifically, stakeholders stated that national data were needed; therefore, HSEES and NTSIP data are used in collaboration with other federal national incident databases (the DOT and NRC incident databases) to provide national incident estimates for national planning purposes. NTSIP states now focus more on promoting progressive practices, such as green chemistry or inherently safer technology and other hazard reduction strategies. The Assessment of Chemical Exposure (ACE) feature of NTSIP was designed after stakeholders suggested that more extensive data collection was necessary for certain incidents with mass casualties, and sharing of lessons learned should be increased. ACE provides a tool kit, or if necessary a public health response team, to rapidly assess the public health effects of a mass casualty chemical incident and develop recommendations for prevention and preparedness. An ACE investigation might result in the identification and formation of a cohort of exposed persons who need to be monitored to assess long-term health consequences of the exposure.

Limitations

The findings in this report are subject to at least six limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, results from these nine states might not be representative of the entire United States. Third, inconsistencies within and across states likely exist because of reporting capacity (e.g., staffing) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. Fourth, changes in reporting guidelines in 2006 had an effect on some of the trends specifically chemicals and factors. Fifth, because some incidents are difficult to identify, such as carbon monoxide or illegal methamphetamine chemical incidents, which often happen in private homes, they might be underreported, with a bias toward those that cause injuries. Finally, incidents that occurred in the transportation and warehousing industries often might be related to motor vehicle crashes, and the associated injuries might be related to the trauma of the crash rather than the chemical release.

Conclusion

The limited number of industries, chemicals, and geographical areas associated with most of the HSEES incidents and injuries could be the main focus of future prevention activities. Improved maintenance of equipment and training of workers and the public should result in decreases in incidents. Because of several large industrial incidents, such as the BP refinery explosion and the BP oil spill in the Gulf of Mexico, the chemical manufacturing and oil refining industry has come under tighter scrutiny in recent years. On August 1, 2013, shortly after the large ammonia nitrate explosion that resulted in 15 deaths, 160 persons injured, and damage to or total destruction of numerous buildings in the town of West, Texas, an executive order was issued: Improving Chemical Facility Safety and Security (*23*). According to the order, in coordination with owners and operators, executive departments and agencies with regulatory authority need to take additional measures to improve chemical facility safety and security, which will better coordinate federal efforts toward reducing large industrial incidents. However, data indicate that nonindustrial sectors as well as transportation sectors (*17*) are responsible for a large number of incidents and injured persons, and the percentage of injuries among members of the public is increasing (*16*). Outreach for these sectors is still needed.

Because of the large number of persons injured in educational institutions and the increasing number of incidents in this sector, ATSDR is evaluating preexisting prevention practices, including green cleaning and green purchasing, chemical cleanout programs, school laboratory education, and mercury and pesticide restrictions. ATSDR is using information from this evaluation to develop a report that synthesizes effective elimination strategies and policies to share with stakeholders to promote a more unified, evidence-based approach to preventing chemical incidents in U.S. schools (*24*). NTSIP also has focused on educating pool owners and operators about safety practices, including state fact sheets (*25*) and a collaboration with the CDC Healthy Swimming Program and the American Chemistry Council to produce a video (*26*) and posters (*27*,*28*). These are just two examples of many NTSIP initiatives to reduce chemical injuries in educational institutions and among members of the general public. In May 2014, ATSDR published a report using NTSIP data pertaining to pool chemical releases (*29*) and the health consequences associated with them, which were cited as baseline data in CDC's Model Aquatic Health Code (MAHC). MAHC is a voluntary guidance document based on science and best practices that can help local and state authorities make swimming and other water activities healthier and safer (*30*). NTSIP continues to help states to collect surveillance data and to promote cost-effective, proactive measures, such as adopting the principles of green chemistry, converting to inherently safer design, and developing geographic mapping of chemically vulnerable areas.

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Temporal Trends of Acute Chemical Incidents and Injuries — Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: Widespread use of hazardous chemicals in the United States is associated with unintentional acute chemical incidents (i.e., uncontrolled or illegal release or threatened release of hazardous substances lasting <72 hours). Efforts by industries, government agencies, academics, and others aim to reduce chemical incidents and the public health consequences, environmental damage, and economic losses; however, incidents are still prevalent.

Reporting Period: 1999–2008.

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry (ATSDR) during January 1991–September 2009 to describe the public health consequences of chemical releases and to develop activities aimed at reducing the harm. This report summarizes temporal trends in the numbers of incidents, injured persons, deaths, and evacuations from the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: A total of 57,975 incidents and 15,506 injured persons, including 354 deaths, were reported. During the surveillance period, several trends were observed: a slight overall decrease occurred in incidents for fixed facilities (R^2 = 0.6) and an increasing trend in deaths (R^2 = 0.7) occurred, particularly for the general public (R^2 = 0.9). The number of incidents increased in the spring during March–June, and a decrease occurred in the remainder of the year (R^2 = 0.5). A decreasing trend in incidents occurred during Monday–Sunday (R^2 = 0.7) that was similar to that for the number of injured persons (R^2 = 0.6). The highest number of incidents occurred earlier in the day (6:00 a.m.–11:59 a.m.) and then decreased as the day went on (R^2 = 0.9); this trend was similar for the number of injured persons (R^2 = 1.0).

Interpretation: Chemical incidents continue to affect public health and appear to be a growing problem for the general public. The number of incidents and injuries varied by month, day of week, and time of day and likely was influenced by other factors such as weather and the economy.

Public Health Implications: Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industries, emergency responders, and others can use the findings in this report to prepare for and prevent chemical incidents and injuries. Specifically, knowing when to expect the most incidents and injuries can guide preparedness and prevention efforts. In addition, new or expanded efforts and outreach to educate consumers who could be exposed to chemicals are needed (e.g., education about the dangers of carbon monoxide poisoning for consumers in areas likely to experience weather-related power outages). Redirection of efforts such as promoting inherently safer technologies should be explored to reduce or eliminate the hazards completely.

Introduction

Hazardous chemicals are widely used in various industries and settings across the United States, and unintentional and illegal chemical releases can cause substantial morbidity and mortality (*1*). Public authorities at all levels, industries, academia, and others are involved in efforts to reduce the number of chemical incidents and associated injuries. These efforts include recommendations made from Chemical Safety Board investigations (*2*), targeted outreach by federal public health and safety agencies (*3,4*), the American Chemistry Council safety initiatives (*5*), and resources and tools provided by the Toxic Use Reduction Institute (*6*).

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To assess whether outreach efforts resulted in reductions over time or whether patterns were detected in the numbers of incidents, injured persons, and deaths, time trend data from the federal Hazardous Substances Emergency Events Surveillance (HSEES) system among the nine states that continuously participated in the system for 10 years were evaluated. This information can be used to develop future outreach activities.

The HSEES database provides information on the characteristics and spatial and temporal dimensions of hazardous chemical releases within the states that participated in the surveillance system (*7*). This report summarizes temporal trends of acute (lasting <72 hours) chemical incidents and associated injuries experienced within 24 hours occurring in selected states during 1999–2008 and is a part of a comprehensive surveillance summary (*8*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industries, emergency responders, and others can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES by health departments in nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 complete calendar years of data collection, 1999–2008. Data from 2009 were not included because several states ended data collection mid-year. A detailed description of the HSEES data used in this analysis is found elsewhere (*8*). Case definitions, exclusion criteria, and 2006 changes in reporting guidelines used for this analysis are described (Box).

Temporal trends in the numbers of incidents, injured persons, and deaths are described. Information collected for HSEES incidents included the time and date of occurrence; type of incident (fixed facility or transportation); location where the incident occurred; industry involved; area affected; proximity to vulnerable populations; chemicals released; number and type of injured persons, injuries, and deaths; evacuation details; and contributing factors for the incident.

In the analysis of deaths, single deaths in transportation incidents were not counted because they often are the result of trauma from a motor vehicle crash or rollover and not from a chemical exposure. Descriptive statistics and the coefficient of determination (R^2, which indicates how well data fit a statistical model) are presented to assess linear trends in number of incidents, number of injured persons by population group, and number of deaths. Other temporal distributions of incidents and injuries (season, day, and time) also were examined.

BOX. Case definitions, exclusions, and reporting guidelines — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Case definition for acute chemical release

An acute chemical release is an uncontrolled or illegal spill or release lasting <72 hours of an uncontrolled or illegal spill or release of any hazardous substance meeting specific predefined criteria. Releases of petroleum only (e.g., crude oil or gasoline) were excluded from the Hazardous Substances Emergency Events Surveillance (HSEES) system because the Comprehensive Environmental Response Compensation and Liability Act (Superfund legislation)† excludes it from Agency for Toxic Substances and Disease Registry authority.

Case definition for threatened release

A threatened release is an incident that resulted in a public health action such as an evacuation or road closure.

Changes in reporting guidelines to improve the uniformity of reporting among states and to maximize resources

- Before 2006, HSEES collected information on any chemical release if the amount was required by federal, state, or local law to be cleaned up.
- Starting in 2006, HSEES collected information on chemical releases if the amount was >10 lbs or >1 gallon or in any amount if the chemical was on the HSEES mandatory reporting list of highly toxic chemicals (e.g., anhydrous ammonia, arsenic, hydrazine, methyl isocyanate, nitric acid, and sulfuric acid).

In 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, and nitrogen oxides were excluded because numerous related incidents occurred but rarely resulted in acute public health impact.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

† Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 95 510 (Dec. 11, 1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99 499 (Oct. 17, 1986), 42 U.S.C. 9604(i).

Results

Number of Incidents

A total of 57,975 incidents occurred during 1999–2008; 41,993 (72%) occurred in a fixed facility, and 15,981 (28%) were transportation related. Incident type was missing for one incident. The total number of incidents varied, and the trend decreased overall (R^2 = 0.3). This decrease was driven by fixed-facility incidents (R^2 = 0.6) because of a slight upward trend that occurred in transportation incidents (R^2 = 0.3) (Figure 1). The highest number of incidents occurred in 2002 (6,499), and the fewest occurred in 2005 (5,194). For each year, the percentage of incidents that occurred in fixed facilities was higher than the percentage that was transportation related.

Number of Injured Persons by Population Group

A total of 15,506 persons were injured; 13,502 were injured in fixed facilities, and 2,004 were injured in transportation-related incidents. The number of injured persons varied greatly over time, primarily because of fluctuations in fixed-facility incidents, and no overall trend was found (Figure 2). The average number of injured persons per year was 1,551. The majority of injured persons were employees (7,674), followed by members of the general public (4,737), students (1,730), and responders (1,340); the population group was unknown for 25 injured persons.

The trend for number of injured employees decreased slightly but was always higher than the other categories (R^2 = 0.3) (Figure 3). The number of injured persons from the general public generally increased over time (R^2 = 0.3). The number of injured responders decreased slightly (R^2 = 0.5). The number of injured students was more variable.

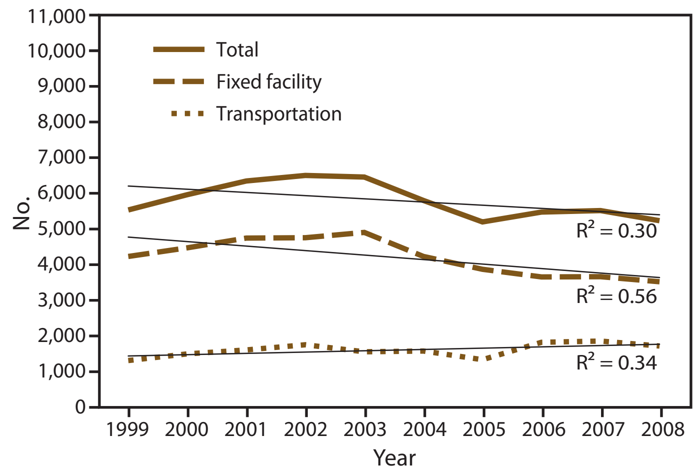
Number of Deaths

A total of 354 deaths occurred during 1999–2008 (Figure 4); 180 deaths were in fixed facilities and 174 were transportation related. The average number of deaths per year was 35. A spike in transportation-related deaths occurred in 2006. The trend for deaths increased (R^2 = 0.7), which was driven by incidents in fixed facilities (R^2 = 0.5). An overall increase in deaths in the general public occurred (R^2 = 0.9); no trends were found among employees or responders (Figure 5).

Trends in Month, Day, and Time of Incidents

The number of incidents increased in the spring during March–June, and a decrease occurred in the remainder of the year (R^2 = 0.5) (Figure 6). The highest number of persons were injured in June (n = 1,683), and the fewest in December (n = 1,034); no trend was found. A decreasing trend in incidents occurred during Monday–Sunday (R^2 = 0.7); this trend was similar for the number of injured persons (R^2 = 0.6) (Figure 7). The highest number of incidents occurred earlier in the day (6:00 a.m.–11:59 a.m.) and then decreased as the day went on (R^2 = 0.9) (Figure 8). Approximately half as many incidents occurred during other times of the day, which was similar for the number of injured persons as well (R^2 = 1.0).

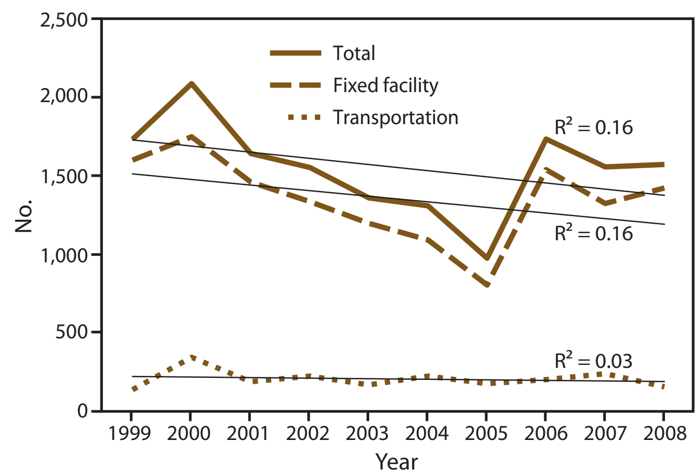
FIGURE 1. Number of chemical incidents, by incident type — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008



Abbreviation: R^2 = coefficient of determination.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

FIGURE 2. Number of persons injured in chemical incidents, by incident type — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008



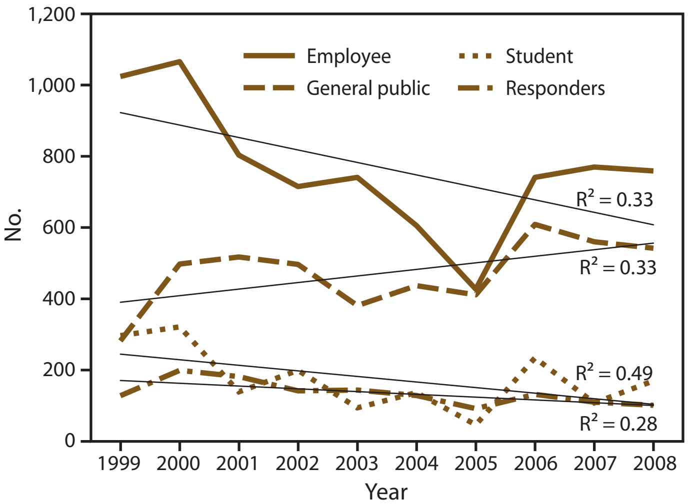
Abbreviation: R^2 = coefficient of determination.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

Discussion

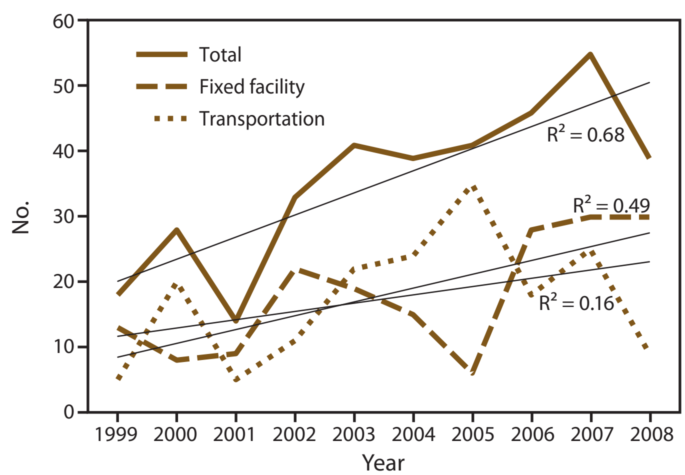
A useful surveillance system collects and archives data that can be used to improve public health. States analyzed the collected data and developed appropriate prevention outreach

FIGURE 3. Number of persons injured in chemical incidents, by category of injured person*— Hazardous Substances Emergency Events Surveillance system, nine states,† 1999–2008



Abbreviation: R^2 = coefficient of determination.
* Category missing for 25 injured persons.
† Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

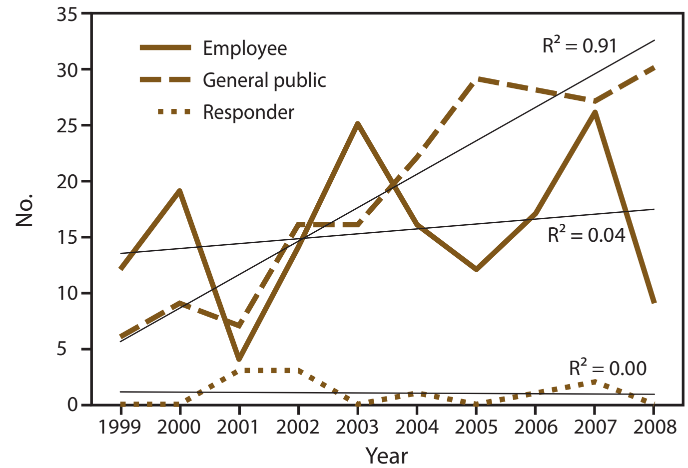
FIGURE 4. Number of deaths from chemical incidents, by incident type — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008



Abbreviation: R^2 = coefficient of determination.
* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

activities. These activities were intended to provide various industries, responders, and the general public with information to help prevent chemical releases and to reduce morbidity and mortality should a release occur. Many different activities were conducted that were dependent on the state-identified problem areas (*9*).

FIGURE 5. Number of deaths from chemical incidents, by category of injured person — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

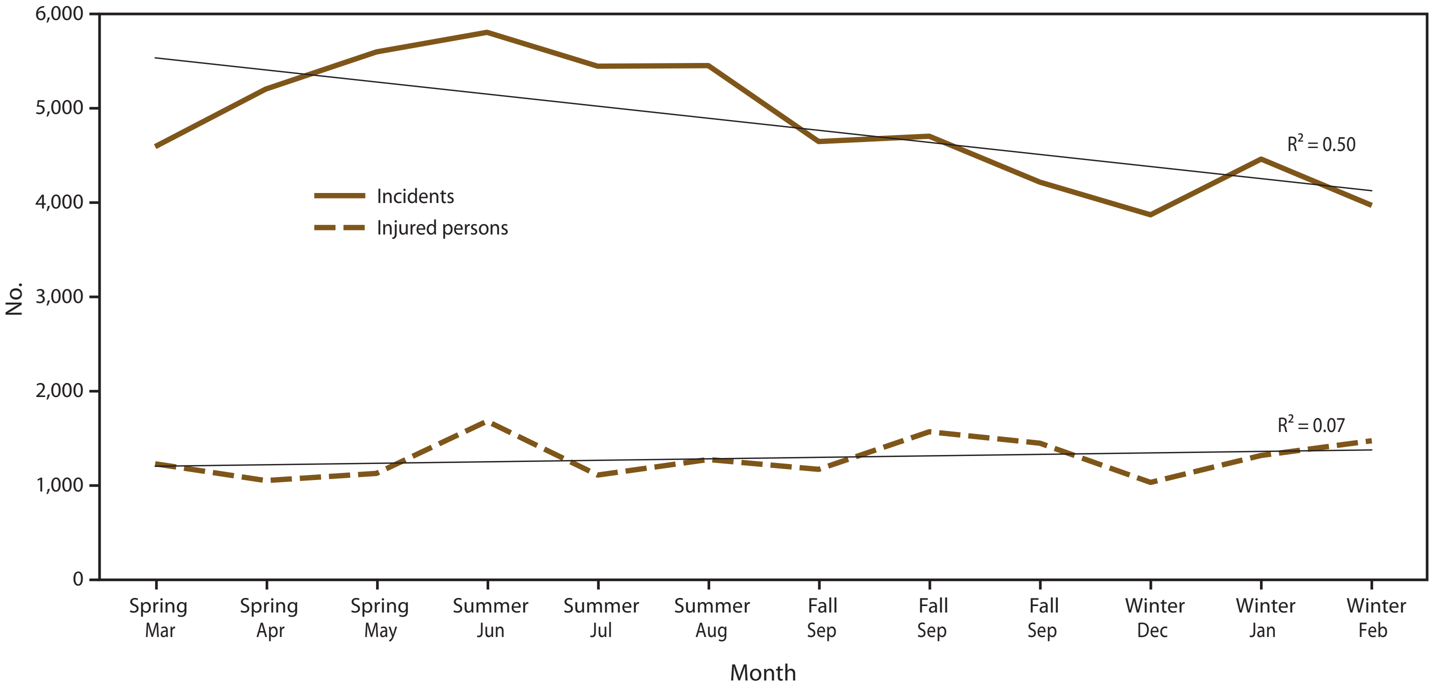


Abbreviation: R^2 = coefficient of determination.
* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

During the surveillance period (1999–2008), the number of chemical incidents reported to HSEES varied by month, day of week, and time of day and likely was influenced by other factors such as weather and the economy. Overall, the number of incidents and injured persons have decreased slightly (primarily because of decreases in fixed-facility incidents) over the 10-year period. However, the number of fixed-facility incidents and injuries per year was always greater than the number for transportation-related incidents. Recent large incidents and the efforts of the U.S. Occupational Safety & Health Administration and Chemical Safety Board have focused attention on worker safety (*10*,*11*). Whereas injuries and deaths among workers decreased, injuries and deaths in the general public increased. This increase might be partially attributable to an effort to obtain more notifications from medical centers, poison control centers, and the media. These sources differ from traditional HSEES notification sources and often include smaller-scale injuries that are not reported to state environmental departments, because many occur in the home to members of the public.

A seasonal trend was observed, with the number of incidents increasing during March–June, which coincides with the spring planting season in agricultural states (*12*). However, a seasonal trend in the number of injured persons did not occur. Although more incidents occurred and more persons were injured on weekdays than on weekends, the fewest number of weekday incidents and injured persons occurred on Mondays, the day operations normally resume or increase. The majority of incidents occurred during 6:00 a.m.–6:00 p.m., which

FIGURE 6. Number of incidents and injured persons,* by month — Hazardous Substances Emergency Events Surveillance system, nine states,† 1999–2008



Abbreviation: R^2 = coefficient of determination.
* Summed over entire period.
† Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

covers the typical workday. Fewer incidents occurred and fewer persons were injured during the third shift, which might be attributed to times during which production is decreased and fewer people are working.

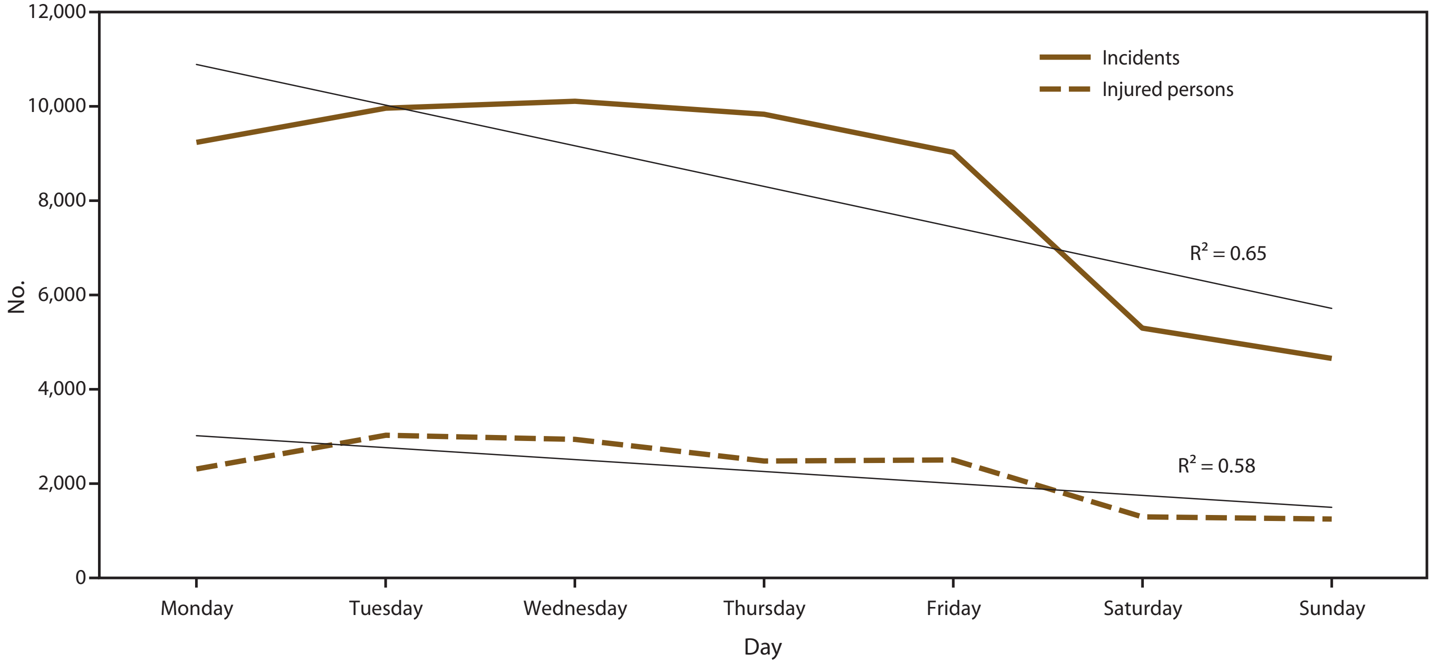
The fewest incidents per year occurred in 2005, the year that also had the fewest total number of injured persons, injured employees, injured responders, and injured students. More employees were injured every year than were any other population group; however, in 2005, only 16 more employees than members of the general public were injured.

The findings in this report appear to be weather related. Hurricane Katrina, which occurred on August 28, 2005, shut down oil pipelines and production facilities as well as transportation routes in the Gulf of Mexico area, causing the price of gas to increase and fewer goods to be shipped (*13*). One hundred and twelve fewer transportation incidents occurred in the 4 months after the hurricane than during that period in the previous year. In addition, 2005 was one of the warmest years since the United States began keeping records and included one of the deadliest tornado outbreaks in recent history, three category 5 hurricanes, and several notable snowstorms (*14*). The extreme weather conditions in 2005 led to facility shutdowns and transportation route disruptions (*15–18*).

Natural disasters can cause substantial variations in the HSEES trends for deaths because of small numbers. For example, 18 deaths occurred in the state of Washington from carbon monoxide poisoning when a harsh winter storm caused an electrical outage. During electrical outages, persons often use alternate heating and electrical sources that can cause carbon monoxide poisoning.

The results of this analysis indicate that the economy and weather measurably affect chemical spill and injury trends. Although HSEES states have recorded decreases in the number of incidents and injured persons, the number of deaths has increased. The decreases appear to be in fixed-facility incidents and employee injuries. Because the economy had been declining, discerning whether the decreases are a result of decreases in production, improved safety culture, or both is difficult. An increase in the numbers of injuries and deaths occurred among members of the general public. Many of the general public injuries are from carbon monoxide poisoning, and carbon monoxide poisoning is more common during bad weather because of the increased misuse of home generators and charcoal grills inside the home (*19*,*20*). Methamphetamine production incidents also have been increasing and are extremely dangerous to the general public (*21*). The number of transportation incidents fluctuated and decreased during times of high gas prices and transportation slowdowns.

FIGURE 7. Number of incidents and injured persons,* by day of the week — Hazardous Substances Emergency Events Surveillance system, nine states,† 1999–2008



Abbreviation: R^2 = coefficient of determination.
* Summed over entire period.
† Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

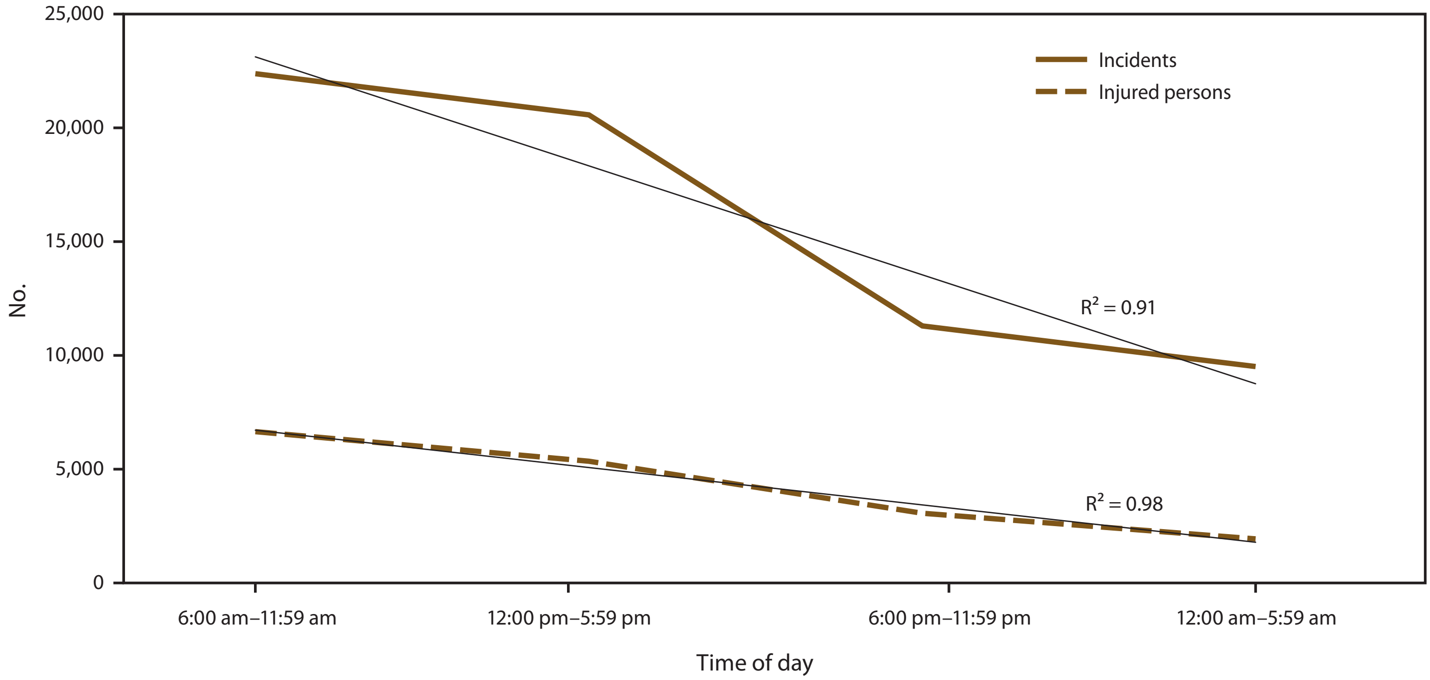
Limitations

The findings in this report are subject to at least six limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, the results from these nine states might not be representative of the entire United States. Third, inconsistencies within and across states likely exist because reporting capacity (e.g., staffing) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. Fourth, changes in reporting guidelines in 2006 (e.g., differences in cleanup requirements) might have affected the trend analyses, particularly because numerous smokestack incidents involving carbon monoxide, sulfur oxides, and nitrogen oxides from manufacturing companies were excluded. However, the elimination of these incidents should not have had a substantial effect on the number of injured persons. Fifth, HSEES did not obtain information on all residential incidents. Finally, the category of injured students was intended to include children injured by incidents that occurred at their school. When children are injured at school by incidents that occurred elsewhere (e.g., a factory air release that affected their school), they should be coded as general public; however, in several instances, they were miscoded as students.

Conclusion

Chemical incidents continue to affect public health and appear to be a growing problem for the general public. The number of incidents and injuries varied by month, day of week, and time of day and likely was influenced by other factors such as weather and the economy. The efforts by industries, academia, government agencies, and others to promote safety should continue. New or expanded efforts and outreach to educate consumers who could be exposed to chemicals are needed (e.g., education about the dangers of carbon monoxide poisoning for consumers in areas likely to experience hurricanes). Because outreach by ATSDR and numerous other groups over this 10-year period only slightly decreased incidents and injuries, redirection of efforts such as promoting inherently safer technologies should be explored to reduce or eliminate the hazards completely.

FIGURE 8. Number of incidents and injured persons,* by time of day— Hazardous Substances Emergency Events Surveillance system, nine states,† 1999–2008



Abbreviation: R^2 = coefficient of determination.
* Summed over entire period.
† Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

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Persons Injured During Acute Chemical Incidents — Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: Persons exposed to chemicals during acute chemical incidents (i.e., uncontrolled or illegal release or threatened release of hazardous substances lasting <72 hours) can experience both acute and chronic health effects. Surveillance of toxic substance incidents provides data that can be used to prevent future incidents and improve the emergency response to those that occur, leading to a decrease in morbidity and mortality from chemical releases.

Reporting Period: 1999–2008

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry (ATSDR) during January 1991–September 2009 to describe the public health consequences of chemical releases and to develop activities aimed at reducing the harm. This report summarizes the data collected on injured persons from the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: A total of 57,975 chemical incidents were reported by these states during the 10-year surveillance period. In 4,621 (8%) of these incidents, 15,506 persons were injured. Among them, 354 deaths occurred. The most commonly reported category of injured persons included employees of the responsible party (7,616 [49%]), members of the general public (4,737 [31%]), students exposed at school (1,730 [11%]), and responders to the incident (1,398 [9%]). Deaths occurred among members of the general public (190 [54%]), employees (154 [44%]), and responders (10 [3%]). The most frequent health effects experienced as a result of these incidents included respiratory irritation (7,443), dizziness or central nervous system problems (3,186), and headache (3,167). The three chemicals associated with the largest number of persons injured were carbon monoxide (2,364), ammonia (1,153), and chlorine (763).

Interpretation: Company employees, followed by members of the general public, are frequently injured in acute chemical incidents. The chemicals most often associated with these injuries are carbon monoxide, ammonia, and chlorine, all of which are hazardous gases that can be found in various locations including schools and homes. Respiratory irritation is the most common health effect.

Public Health Implications: By understanding the types of persons injured in chemical release incidents, as well as how they are injured and the injuries sustained, prevention outreach activities can be focused to protect the health of these groups in the future. Improved awareness among and training for not just employees but also the public is needed, particularly regarding carbon monoxide, ammonia, and chlorine. Appropriate measures to provide protection from respiratory effects of chemical incidents could prevent injuries.

Introduction

Chemicals that can cause adverse health effects are used in many settings, including manufacturing industries, water treatment facilities, food processing plants, schools, and homes. Because of this, chemicals are involved in tens of thousands of emergency incidents each year and lead to thousands of personal injuries and hundreds of deaths. In addition to physical injuries, persons exposed to chemical releases can experience long-lasting mental health effects (*1–3*), and communities where incidents occur can be strained (*4*).

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The Hazardous Substances Emergency Events Surveillance (HSEES) database provides information on the characteristics and spatial and temporal dimensions of hazardous chemical releases within the states that participated in the surveillance system (*5*). This report summarizes the data collected on injured persons in selected states during 1999–2008 and is a part of a comprehensive collection of surveillance summaries (*6*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industry employees, emergency responders, and others who prepare for or respond to chemical incidents can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES by health departments in nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 complete calendar years of data collection, 1999–2008. Data from 2009 were not included because several states ended data collection mid-year. A detailed description of the HSEES data used in this analysis is found elsewhere (*6*). Case definitions, exclusion criteria, and 2006 changes in reporting guidelines used for this analysis are described (Box).

Chemical incidents that result in injuries were characterized and the injured persons were described by analyzing collected data that included location, industry, substances released, contributing factors, injured persons, injuries experienced, and shelter-in-place or evacuation orders. These data were entered into an Agency for Toxic Substances and Disease Registry (ATSDR) online data collection system. Data analysis using statistical software was performed and included descriptive statistics and odds ratios (ORs) with 95% confidence intervals (CIs) for injury given different protective actions, including evacuation, shelter in place, and decontamination. Chi square for linear trend in proportions also was calculated. P values of <0.05 were considered significant. In this analysis, members of a company response team were categorized as responders and not considered to be employees of their company.

HSEES defined an injured person as a person who experienced at least one documented acute (i.e., occurring in <24 hours) adverse health effect or who died as a consequence of the incident; injured persons must have at least one injury type or symptom, and up to seven could be listed (*5*).

BOX. Case definitions, exclusions, and reporting guidelines — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Case definition for acute chemical release

An acute chemical release is an uncontrolled or illegal spill or release lasting <72 hours of an uncontrolled or illegal spill or release of any hazardous substance meeting specific predefined criteria. Releases of petroleum only (e.g., crude oil or gasoline) were excluded from the Hazardous Substances Emergency Events Surveillance (HSEES) system because the Comprehensive Environmental Response Compensation and Liability Act (Superfund legislation)† excludes it from Agency for Toxic Substances and Disease Registry authority.

Case definition for threatened release

A threatened release is an incident that resulted in a public health action such as an evacuation or road closure.

Changes in reporting guidelines to improve the uniformity of reporting among states and to maximize resources

- Before 2006, HSEES collected information on any chemical release if the amount was required by federal, state, or local law to be cleaned up.
- Starting in 2006, HSEES collected information on chemical releases if the amount was >10 lbs or >1 gallon or in any amount if the chemical was on the HSEES mandatory reporting list of highly toxic chemicals (e.g., anhydrous ammonia, arsenic, hydrazine, methyl isocyanate, nitric acid, and sulfuric acid).

In 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, and nitrogen oxides were excluded because numerous related incidents occurred but rarely resulted in acute public health impact.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

† Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 95 510 (Dec. 11, 1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99 499 (Oct. 17, 1986), 42 U.S.C. 9604(i).

Results

A total of 57,975 chemical incidents were reported by the nine states to HSEES during 1999–2008. In 4,621 (8%) of these incidents, 15,506 persons were injured (Table 1). The number of incidents with injuries during this period varied among states because of differences in population and industry composition, from 157 in Colorado to 1,260 in New York. The proportion of incidents in which injuries occurred varied from 2% in Texas to 27% in Washington. In both Oregon and Washington, the proportion of incidents resulting in injury decreased over the 10-year period (p<0.05). The number of persons injured in each incident ranged from one to 259 (mean: three to four, median: one) (Table 2). A total of 4,041 incidents occurred in which a single chemical was released, resulting in 13,198 persons being injured; 9,230 (70%), of

TABLE 1. Number and percentage of incidents resulting in injuries,* by state and year — Hazardous Substances Emergency Events Surveillance system, nine states,† 1999–2008

	1999		2000		2001		2002		2003		2004		2005		2006		2007		2008		Total	
State	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Colorado	11	(4)	11	(5)	7	(3)	20	(10)	24	(13)	21	(12)	18	(11)	14	(7)	16	(8)	15	(9)	**157**	**(8)**
Iowa	47	(16)	22	(8)	34	(10)	27	(9)	31	(9)	25	(7)	28	(9)	51	(19)	84	(21)	88	(22)	**437**	**(13)**
Minnesota	24	(7)	29	(7)	19	(5)	16	(4)	30	(7)	26	(6)	26	(6)	31	(6)	32	(5)	55	(9)	**288**	**(6)**
North Carolina	32	(10)	26	(9)	25	(8)	39	(13)	38	(10)	29	(8)	22	(7)	27	(8)	25	(8)	17	(6)	**280**	**(9)**
New York	65	(11)	180	(17)	144	(12)	107	(10)	112	(10)	124	(11)	89	(9)	142	(13)	145	(13)	152	(14)	**1,260**	**(12)**
Oregon	18	(17)	34	(13)	36	(13)	31	(11)	39	(15)	25	(11)	17	(9)	13	(5)	20	(8)	24	(9)	**257**	**(11)**
Texas	49	(2)	53	(2)	65	(3)	39	(1)	37	(1)	40	(2)	60	(3)	78	(4)	59	(3)	99	(5)	**579**	**(2)**
Washington	168	(40)	180	(41)	168	(32)	153	(24)	153	(26)	85	(23)	22	(12)	95	(29)	26	(11)	23	(9)	**1,073**	**(27)**
Wisconsin	28	(6)	31	(6)	30	(6)	80	(15)	31	(8)	15	(4)	14	(4)	17	(5)	20	(6)	24	(8)	**290**	**(7)**
Total	**442**	**(8)**	**566**	**(10)**	**528**	**(8)**	**512**	**(8)**	**495**	**(8)**	**390**	**(7)**	**296**	**(6)**	**468**	**(9)**	**427**	**(8)**	**497**	**(10)**	**4,621**	**(8)**

* Percentage of incidents in that state during that year or the total time that resulted in injured persons.
† Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.

TABLE 2. Number of persons injured in acute chemical incidents, by year — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Year	No. of incidents with injuries	Mean no. injured in an incident	Median no. injured in an incident	Maximum no. injured in an incident	Total no. of persons injured
1999	442	4	1	141	**1,731**
2000	566	4	1	259	**2,087**
2001	528	3	1	54	**1,641**
2002	512	3	1	54	**1,552**
2003	495	3	1	85	**1,357**
2004	390	3	1	57	**1,307**
2005	296	3	1	67	**972**
2006	468	4	1	109	**1,733**
2007	427	4	1	52	**1,555**
2008	497	3	1	44	**1,571**
Total	**4,621**	**3**	**1**	**259**	**15,506**

* Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.

these incidents involved volatilization or aerosolization of the chemical (Table 3).

The sex of 12,611 injured persons was known; 8,096 (64%) were male and 4,515 (36%) were female. The majority of responders (91%) and employees (70%) of the responsible party were male. More members of the general public who were injured in chemical incidents were male (54%), whereas more students injured at school were female (58%). The mean age was similar for employees (37 years), responders (36 years), and the general public (34 years). Students exposed at school were an average age of 13 years.

Employees of the company responsible for the chemical release were the persons most frequently injured in these incidents (7,616) (Table 4). The next most commonly injured groups were members of the general public (4,737) and students exposed at school (1,730). Emergency responders, primarily firefighters and police officers, also were commonly injured in incidents involving chemical releases (1,398). Of the 543 incidents in which responders were injured, the most common locations involved private households (33 [6%]), merchant wholesalers (13 [2%]), utilities (11 [2%]), chemical manufacturing (10 [2%]), and food manufacturing (10 [2%]). Methamphetamine laboratories often are in private households. Two hundred thirty-one (17%) of the 1,398 responders were injured when responding to incidents in illegal methamphetamine laboratories. Throughout the 10-year period, the proportion of injured persons that were members of the general public has shown an increasing trend ($p<0.05$).

Medical care received as a result of the incident is known for 15,369 persons (Table 5). The majority of persons received

TABLE 3. Number of persons injured in acute single-chemical release incidents, by type of release — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Type of chemical release	No. injured	(%)
Single type of release		
Volatilization or aerosolized (vapor)	7,575	(57)
Spill (liquid or solid)	2,983	(23)
Fire	275	(2)
Explosion	235	(2)
Not applicable, threatened release	53	(0.4)
Radiation	8	(0.06)
Other	4	(0.03)
Total injured	**11,133**	**(84)**
Multiple types of releases		
Spill and volatilization or aerosolized	1,655	(13)
Volatilization/aerosolized and fire	121	(0.9)
Fire and explosion	112	(0.8)
Volatilization or aerosolized and explosion	72	(0.5)
Spill and fire	47	(0.4)
Spill and explosion	24	(0.2)
Spill and other	4	(0.03)
Spill and radiation	1	(0.01)
Spill and not applicable, threatened release	1	(0.01)
Fire and not applicable, threatened release	1	(0.01)
Total injured	**2,038**	**(15)**
Unknown	27	(0.2)
Total injured (single release, multiple release, and unknown)	**13,198**	—

* Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.

care at a hospital, including those observed without treatment (414 [3%]), treated in the emergency department and released (8,414 [55%]), or admitted for hospital care (1,189 [8%]). Almost one fourth (3,431 [22%]) of injured persons were treated with first aid at the scene of the incident. Some injured persons (683 [4%]) sought care with their primary care physician within 24 hours of the incident. Of those admitted to a hospital, 663 (56%) were employees of the responsible party, 418 (35%) were members of the public, 83 (7%) were responders, and 25 (2%) were students exposed during an incident at a school. A total of 354 deaths occurred as a result of these incidents. Among deaths for which location was known, 257 (87%) occurred at the scene or were declared when the person arrived at the hospital. Thirty-seven (13%) deaths occurred after the injured person arrived at the hospital. The location of death for 60 persons was not collected. A total of 190 (54%) of the deaths occurred among members of the general public, 154 (44%) among employees of the responsible party, and 10 (3%) among responders.

Injured persons must have had at least one injury listed (and could have up to seven). The most frequently reported injuries included respiratory irritation (7,443 [30%]), dizziness or central nervous system problems (3,186 [13%]), and headache (3,167 [13%]) (Table 6). Trauma, which is common in motor vehicle accidents, could be unrelated to the chemicals involved in the incident or could be the result of the chemical. Likewise, burns could either be thermal or related to the chemical. Persons injured in chemical incidents often have more than one symptom, such as respiratory irritation and eye irritation. In addition, heat stress might be a result of wearing personal protective equipment (PPE) during responses with a high ambient air temperatures rather than be caused by the chemical incident. However, most persons injured during acute chemical incidents were not wearing any PPE (12,354 [82%]) (Table 7).

Sheltering in place and evacuations are used to protect the local population from becoming exposed during a chemical incident. Although HSEES summary data do not have sufficient detail to determine at which point during an incident

TABLE 4. Number and percentage of persons injured in acute chemical incidents, by category of injured person — Hazardous Substances Emergency Events Surveillance System, nine states,* 1999–2008

Category of injured person	No.	(%)
Employee of responsible party		
General employee of company†	7,616	(49)
Responder to the incident		
Professional firefighter	431	(3)
Police officer	418	(3)
Volunteer firefighter	260	(2)
Firefighter not specified	86	(0.6)
Member of company response team	58	(0.4)
Emergency medical technicians	56	(0.4)
Responder not specified	51	(0.3)
Third party clean-up contractor	20	(0.1)
Hospital personnel e.g., doctor, nurse	18	(0.1)
Total responders	1,398	(9)
Member of the public		
General public	4,737	(31)
Student exposed at school	1,730	(11)
Total members of public	6,467	(42)
Unknown	25	(0.2)
Total	**15,506**	—

* Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.
† Excludes members of company's response team.

TABLE 5. Treatment received by persons injured in acute chemical incidents — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Treatment received or disposition	No.	(%)
Treated on scene with first aid	3,431	(22)
Treated at hospital, not admitted	8,414	(55)
Treated at hospital, admitted	1,189	(8)
Observation at hospital, no treatment	414	(3)
Seen by private physician within 24-hours	683	(4)
Injury reported by official	884	(6)
Death on scene or on arrival at hospital	257	(2)
Death after arrival at hospital	37	(0.2)
Death unknown location†	60	(0.4)
Total	**15,369§**	—

* Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.
† Location of death was not collected during 1999–2001.
§ Disposition of 137 injured persons is not known.

TABLE 6. Type of injuries received from acute chemical incidents — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Type of injury†	No.	(%)
Respiratory irritation	7,443	(30)
Dizziness or central nervous system problems	3,186	(13)
Headache	3,167	(13)
Eye irritation	2,674	(11)
Gastrointestinal problem	2,597	(10)
Burn§	1,504	(6)
Trauma¶	1,426	(6)
Skin irritation	1,098	(4)
Shortness of breath	781	(3)
Other**	671	(3)
Heart problem	217	(0.9)
Heat stress	116	(0.5)
Total††	**24,880**	—

* Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.
† Not all injuries are the result of the chemical.
§ Chemical related (n = 423), thermal (n = 544), both (n = 72), and unknown (n = 465).
¶ Chemical related (n = 278), not chemical related (n = 729), both (n = 8), and unknown (n = 411).
** Includes injury types such as carbon monoxide poisoning, hypertension, and chest pain.
†† Injured persons must have had at least one listed injury (and could have up to seven).

TABLE 7. Protective equipment worn by those injured in acute chemical incidents — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Personal protective equipment worn	No.	(%)
Level A†	60	(0.4)
Level B†	47	(0.3)
Level C†	65	(0.4)
Level D†	385	(3)
Firefighter turn-out gear with respiratory protection	469	(3)
Firefighter turn-out gear without respiratory protection	187	(1)
Other types of protection§	1,090	(7)
Unknown type	390	(3)
None	12,354	(82)
Total	**15,047**	—

* Colorado, Iowa, Minnesota, North Carolina, New York, Oregon, Texas, Washington, and Wisconsin.

† The four levels of personal protective equipment range from level A (maximum protection for use when the greatest potential for exposure exists) to level D (minimal protection). (**Source:** Environmental Protection Agency. Personal protective equipment. Emergency hazardous substances. Washington, DC: Environmental Protection Agency; 2011. Available at http://www.epa.gov/osweroe1/content/hazsubs/equip.htm.)

§ Includes eye protection (n = 815), hard hat (n = 653), steel-toed shoes (n = 633), and gloves (n = 376).

the injuries occurred, ORs were calculated for shelter-in-place orders and evacuations, using injury during the incident as the outcome measure. Among the 4,621 incidents in which persons were injured, a shelter-in-place order was issued for 156 incidents, and an evacuation was ordered for 1,439 incidents. The odds of a shelter-in-place or evacuation order being given in incidents with injuries were higher than the odds of this order being given among incidents without injuries (OR: 5.4; CI: 4.4–6.5, OR: 8.5; CI: 7.9– 9.2, respectively).

Decontamination is used to remove chemicals from contaminated persons to prevent future exposure to the chemicals and prevent additional contamination and secondary exposures. Decontamination was performed in 1,152 of the 4,621 incidents in which persons were injured. The odds of decontamination being performed were greater in incidents with injuries than in incidents without injuries (OR: 17.1; CI: 15.6-18.7).

Discussion

Acute chemical releases are common in the United States, and injuries and deaths caused by these incidents remain a problem. Data obtained by surveillance of chemical release incidents can be used to develop prevention activities to decrease the number of incidents and the resulting morbidity and mortality.

Four distinct groups were injured during chemical incidents: employees of the responsible party, the general public, students exposed at school, and responders to the incident. The reasons various groups are exposed during these incidents and the methods needed to protect them are different.

Employees of the entity responsible for the chemical release are the most commonly injured persons and represent the highest proportion of those hospitalized. The Occupational Safety and Health Administration, whose mission is to ensure safe and healthful working conditions, recommends a hierarchy of control to protect the health of employees who work with chemicals (*7*). The most effective way to protect those who work with toxic chemicals is to completely eliminate use of a known hazardous chemical or substitute it with a less toxic one. The next most effective method is to establish an engineering control that creates barriers or prevents workers from performing actions that could result in a chemical exposure or release. Administrative controls, which require a worker to perform a specific action, or use of PPE are less effective workplace protective measures. Employees have a right to a safe workplace, and employers have responsibilities under occupational safety and health laws to ensure that these rights are protected (*8*). Injury and illness prevention programs are fundamental for protecting workers and transforming workplace culture, leading to reductions in injuries, illnesses, and deaths. These programs also decrease workers' compensation and other costs, improve morale and communication, enhance image and reputation, and improve processes, products and services. Important characteristics of effective programs include management commitment and leadership, effective employee participation, integration of health and safety with business planning, and continuous program evaluation (*9*). Over the 10-year surveillance period, the number of injured employees decreased slightly (*10*), which might be attributable to advances in worker safety and training.

Members of the general public are the second most commonly injured group and have the largest number of deaths. The percentage of all injured persons in the general public has increased as the percentage of injured workers decreased. The public might be affected by various types of incidents, including an explosion at a nearby factory, a transportation incident such as a truck rollover or train derailment, or illegal activities such as methamphetamine production in the home. Avoiding the transport of hazardous substances through densely populated areas or through small secondary roads, where responding to an emergency would be difficult, could help decrease injuries and deaths among members of the general public. In addition, local industries can provide a list of the chemicals they use to their local emergency planning committees so that the committees can plan for possible related emergencies. Use of the best available data by all relevant persons and facilities, including first responders, hospitals, and industries, increases understanding of potential chemical incidents, which helps ensure efficient coordination and response during an incident.

Children are inherently more susceptible to environmental hazards because their bodies are still developing and because of certain age-associated behaviors (*11*). Although students in primary and secondary schools comprise the group that is the third most commonly exposed to chemical incidents, this proportion does not adequately describe the number or severity of injuries experienced during incidents at schools. In addition to students being exposed, teachers and other staff members are often also exposed or are the only persons exposed. However, although numerous student injuries occurred, few were severe enough to result in hospitalization, and none resulted in death. Triage and treatment of minor symptoms at the scene of a school incident could decrease unnecessary transport of students to hospitals. Campaigns to replace toxic cleaning substances with safer chemicals will help decrease exposure of children to toxic chemicals. In addition, a combination of educational campaigns such as Don't Mess with Mercury (*12*) and strict enforcement of bans on items such as homemade chemical bombs (e.g., bottle bombs) and pepper spray also can help minimize the number of school-related chemical incidents.

Firefighters and police officers who respond to chemical releases or incidents in which chemicals are present are the fourth most commonly affected group. Like employees of the responsible party, responders are employees who should receive appropriate training and be issued the PPE needed to prevent exposure to toxic chemicals. Responders who are injured during a chemical release often are unable assist and rescue others during a response. Responders who might encounter circumstances necessitating use of a respirator should be medically screened for respirator use, be properly equipped, and receive respirator use training that includes recognizing hazards (*13*,*14*). This training should be renewed frequently. All responders should receive training on how to recognize and handle a situation involving chemicals that could be hazardous. In addition, responders should be able to determine which incidents require decontamination, not only to prevent additional exposure among contaminated persons but also to prevent contamination among those providing medical care, in ambulances, and in hospitals.

A higher proportion of injuries occurred during incidents in which a shelter-in-place or evacuation order was issued or in which decontamination was performed than during incidents with no such orders or decontamination. Surveillance data such as those from HSEES do not indicate whether the injuries occurred before or after the public health action was implemented. Only a small percentage of chemical release incidents have a shelter-in-place order, evacuation, or decontamination during the response; these incidents generally involve the largest releases and the most toxic substances.

Limitations

The findings in this report are subject to at least seven limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, results are not generalizable because circumstances in specific states might not be representative of the entire United States. Third, inconsistencies within and across states likely exist because reporting capacity (e.g., staffing or participating units) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. These factors might influence the quality and number of reports or level of detail provided about the incidents. Fourth, states with access to data on sources of injury, such as occupational injury or hospital discharge data, might identify more injuries than other states even though they did not actually have more incidents with injuries. For example, Washington was the only state to have access to the occupational injury database of its state department of labor, which might have led to their high number of reported injuries. Fifth, states with stricter reporting requirements might have more small-scale incidents and thereby a lower proportion of incidents with injuries. Sixth, incidents that occurred in the transportation and warehousing industries often were related to motor vehicle crashes, and the associated injuries might have been related to the trauma of the crash rather than to the chemical release. Finally, because the timing of the injury cannot be determined (e.g., before or after protective actions were implemented), the effectiveness of public health interventions such as shelter-in-place orders, evacuation orders, or decontamination cannot be assessed. A separate analysis discusses this point in greater detail (*15*).

Conclusion

Chemical releases continue to cause injuries and deaths, not only among persons who work with chemicals but also among members of the public. Because new trends in incidents can emerge, ATSDR is continuing surveillance on chemical releases to develop interventions. In 2010, the HSEES program merged with the National Toxic Substance Incidents Program (NTSIP) (*16*). NTSIP has a new component called incident investigations, or the Assessment of Chemical Exposures (ACE) program (*17*). Through these investigations, a thorough evaluation of large-scale chemical releases can supplement what is known about acute health effects caused by chemical releases. In addition, effectiveness of communication and public health actions such as shelter-in-place or evacuation orders can be evaluated. ACE was designed to provide data to state and local health partners and responders to decrease morbidity and mortality caused by acute chemical releases.

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Public Health Response to Acute Chemical Incidents — Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: Acute chemical incidents (i.e., uncontrolled or illegal release or threatened release of hazardous substances lasting <72 hours) represent a substantial threat to the environment, public health and safety, and community well-being. Providing a timely and appropriate public health response can prevent or reduce the impact of these incidents.

Reporting Period: 1999–2008.

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry (ATSDR) during January 1991–September 2009 to describe the public health consequences of chemical releases and to develop activities aimed at reducing the harm. This report summarizes types, frequency, and trends in public health actions taken in response to hazardous substance incidents in the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: Of the 57,975 HSEES incidents that occurred during 1999–2008, a total of 15,203 (26.2%) incidents resulted in at least one public health action taken to protect public health. Evacuations were ordered in 4,281 (7.4%) HSEES incidents, shelter in place was ordered in 509 (0.9%) incidents, and access to the affected area was restricted in 10,345 (25.9%) incidents. Decontamination occurred in 2,171 (3.7%) incidents; 13,461 persons were decontaminated, including 1,152 injured persons. Actions to protect public health (e.g., environmental sampling or issuance of health advisories) were taken in 6,693 (11.5%) incidents. The highest number of evacuations and orders to shelter in place occurred in Washington (n = 558 [16.1%] and n = 121 [3.2%], respectively). Carbon monoxide and ammonia releases resulted in the highest percentage of orders to evacuate and shelter in place. The most frequently reported responders to chemical incidents were company response teams.

Interpretation: The most frequent public health response was restricting access to the area (26% of incidents), public health actions (12%), evacuation (7%), decontamination (4%), and shelter-in-place (1%). Ammonia and carbon monoxide were associated with adverse health effects in the population and the most public health response actions. Therefore, these chemicals can be considered a high priority for prevention and response efforts.

Public Health Implications: States and communities can collaborate with facilities to use the information collected through community right-to-know legislation and this report to improve chemical safety and protect public health and the environment, such as being prepared to handle the most common chemicals in their area and probable public health actions.

Introduction

Chemical incidents can cause adverse health effects, serious injuries or deaths, and environmental damage. The prevention of incidents involving hazardous substances is the priority of public authorities at all levels, industries, and employees and their representatives. Regardless, toxic chemical incidents continue to occur, affecting the health and lives of many. Therefore, efforts to prevent or decrease exposures to chemical hazards during these incidents are vital (*1*). Protective actions during an incident involving the release of hazardous substances are steps that are taken to preserve the health and safety of the members of the public and emergency responders (*2*,*3*).

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Evacuating members of the public out of an area affected by a hazardous material release or requesting that they remain indoors and shelter in place by closing up the building and waiting for the danger to pass are two basic tools used by emergency response officials to protect the public when they are threatened by exposure to chemical spills (*2*,*3*). Depending on the severity of the situation, additional actions taken might include decontamination and the closing of buildings, roads, bridges, and parking lots.

The Hazardous Substances Emergency Events Surveillance (HSEES) system provides information on the characteristics and spatial and temporal dimensions of hazardous chemical releases within the states that participated in the surveillance system (*4*). This report summarizes the public health response to chemical incidents occurring in selected states during 1999–2008 and is a part of a comprehensive surveillance summary (*1*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industries, emergency responders, and others who prepare for or respond to chemical incidents can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES by health departments in nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 complete calendar years of data collection, 1999–2008. Data from 2009 were not included because several states ended data collection mid-year. A detailed description of the HSEES data used in this analysis is found elsewhere (*1*). Case definitions, exclusion criteria, and 2006 changes in reporting guidelines used for this analysis are described (Box).

The types, frequency, and trends in public health response were assessed on the basis of evacuations, shelter-in-place orders, area access restrictions, decontamination, and other actions to protect public health, as well as information on who responded to the incident. These data were analyzed using statistical software to produce descriptive statistics.

Variable Definitions

Transportation-related chemical incidents are those that occur 1) during surface, air, pipeline, or water transport of hazardous substances and 2) before the chemical was totally unloaded from a vehicle or vessel. All other incidents are considered fixed-facility incidents.

HSEES defined an injured person as a person who experienced at least one documented acute (i.e., occurring in <24 hours) adverse health effect or who died as a consequence of the incident; injured persons must have had at least one injury type or symptom, and up to seven could be listed (*5*).

The public health response is defined as the actions taken to protect public health as a result of the incident (e.g., evacuation, health advisory, well survey, alternate water, fishing ban, prohibit consumption of livestock or produce, health investigation, shutdown of water intakes, or environmental sampling).

BOX. Case definitions, exclusions, and reporting guidelines — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Case definition for acute chemical release

An acute chemical release is an uncontrolled or illegal spill or release lasting <72 hours of an uncontrolled or illegal spill or release of any hazardous substance meeting specific predefined criteria. Releases of petroleum only (e.g., crude oil or gasoline) were excluded from the Hazardous Substances Emergency Events Surveillance (HSEES) system because the Comprehensive Environmental Response Compensation and Liability Act (Superfund legislation)† excludes it from Agency for Toxic Substances and Disease Registry authority.

Case definition for threatened release

A threatened release is an incident that resulted in a public health action such as an evacuation or road closure.

Changes in reporting guidelines to improve the uniformity of reporting among states and to maximize resources

- Before 2006, HSEES collected information on any chemical release if the amount was required by federal, state, or local law to be cleaned up.
- Starting in 2006, HSEES collected information on chemical releases if the amount was >10 lbs or >1 gallon or in any amount if the chemical was on the HSEES mandatory reporting list of highly toxic chemicals (e.g., anhydrous ammonia, arsenic, hydrazine, methyl isocyanate, nitric acid, and sulfuric acid).

In 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, and nitrogen oxides were excluded because numerous related incidents occurred but rarely resulted in acute public health impact.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 95 510 (Dec. 11, 1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99 499 (Oct. 17, 1986), 42 U.S.C. 9604(i).

Results

Approximately 26% (n = 15,203) of the total 57,975 HSEES incidents involved at least one public health action, including evacuation, sheltering in place, restricted access to the affected area, and other actions to protect public health. A total of 77% (n = 11,746) of these actions resulted from transportation incidents and 23% (n = 3,457) resulted from fixed-facility incidents.

Shelter in Place

Sheltering in place, or remaining inside of a sealed building until a release dissipates, was ordered in 1% of incidents (n = 509), (Figure 1). Approximately 84% (n = 428) of these incidents were associated with fixed facilities, and 16% (n = 81) were associated with transportation incidents. The highest percentage of incidents that required sheltering in place occurred in Washington, and the lowest occurred in Iowa (Figure 1). Incidents with an order to shelter in place increased during 2000–2004, with minimal changes during 2005–2008 (Figure 2).

Evacuations

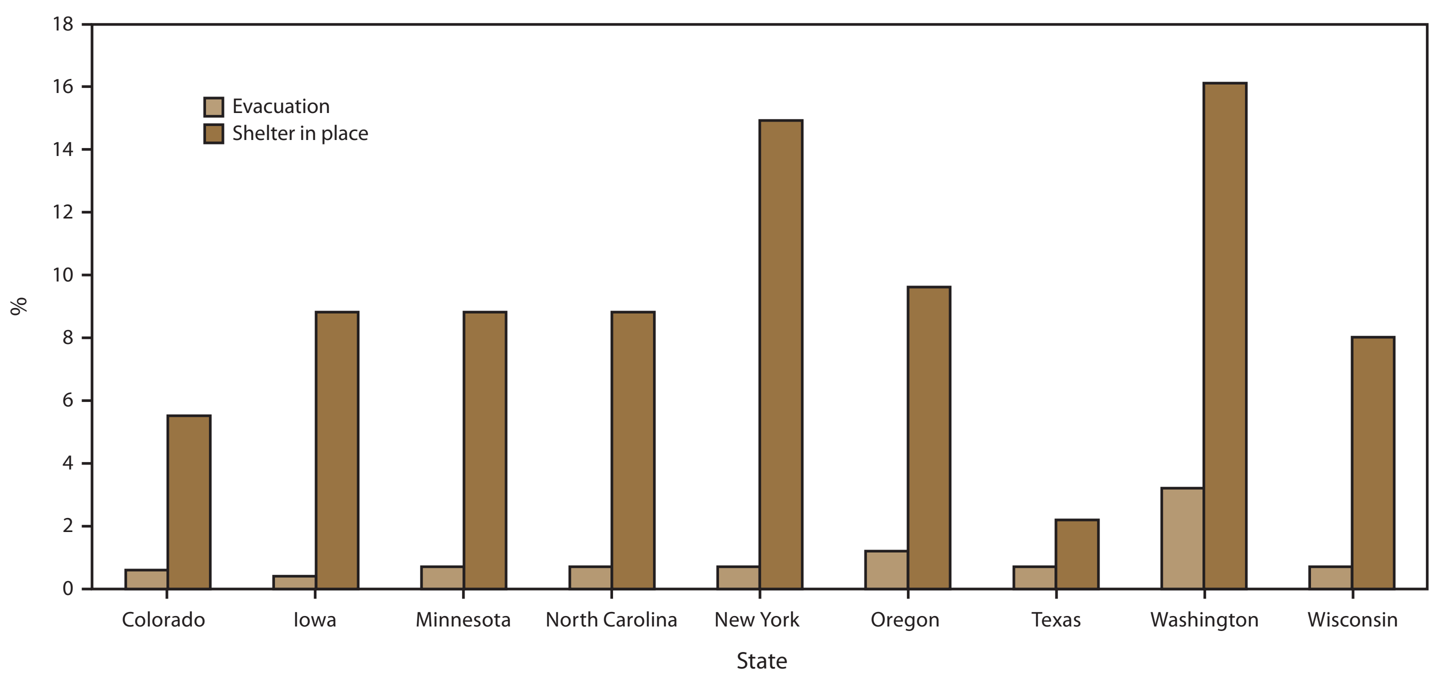
An evacuation was ordered in 7% (n = 4,281) of incidents. Approximately 90% (n = 3,858) of these incidents were associated with fixed facilities and 10% (n = 423) with transportation. The percentage of chemical incidents with an ordered evacuation varied by state and ranged from a low of 2% (n = 517) in Texas to a high of 16% (n = 558) in Washington (Figure 1). The percentage of incidents with an ordered evacuation decreased from 9% in 1999 to 6% in 2005 and then increased to 9% in 2008 (Figure 2). The total length of all evacuations combined was 43,686 hours, with an average of 11 days. The shortest evacuation ended within an hour, and the longest continued for 84 days.

At least 367,783 people were evacuated during the reporting period, ranging from a low of 25,209 in 2003 to a high of 63,045 in 1999 (Figure 3). The average number of persons evacuated per year was 36,778. No linear trend in number of persons evacuated over time was detected (R^2 = 0.21).

New York had the greatest number of evacuees (n = 125,575), followed by Texas (n = 67,801), Washington (n = 38,305), and North Carolina (n = 37,748). Colorado (n = 10,648) and Oregon (n = 12,942) had the fewest evacuees (Figure 4). The number of evacuees is influenced not only by the percentage of incidents involving evacuations but also by the total number of incidents. New York, Texas, and Washington reported the greatest number of incidents, whereas Oregon and Colorado reported the fewest.

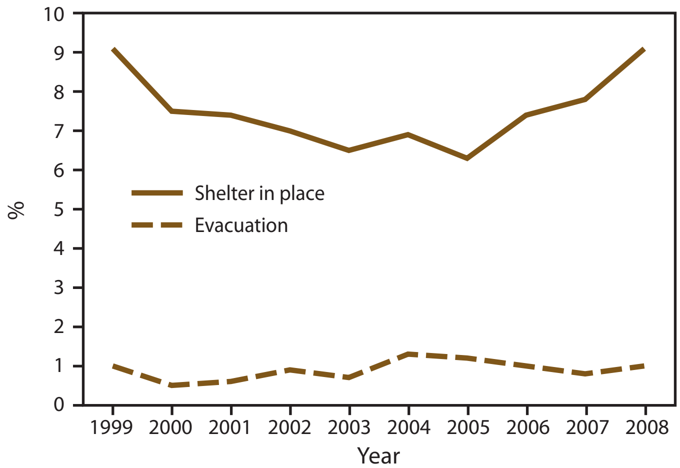
North Carolina, Washington, and Wisconsin had the greatest decrease in number of persons evacuated, whereas Minnesota and Iowa had the greatest increase (Table 1). The most frequent type of evacuation involved an entire building or part of a building (n = 3,176 [75%]). Less common evacuations were of a circle or radius (n = 544; 13%), downwind or downstream (n = 218 [5%]), and circle and downwind or downstream

FIGURE 1. Percentage of incidents* with shelter-in-place and evacuation orders — Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008



* Colorado, N = 1,973; Iowa, N = 3,271; Minnesota, N = 4,591; North Carolina, N = 3,274; New York, N = 10,475; Oregon, N = 2,377; Texas, N = 23,832; Washington, N = 3,979; Wisconsin, N = 4,203.

FIGURE 2. Percentage of incidents* with shelter-in-place and evacuation orders, by year— Hazardous Substances Emergency Events Surveillance system, nine states,† 1999–2008



* 1999, N = 5,529; 2000, N = 5,957; 2001, N = 6,341; 2002, N = 6,499; 2003, N = 6,452; 2004, N = 5,795; 2005, N = 5,194; 2006, N = 5,469; 2007, N = 5,511; 2008, N = 5,228.

† Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

(n = 169 [4%]). The type of evacuation for the remaining evacuations was not defined (n = 112 [3%]). Evacuation information was missing for 590 (1%) incidents.

Analysis of public health actions by substance category was performed for 54,990 incidents that involved only a single substance. The highest number of evacuations were caused by carbon monoxide (n = 784 [20.8%]), followed by ammonia (n = 611 [16.2%]), other inorganic substances (n = 442 [11.7%]), and volatile organic compounds (VOCs) (n = 345 [9.2%]). In addition, incidents involving ammonia, mixtures involving more than one chemical category, other inorganic substances, and VOCs had the highest percentage of orders to shelter in place (20%, 19%, 11%, and 11%, respectively).

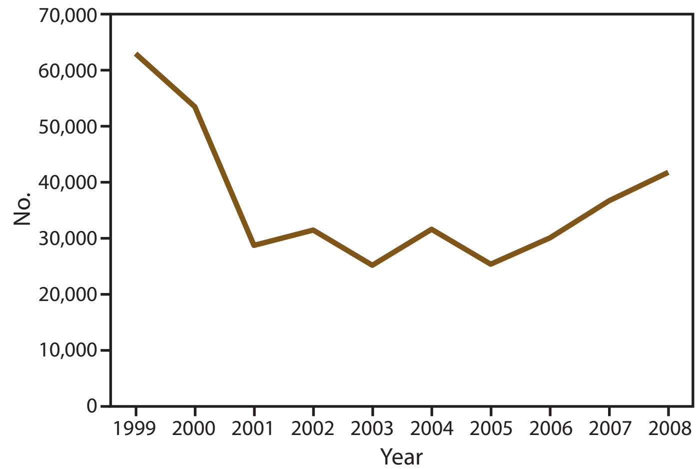
Decontamination

Decontamination is used to remove chemicals from contaminated persons to prevent additional contamination of the person and to prevent spreading and secondary contamination of others. Decontamination occurred in 4% (n = 2,171) of incidents; 13,461 persons were decontaminated, including 1,152 injured persons.

Other Public Health Actions

Data on restricted access to a site as a result of a chemical incident have been collected since 2002. Access to the area of the release was restricted in 26% (n = 10,345) of all incidents, categorized according to the largest area restricted (the building

FIGURE 3. Number of persons evacuated for chemical incidents, by year— Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008



* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

[n = 2,792], the room [n = 2,095], the entire facility including grounds [n = 1,123], and a wing or section of the building [n = 1,175]). Routes or roads were closed during 1,188 incidents and parking lots during 401 incidents. Because of the type and amount of chemical released, entrance to other adjacent areas was restricted 3,499 times. Approximately 72% (n = 28,938) of the incidents did not require any restrictions. Area restrictions were unknown for 2% (n = 865) of incidents. Generally, the percentage of incidents with required restrictions increased significantly from 20% (n = 1,275) in 2002 to 30% (n = 1,559) in 2008 ($p \leq 0.001$) (Figure 5). New York had the highest percentage of restrictions (n = 4,920 [47%]), and Texas had the lowest (n = 981 [4%]) (Figure 6).

Public health actions were taken during or after 12% (n = 6,693) of incidents. Some incidents involved several different types of actions. The most common actions were conducting environmental sampling (n = 6,463), issuing a health advisory (n = 133), performing a health investigation (n = 54), and conducting well surveys (n = 30).

Responder Category

A single responder category was reported for 53% (n = 30,669) of incidents, and multiple responder categories were reported for 16% (n = 9,217) of incidents. Responder type was not reported for 3,417 incidents. The most frequently reported responder group was a company response team, followed by fire departments, law enforcement agencies, certified hazardous materials teams, the U.S. Environmental Protection Agency, and an emergency medical technician response team (Table 2).

FIGURE 4. Number of persons evacuated for chemical incidents, by state— Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008

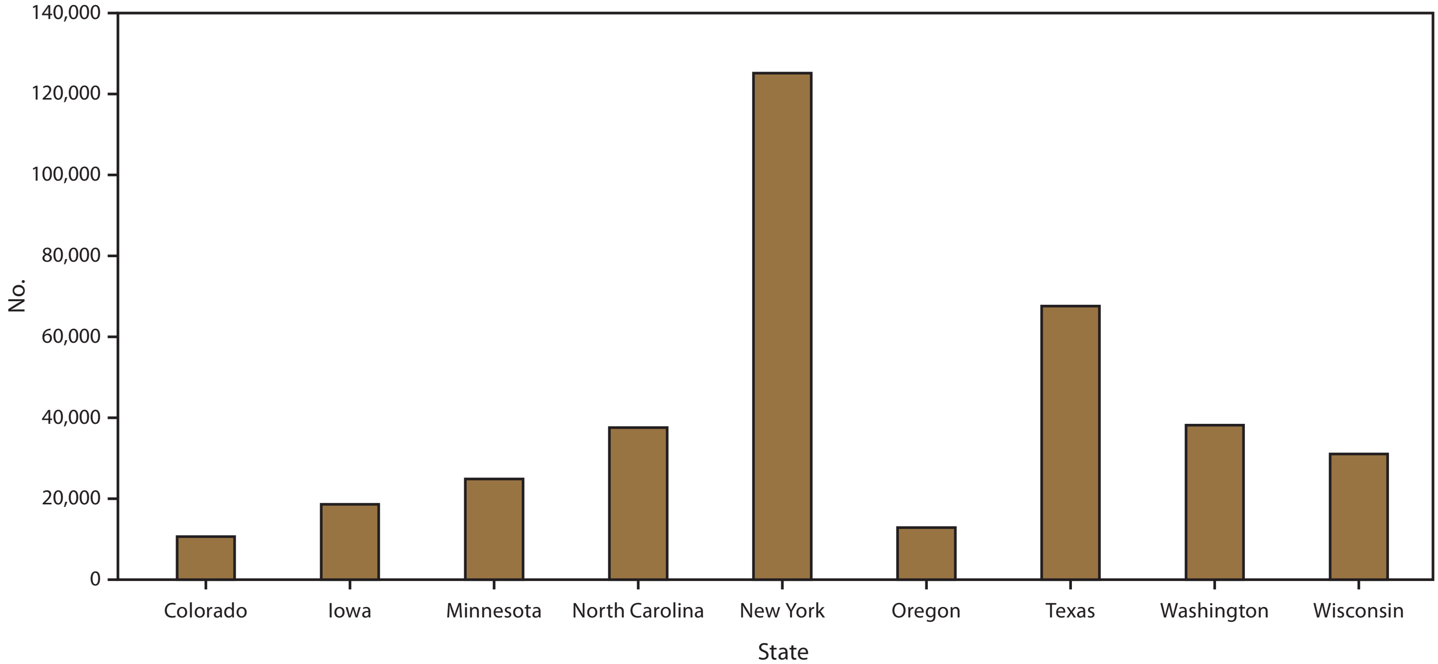


TABLE 1. Number of persons evacuated for chemical incidents, by state and year — Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008

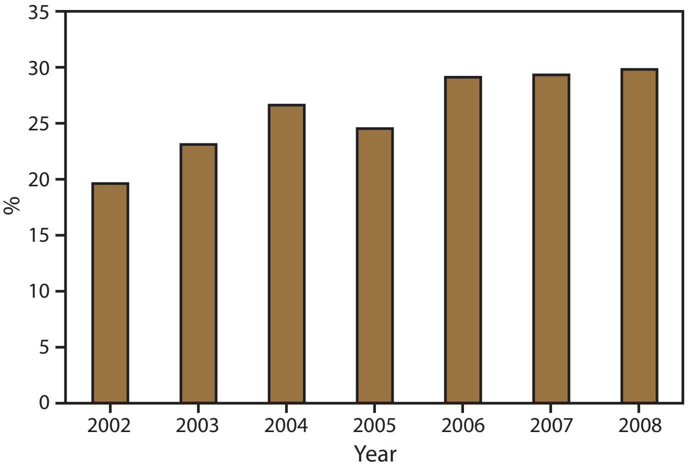
State	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Colorado	1,493	324	145	2,620	133	2,415	397	879	1,294	948	**10,648**
Iowa	1,934	1,368	1,379	981	1,961	2,178	1,831	1,029	3,027	2,958	**18,646**
Michigan	2,259	3,366	2,184	383	1,097	991	1,126	4,856	4,026	4,649	**24,937**
New York	11,322	21,519	10,214	8,737	9,648	13,530	10,593	11,140	12,003	16,798	**125,575**
North Carolina	14,041	2,741	1,928	4,958	5,310	1,898	377	3,756	2,163	603	**37,748**
Oregon	1,887	78	3,434	347	1,282	595	728	1,086	2,263	1,242	**12,942**
Texas	17,758	8,074	4,367	4,228	1,670	3,660	6,474	5,225	4,029	12,316	**67,801**
Washington	5,210	12,049	2,261	5,617	3,382	4,788	1,801	1,242	1,629	326	**38,305**
Wisconsin	7,168	3,918	2,883	3,650	726	1,590	2,074	902	6,289	1,981	**31,181**
Total	**63,045**	**53,508**	**28,795**	**31,521**	**25,209**	**31,645**	**25,401**	**30,115**	**36,723**	**41,821**	**367,783**

Discussion

Although the highly industrialized states of Texas and New York reported the greatest number of chemical incidents, the highest percentage of incidents resulting in evacuations and orders to shelter in place occurred in Washington (16.1%), followed by New York (14.9%). New York also reported the highest total number of evacuees (125,575) and the highest percentage of incidents requiring restrictions after the incident (45.1%). One possible explanation for this finding is that the high density of industries and population concentrated in New York City, New York, and Seattle, Washington. Differences in state response protocols could be another explanation. Although Texas reported the greatest number of chemical incidents, only 2.2% of these incidents resulted in evacuations. Since 2002, the total number of incidents has decreased; however, the percentage of incidents with area restrictions increased from 19.6% in 2002 to 29.8% in 2008, which might indicate an increased awareness and use of actions to reduce public exposures.

In 1986, Congress enacted the Emergency Planning and Community Right-to-Know Act (*6*) to establish requirements for federal, state, and local governments; tribes; and industries regarding emergency planning and the right of the public to have information about reported hazardous and toxic chemicals. The community right-to-know provisions help increase knowledge of and access to information on chemicals at individual facilities, as well as their uses and releases into the environment for members of the general public. HSEES was created to help identify areas most vulnerable to chemical incidents and to plan public safety interventions such as establishing evacuation routes and educating the community

FIGURE 5. Percentage of chemical incidents* with required restrictions† after the incident, by year — Hazardous Substances Emergency Events Surveillance system, nine states,§ 1999–2008



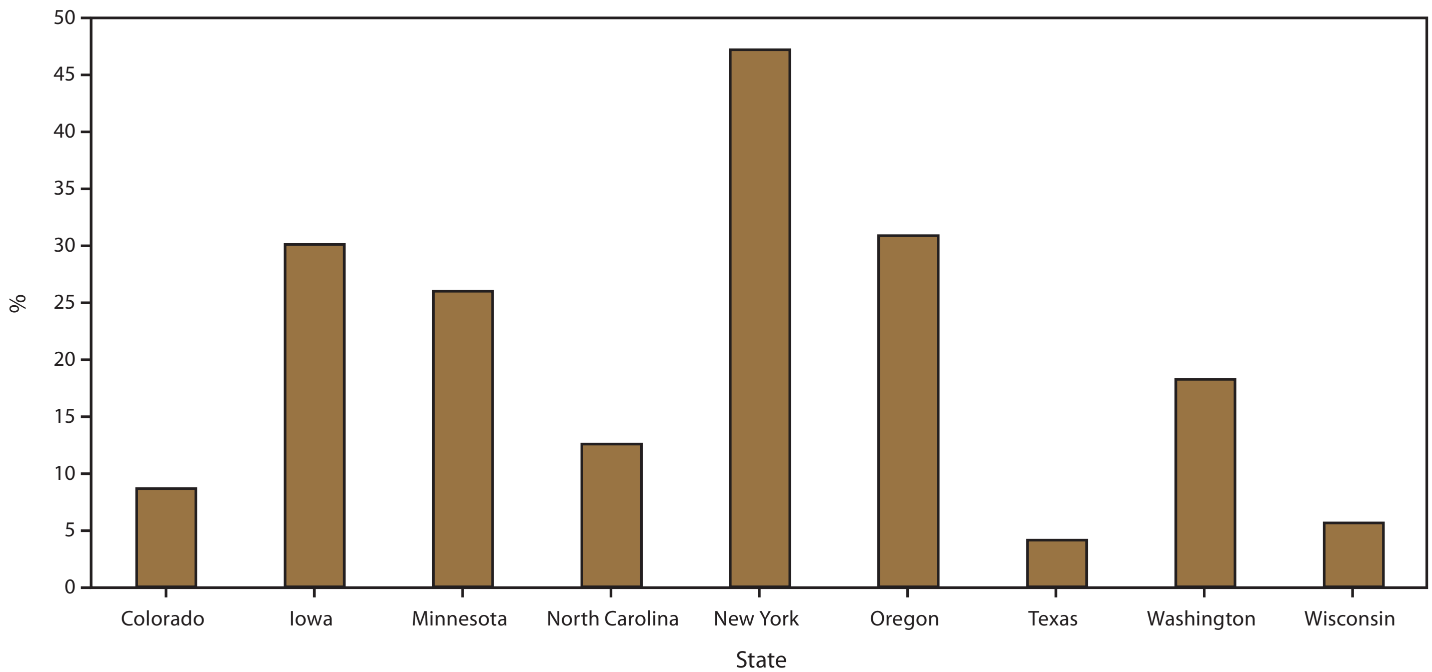
*2002, N = 6,499; 2003, N = 6,452; 2004, N = 5,795; 2005, N = 5,194; 2006, N = 5,469; 2007, N = 5,511; 2008, N = 5,228.
† Several types of restrictions could be applied during one event.
§ Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

of shelter-in-place instructions. Public information programs are especially important for sheltering in place because fleeing from danger is a natural instinct (*7*). Acute, unintended releases of carbon monoxide, ammonia, and other inorganic substances were among the chemical releases most often associated with adverse health effects in the population (*8*). The volatility of these chemicals might explain why they cause so many injuries and thus more public health actions. The findings in this reports also showed that company response teams were the most frequently reported responder group in HSEES incidents. This group would benefit from training for protective measures.

Limitations

The findings in this report are subject to at least five limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, the results from these nine states might not be representative of the entire

FIGURE 6. Percentage of incidents* with restrictions,† by state — Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008



* Colorado, N = 1,973; Iowa, N = 3,271; Minnesota, N = 4,591; North Carolina, N = 3,274; New York, N = 10,475; Oregon, N = 2,377; Texas, N = 23,832; Washington, N = 3,979; Wisconsin, N = 4,203.
† Several types of restrictions could be applied during one event.

TABLE 2. Number of chemical incidents, by type of responder — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Responder category†	No. of incidents
Company's response team	27,482
Fire department	6,934
Law enforcement agency	5,325
Certified hazardous materials team	3,764
Environmental agency or U.S. Environmental Protection Agency response team	3,041
Emergency medical technicians	2,316
Third-party clean up contractors	2,264
Other	2,957

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Total (57,500) is greater than the total number of incidents because multiple responder categories could be reported per incident.

United States. Third, inconsistencies within and across states likely exist because reporting capacity (e.g., staffing) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. Fourth, because of changes in reporting guidelines in 2006, the definition of eligible incidents could vary among states because of the differences in clean-up requirements. Finally, underreporting of incidents that did not have a public health response could have inflated the number incidents with responses.

Conclusion

States and communities can collaborate with facilities to use the information collected through the community right-to-know legislation and from this report to improve chemical safety and protect public health and the environment (e.g., being prepared to handle the most common chemicals in their area and establishing probable public health actions). Additional efforts to increase the community's knowledge about chemicals at individual facilities and their uses and releases into the environment, as well as community knowledge and skills regarding public safety interventions (e.g., evacuations or sheltering in place), can improve outcomes. Improving emergency planning requirements, providing the specificity of chemicals (ammonia and carbon monoxide) and local features and circumstances, and involving the community in the planning process will improve public safety. Providing special training courses for first responders on how to effectively and safely protect the public and themselves can reduce the overall number of injuries. Better prepared first responders and a more educated public will result in fewer public health effects from chemical releases, fulfilling the mission of the HSEES program and the National Toxic Substance Incidents Program, which merged with HSEES in 2010.

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Geographic Distribution of Acute Chemical Incidents — Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: Hazardous chemicals are transported and used widely in the United States, and acute chemical releases (lasting <72 hours) are not uncommon. Characterizing acute incidents within geographic areas can help researchers identify spatial patterns and differences and enable public and environmental health and safety practitioners, members of local emergency planning committees, preparedness coordinators, industry managers, emergency responders, and others to prepare for and respond to chemical incidents.

Reporting Period: 1999–2008.

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry (ATSDR) during January 1991–September 2009 to collect data on hazardous chemical releases that would enable researchers to describe the public health consequences of these acute releases and to develop activities aimed at reducing the ensuing harm to the public. This report summarizes data for the geographic distribution of reported acute incidents by states, counties, and Metropolitan Statistical Areas (MSAs) from the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: A total of 57,975 acute incidents occurred during 1999–2008; five MSAs accounted for 40.1% of all incidents. Texas reported 41% of all incidents reported by the nine states during the 10-year study period, and Colorado reported the fewest incidents (3.4%).

Interpretation: Storage, use, and transport of hazardous substances often are associated with unanticipated releases. In general, releases occurred more frequently in areas that use or store more hazardous chemicals and in urbanized areas compared with rural areas. In rural areas, most incidents were related to the transport of hazardous chemicals. The primary economic activities in an area had a strong influence on the frequency and type of chemicals released in the area.

Public Health Implications: Exposure to hazardous chemicals can have immediate and serious health consequences. Harmful releases can occur wherever hazardous chemicals are used, stored, or transported. The time and location of releases is unpredictable. Taken together, these elements underscore the need for preparedness. A culture of safety, prevention, and preparedness can minimize the consequences of future incidents.

Introduction

The chemical industry is a major component of the U.S. economy, accounting for >600,000 jobs and more than $49 billion in payroll in 2011 (*1*). The chemical industry manufactures all sorts of substances for consumer products, agriculture, and every major sector of the U.S. economy. Chemical substances usually are controlled during production, distribution, and use, thereby limiting human and environmental exposures. Although many of the substances produced and used will have no harmful public health consequences, other chemicals pose a danger to health. Hazardous chemicals are transported and used widely in the United States, and chemical releases are not uncommon. The U.S. Department of Transportation estimates that nearly 1 million shipments of hazardous materials occur daily in the United States (*2*). When hazardous chemicals are released, serious consequences (e.g., environmental damage and human exposure) can ensue that result in morbidity or mortality. A total of 1,177 injuries were associated with acute chemical incidents in 2011, including 62 deaths (*3*).

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The Hazardous Substances Emergency Events Surveillance (HSEES) database provides information on the characteristics and spatial and temporal dimensions of hazardous chemical releases within the states that participated in the surveillance system (*4*). This report provides an overview of the geographic distribution of hazardous chemical releases occurring in selected states during 1999–2008 and is a part of a comprehensive surveillance summary (*5*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industry managers, emergency responders, and others who prepare for or respond to chemical incidents can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES by health departments in nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 complete calendar years of data collection (1999–2008). Data from 2009 were not included because several states ended data collection mid-year. A detailed description of the HSEES data used in this analysis is found elsewhere (*6*). Case definitions, exclusion criteria, and 2006 changes in reporting guidelines used for this analysis are described (Box).

HSEES defined an injured person as a person who experienced at least one documented acute adverse health effect (i.e., one occurring in <24 hours) or who died as a consequence of the event; injured persons must have had at least one injury type or symptom, and up to seven could be listed (*7*).

This report describes the geographic distribution of the incidents by aggregating them to three levels: state, county, and Metropolitan Statistical Area (MSA).* Summarizing the data over geographic areas reveals spatial patterns across the study area. Boundaries and population data from the 2000 U.S. Census were used (*8*). The maps were generated by using ArcGIS software (ESRI, ArcMap v10). In 2000, the U.S. Census Bureau delineated 111 MSAs in the nine study states. At the MSA level, a density of incidents was derived by dividing the number of incidents recorded within each MSA by the MSA's area (in square miles). MSAs in the top 20% of density of incidents then were mapped.

Most of the analyses were made on the basis of simple counts of incidents within states, counties, or MSAs. The first step was to ascertain the overall number of incidents within the various geographic areas. At the state level, the frequency with which various substances were released was considered. HSEES recorded all substances that were released at all incidents. For each state, the database was searched for the five chemicals which were released most frequently. The industry associated with each incident was coded by using the U.S. Census Bureau's 2002 North American Industry Classification System (NAICS). For each state, the database was searched to ascertain which five NAICS industry categories appeared most frequently. Data from the 2002 U.S. Economic Census were used to characterize the economic activities in each state (*9*).

* MSAs are U.S. Census–defined conglomerations of counties around a metropolitan core area (*12*).

BOX. Case definitions, exclusions, and reporting guidelines — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Case definition for acute chemical release

An acute chemical release is an uncontrolled or illegal spill or release lasting <72 hours of an uncontrolled or illegal spill or release of any hazardous substance meeting specific predefined criteria. Releases of petroleum only (e.g., crude oil or gasoline) were excluded from the Hazardous Substances Emergency Events Surveillance (HSEES) system because the Comprehensive Environmental Response Compensation and Liability Act (Superfund legislation)† excludes it from Agency for Toxic Substances and Disease Registry authority.

Case definition for threatened release

A threatened release is an incident that resulted in a public health action such as an evacuation or road closure.

Changes in reporting guidelines to improve the uniformity of reporting among states and to maximize resources

- Before 2006, HSEES collected information on any chemical release if the amount was required by federal, state, or local law to be cleaned up.
- Starting in 2006, HSEES collected information on chemical releases if the amount was >10 lbs or >1 gallon or in any amount if the chemical was on the HSEES mandatory reporting list of highly toxic chemicals (e.g., anhydrous ammonia, arsenic, hydrazine, methyl isocyanate, nitric acid, and sulfuric acid).

In 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, and nitrogen oxides were excluded because numerous related incidents occurred but rarely resulted in acute public health impact.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

† Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 95 510 (Dec. 11, 1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99 499 (Oct. 17, 1986), 42 U.S.C. 9604(i).

At the county level, the number of HSEES incidents in relation to each county's urban or rural character was considered by using the urban-rural continuum codes established by the U.S. Department of Agriculture for 2003 (*10*) (Table 1). For each county, the ratio of transportation-related incidents to incidents at fixed facilities was calculated. The transportation versus fixed ratios to the counties' urban-rural codes were

TABLE 1. U.S. Department of Agriculture urban-rural continuum codes, 2003

Code	Description
1	County in metro area with ≥1 million population
2	County in metro area of 250,000–1 million population
3	County in metro area of <250,000 population
4	Nonmetro county with urban population of ≥20,000, adjacent to a metro area
5	Nonmetro county with urban population of ≥20,000, not adjacent to a metro area
6	Nonmetro county with urban population of 2,500–19,999, adjacent to a metro area
7	Nonmetro county with urban population of 2,500–19,999, not adjacent to a metro area
8	Nonmetro county completely rural or <2,500 urban population, adjacent to metro area
9	Nonmetro county completely rural or <2,500 urban population, not adjacent to metro area

Source: US Department of Agriculture, Economic Research Service. Rural-urban continuum codes. Washington, DC: US Department of Agriculture; 2013. Available at http://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx.

TABLE 2. Categories for pounds of chemicals stored at Toxics Release Inventory facilities

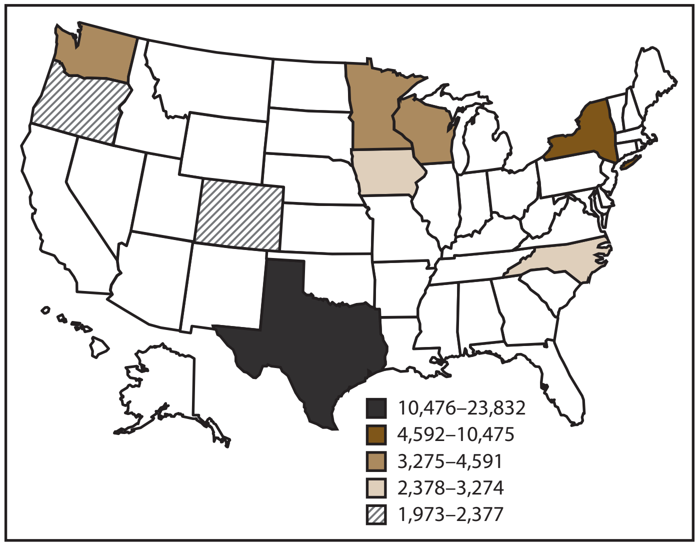
Code	Range of pounds stored	Midpoint
01	1–99	50
02	100–999	550
03	1,000–9,999	5,500
04	10,000–99,999	55,000
05	100,000–999,999	550,000
06	1,000,000–9,999,999	5,500,000
07	10,000,000–49,999,999	30,000,000
08	50,000,000–99,999,999	75,000,000
09	100,000,000–499,999,999	300,000,000
10	500,000,000–999,999,999	750,000,000
11	≥1,000,000,000	1,000,000,000

Source: US Environmental Protection Agency. Toxic chemical release inventory reporting forms and instructions, revised 2007 version. Washington, DC: US Environmental Protection Agency; 2007.

compared by calculating the average ratio for each urban/rural category.

At the county level, the number of HSEES incidents was compared with the quantity of chemicals stored at sites that reported to the Environmental Protection Agency's Toxics Release Inventory (TRI) (*11*). The TRI database records the quantity of chemicals stored at each TRI facility as a range of pounds. The midpoint of each range was used to approximate the number of pounds at each facility. The codes and ranges defined by TRI, along with the midpoint values (in pounds) used for each, are summarized (Table 2). The approximated weights for all TRI sites within each county were summed. Finally, the statistical correlation (Pearson's r) between the number of HSEES incidents and the approximated total weight of chemicals stored at TRI sites in each county was calculated.

FIGURE 1. Number* of acute chemical incidents, by state — Hazardous Substances Emergency Events Surveillance system, nine states,† 1999-2008§



* N = 57,975.

† Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

§ Cutpoints for categories determined by using Jenks Natural Breaks Optimization in ArcGIS.

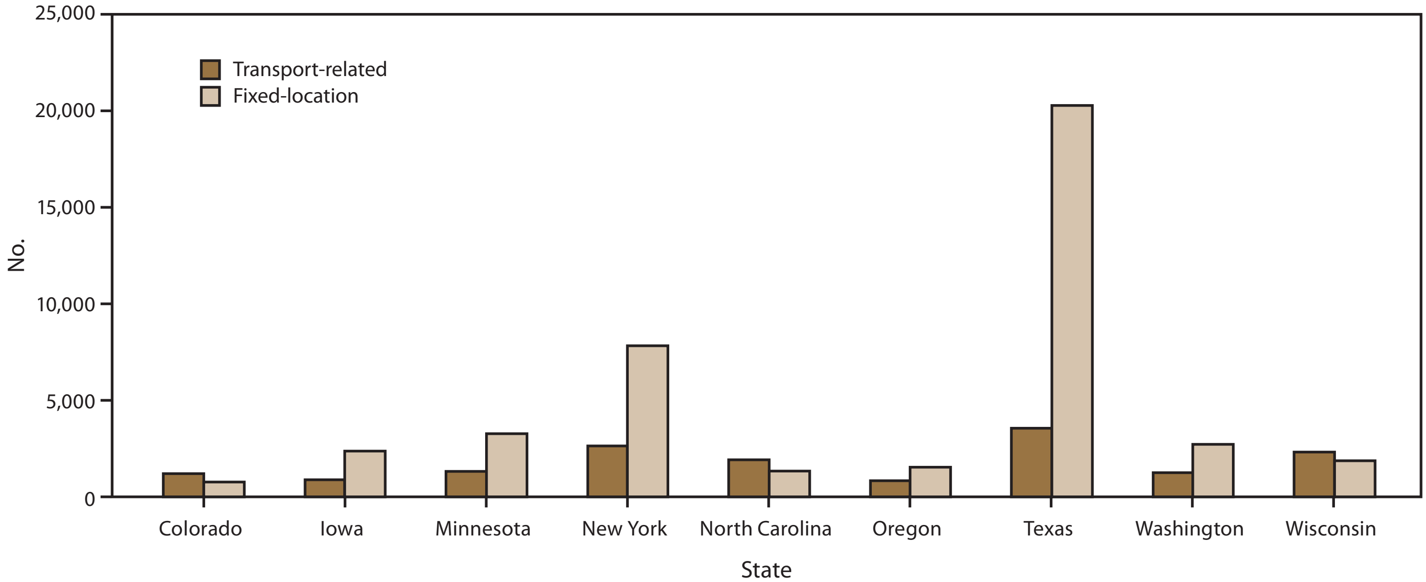
Results

A total of 57,975 incidents were recorded by the nine states during the 10-year study period (Figure 1). With one exception (Oregon, December 1999), at least one incident was recorded for each state during every month. The greatest number of incidents in a single state during a single month was 304 recorded for Texas in October 2002. Texas reported by far the greatest number of incidents, accounting for 41% of all incidents reported by the nine states. Colorado had the fewest incidents, with 1,943 during the 10-year study period (3.4% of all incidents in the study).

The number of incidents recorded for each state, as well as the proportion of fixed versus transport-related incidents, varied greatly (Figure 2). In six states (Iowa, Minnesota, New York, Oregon, Texas, and Washington), a greater proportion of incidents occurred at fixed facilities; in Texas, 85% of incidents occurred at fixed facilities. In three states (Colorado, North Carolina, and Wisconsin), the majority of incidents were transportation-related. At the county level, a correlation was identified between a county's urban-rural classification and the proportion of incidents that occurred in transit. On average, counties classified as rural had five times as many transit-related incidents as fixed-facility incidents.

The number of incidents in a state was correlated with the state's population, with Texas and New York having both the most chemical incidents and the largest populations. Of the nine states that participated in HSEES during the study period,

FIGURE 2. Number* of acute chemical incidents, by type — Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008



* N = 57,960. Total excludes 15 incidents for which type was not reported.

the three least populous states (Colorado, Iowa, and Oregon) had the fewest chemical incidents.

Chemical incidents were reported in nearly all parts of each state. Among the 813 counties within the nine states, 43 counties recorded no incidents, and the remaining 770 counties had at least one incident. However, there was great variation among counties in the number of incidents. Combined, the 43 counties that reported no incidents and the 53 counties that reported only one incident represent 12% of all counties in the study states. In contrast, Harris County, Texas (which includes the city of Houston), recorded the greatest number of incidents in a single county: 7,051 incidents during the 10-year study period. The county-level descriptive statistics for the number of HSEES incidents reported in the nine states during the study period are listed (Table 3).

Of the nine states studied, Texas had the greatest variation in the number of incidents reported within its counties (standard deviation [SD]: 517). When the study counties are ranked by number of incidents reported, the top three counties (Brazoria, Harris, and Jefferson) were all in Texas. However, in 32 Texas counties, no incidents were reported during the entire 10-year period. Those 32 counties are mostly rural, comprising 13% of the state's area but containing <1% of its population. Iowa counties showed the least variation in the number of chemical incidents (SD: 42). Every county in Iowa had at least three incidents during the study period, and in one county (Polk), the greatest number of incidents recorded was 299.

TABLE 3. County-level variation in the number of acute chemical release incidents by state — Hazardous Substances Emergency Events Surveillance system, nine states, 1999–2008

State	County minimum	County maximum	County average	County median	SD
Colorado	0	982	30.8	5	123.1
Iowa	3	299	33	21	42.4
Minnesota	0	667	52.8	18	113.7
New York	6	950	168.9	55	241.6
North Carolina	0	818	32.7	13	89.4
Oregon	1	695	66	24	119.6
Texas	0	7,051	93.8	4	516.8
Washington	1	1,268	102	28	208.5
Wisconsin	0	1,030	58.4	28	126.9

Abbreviation: SD = standard deviation.

The trend of more incidents occurring in more populous states also was reflected at the county level. The 20 most populous counties studied (3% of study counties) accounted for one third of all incidents reported, whereas the 406 counties comprising the lower 50% of population accounted for only 10% of incidents reported. In essence, chemical incidents occurred much more frequently in urban areas. The 10 MSAs within the study states that recorded the most incidents are listed (Table 4). Five MSAs accounted for 40% of all incidents. The MSAs in the top 20% are mapped in terms of density of incidents (incidents per square mile) within the study area (Figure 3).

A state's major economic activities generally were reflected by the number and type of incidents reported by that state. For example, Texas ranks first in the nation in terms of

TABLE 4. Metropolitan Statistical Areas with the most acute chemical release incidents — Hazardous Substances Emergency Events Surveillance system, 1999–2008

Area	No. of incidents	Area (square miles)	No. of incidents per 100 square miles
Houston, Texas	10,977	9,193	119
New York, New York	4,730	6,915	68
Beaumont/Port Arthur, Texas	3,263	2,267	144
Minneapolis/St. Paul, Minnesota	2,678	6,363	42
Seattle/Tacoma, Washington	1,882	5,991	31
Dallas/Fort Worth, Texas	1,791	9,284	19
Victoria, Texas	1,481	2,279	65
Denver, Colorado	1,370	8,402	16
Corpus Christi, Texas	1,360	1,790	76
Portland, Oregon	1,354	6,818	20

petroleum and chemical products manufacturing (*3*). The scale and intensity of those activities in Texas led to 11,381 releases associated with chemical and petroleum manufacturing processes. Texas accounted for 84% of all incidents that were related to chemical and petroleum manufacturing.

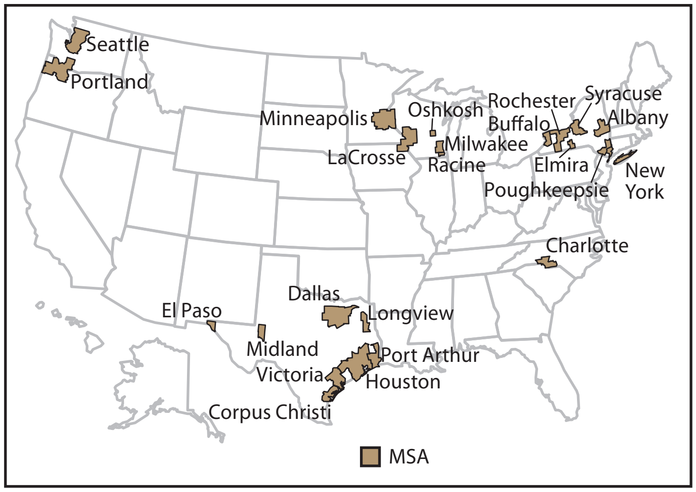
In Iowa, a leading agricultural state, one third of HSEES incidents were associated with agriculture or farm supplies. Iowa alone accounted for 46% of the incidents that were associated with crop production. A disproportionate number of the incidents in Iowa involved ammonia, likely attributable to the widespread use of ammonia as a fertilizer. Iowa reported 1,025 incidents involving ammonia, compared with 640 in Texas. For each state, the proportion of spills by industry sector and the proportion of the most often released chemicals are shown (Table 5).

The number of incidents recorded in HSEES was compared by county to the number of pounds of chemicals documented by TRI for the state of Texas (Figures 4 and 5). Similar patterns were noted, consistent with the finding of a strong correlation (Pearson's r = +0.7) between the number of incidents in a county and the amount of chemicals used or stored at TRI facilities in the county.

Discussion

The HSEES data characterize the general scale and dimensions of an important public health problem. This analysis of 57,975 incidents that occurred in nine states during a 10-year period indicates that the storage, use, and transport of hazardous substances often is associated with unanticipated releases. Rather than describing individual incidents, this report describes the geographic distribution of the incidents by aggregating them to the state, county, and MSA levels. Four main findings were noted. First, areas that use or store more hazardous chemicals had more releases. Second, releases occurred more frequently in urbanized areas compared with rural areas. Third, in rural areas, most incidents were related to the transport of hazardous chemicals. Finally, the primary economic activities in an area had a strong influence on the frequency and type of chemicals released in the area.

FIGURE 3. Metropolitan statistical areas in the top quintile of acute chemical incidents per 100 square miles — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008



Abbreviation: MSA = metropolitan statistical area.
* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

Human exposures to toxic chemicals were recorded for many of the incidents. The database records 15,506 exposed persons during the 10-year period. Because releases generally occur more frequently in urbanized areas, there may be a greater likelihood that a given release could affect more people. However, urbanized areas generally have emergency response units and medical facilities that can treat persons with symptoms of chemical exposure. Releases are rare in rural and more isolated areas, but access to effective treatment also is limited in those areas.

Limitations

The findings in this report are subject to at least four limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, the results from these nine states might not be representative of the entire United States. Third, inconsistencies within and across states likely exist because reporting capacity (e.g., staffing) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. Finally, changes

TABLE 5. Top five industries and top five substances involved in chemical incidents, by state — Hazardous Substances Emergency Events, nine states, 1999–2008

State (No.)	Industry	No.	(%)	Substance	No.	(%)
Colorado (1,973)	Trucking	1,145	(58.0)	Paint, NOS	137	(6.9)
	Other industries	345	(17.5)	Alkaline hydroxide	132	(6.7)
	Utilities	104	(5.3)	Sulfuric acid	104	(5.2)
	Warehousing and storage	92	(4.7)	Ammonia	86	(4.4)
	Rail	74	(3.8)	Hydrochloric acid	61	(3.1)
Iowa (3,271)	Other industries	1,026	(31.4)	Ammonia	1,025	(31.3)
	Nondurable wholesalers	648	(19.8)	Fertilizer	172	(5.2)
	Chemical manufacturing	434	(13.3)	Hydrochloric acid	76	(2.3)
	Crop production	371	(11.3)	Sulfuric acid	56	(1.7)
	Food manufacturing	247	(7.6)	Mercury	37	(1.1)
Minnesota (4,591)	Other industries	1,584	(34.0)	Ammonia	493	(10.7)
	Trucking	716	(15.4)	Mercury	294	(6.4)
	Utilities	409	(8.8)	Paint, NOS	174	(3.8)
	Nondurable wholesalers	402	(8.6)	Sulfuric acid	152	(3.3)
	Chemical manufacturing	360	(7.7)	Alkaline hydroxide	145	(3.2)
New York (10,475)	Other industries	3,925	(36.7)	Carbon monoxide	812	(7.8)
	Trucking	2,002	(18.7)	Ethylene glycol	720	(6.9)
	Utilities	1,666	(15.6)	Mercury	606	(5.8)
	Private households	931	(8.7)	Alkaline hydroxide	376	(3.6)
	Chemical manufacturing	837	(7.8)	Paint, NOS	347	(3.3)
North Carolina (3,274)	Trucking	1,755	(53.6)	Paint, NOS	269	(8.2)
	Other industries	728	(22.2)	Alkaline hydroxide	184	(5.6)
	Chemical manufacturing	197	(6.0)	Ammonia	150	(4.6)
	Utilities	138	(4.2)	Hydrochloric acid	94	(2.9)
	Private households	116	(3.5)	Phosphoric acid	69	(2.1)
Oregon (2,377)	Other industries	1,222	(51.4)	Methamphetamine chemicals	182	(7.6)
	Trucking	495	(20.8)	Paint, NOS	127	(5.3)
	Utilities	180	(7.6)	Ammonia	121	(5.1)
	Private households	103	(4.3)	Alkaline hydroxide	82	(3.4)
	Chemical manufacturing	88	(3.7)	Hydraulic fluid	74	(3.1)
Texas (23,832)	Chemical manufacturing	11,381	(47.8)	Ammonia	657	(2.8)
	Petroleum and coal products manufacturing	5,155	(21.6)	Sulfur dioxide	630	(2.6)
	Trucking	2,944	(12.4)	Nitric oxide	614	(2.6)
	Other industries	1,512	(6.3)	Benzene	561	(2.4)
	Oil and gas extraction	836	(3.5)	Alkaline hydroxide	482	(2.0)
Washington (3,979)	Other industries	1,719	(43.2)	Ammonia	322	(8.1)
	Trucking	610	(15.3)	Paint, NOS	193	(4.8)
	Private households	345	(8.7)	Carbon monoxide	149	(3.7)
	Utilities	263	(6.6)	Methamphetamine chemicals	118	(3.0)
	Petroleum and coal products manufacturing	173	(4.3)	Sulfuric acid	117	(2.9)
Wisconsin (4,203)	Trucking	1,968	(46.8)	Ammonia	331	(7.9)
	Other industries	1,055	(25.1)	Paint, NOS	213	(5.1)
	Private households	251	(6.0)	Alkaline hydroxide	162	(3.8)
	Utilities	215	(5.1)	Corrosive, NOS	132	(3.1)
	Food manufacturing	192	(4.6)	Acid, NOS	118	(2.8)

Abbreviation: NOS = not otherwise specified.

in reporting guidelines in 2006 (e.g., the reporting requirement changed based on the amount of the release to >10 pounds or >1 gallon or any release amount for substances on the HSEES mandatory list) could have led to increased reporting of some types of incidents and decreased reporting of others. This also could have affected the reports of industries that had releases.

Conclusion

Harmful releases can occur wherever hazardous chemicals are used, stored, or transported, underscoring the need for preparedness. Surveillance programs cannot be used to predict when and where the next incidents will occur. But understanding the overall pattern is helpful because releases will likely continue: both accidental and intentional incidents will occur in populous areas, and some of the releases will have serious health consequences, including death. The value of surveillance activities such as HSEES is that they enable researchers to understand overall patterns that should inform prevention and preparedness decisions. A culture of safety, prevention, and preparedness can minimize the consequences of future incidents.

FIGURE 4. Number of acute chemical incidents, by quintile and county — Texas, Hazardous Substances Emergency Events Surveillance system, 1999–2008

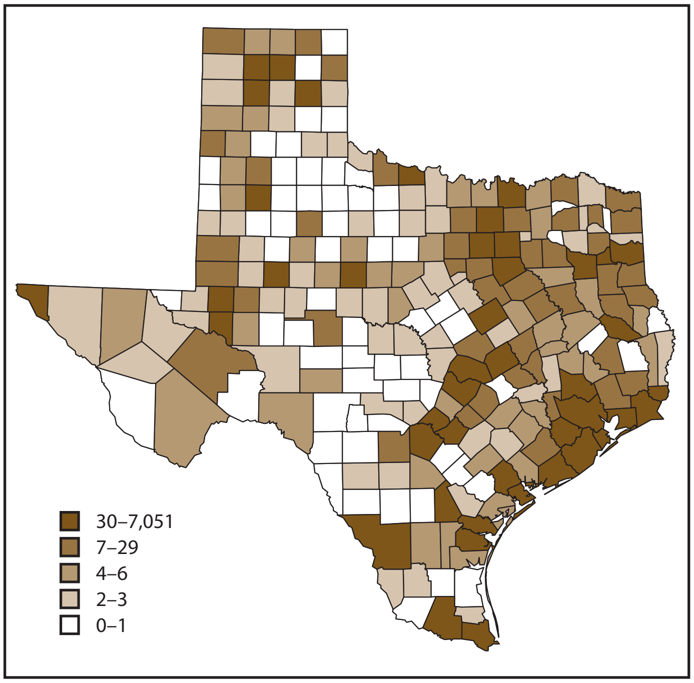
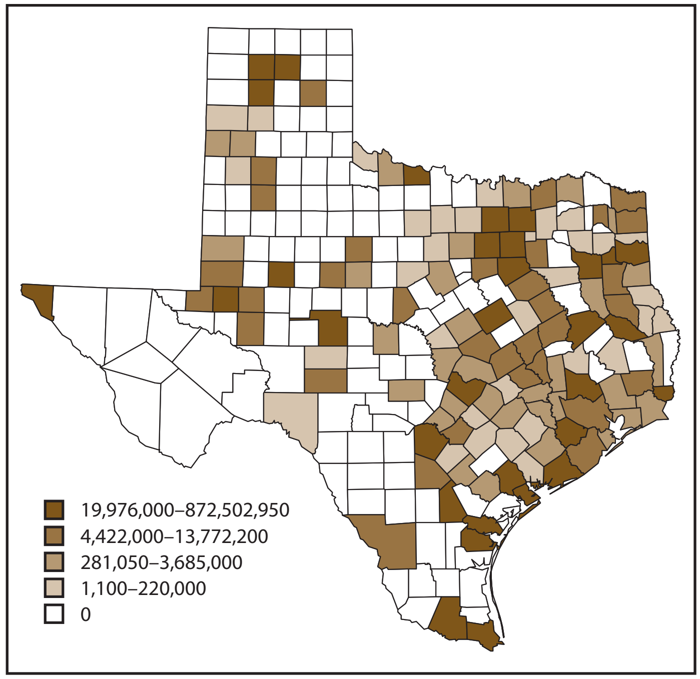


FIGURE 5. Number of pounds of chemicals onsite, by quintile and county — Texas, Environmental Protection Agency's Toxic Release Inventory, 2003



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Top Five Chemicals Resulting in Injuries from Acute Chemical Incidents — Hazardous Substances Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: The Toxic Substances Control Act Chemical Substance Inventory lists >84,000 chemicals used in commerce (http://www.epa.gov/oppt/existingchemicals/pubs/tscainventory/basic.html). With chemicals having a multitude of uses, persons are potentially at risk daily for exposure to chemicals as a result of an acute chemical incident (lasting <72 hours). Depending on the level of exposure and the type of chemical, exposure can result in morbidity and, in some cases, mortality.

Reporting Period: 1999–2008.

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry during January 1991–September 2009 to collect data that would enable researchers to describe the public health consequences of chemical incidents and to develop activities aimed at reducing the harm from such incidents. This report identifies the top five chemicals that caused injuries in the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: Of the 57,975 incidents that were reported, 54,989 (95%) involved the release of only one chemical. The top five chemicals associated with injury were carbon monoxide (2,364), ammonia (1,153), chlorine (763), hydrochloric acid (326), and sulfuric acid (318). Carbon monoxide and ammonia by far caused the most injuries, deaths, and evacuations. Chlorine, while not in the top 10 chemicals released, was in the top five chemicals associated with injury because of its hazardous properties.

Interpretation: Multiple measures can be taken to prevent injuries associated with the top five chemicals. Because many carbon monoxide releases occur in residential settings, use of carbon monoxide detectors can prevent injuries. Substituting chemicals with less lethal alternatives can result in mitigating injuries associated with ammonia. Routine maintenance of equipment and engineering controls can reduce injuries associated with chlorine and sulfuric acid, and proper chemical handling training can reduce injuries associated with hydrochloric acid.

Public Health Implications: Understanding the most frequently reported locations where carbon monoxide, ammonia, chlorine, hydrochloric acid, and sulfuric acid are released along with the most frequently reported contributing factors can help mitigate injuries associated with these releases. Prevention initiatives should focus on educating the public and workers about the dangers of these chemicals and about proper handling of these chemicals along with routine maintenance of equipment.

Introduction

Every year thousands of chemicals are manufactured and transported in the United States. As the use of chemicals increases, so does the likelihood of unintentional releases (*1,2*). Acute chemical releases (releases that last <72 hours) can pose a great public health impact, persons exposed can be injured, and serious exposures (e.g., an exposure to high levels of toxic chemicals such as carbon monoxide) can result in death. Collecting data on chemical releases is one method to determine which chemicals have a greater public health impact, protect public health, improve industry safety, and reduce impacts on the environment (*3*).

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The Hazardous Substances Emergency Events Surveillance (HSEES) database provides information on the characteristics and spatial and temporal dimensions of hazardous chemical releases within the states that participated in the surveillance system. This report summarizes the top five chemicals causing injury occurring in selected states during 1999 to 2008 and is a part of a comprehensive surveillance summary (*4*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industry managers, emergency responders, and others who prepare for or respond to chemical incidents can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES by health departments in nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008). Data from 2009 were not included because several states ended data collection mid-year. Case definitions, exclusion criteria, and 2006 changes in reporting guidelines used for this analysis are described (Box).

This report describes the characteristics of the chemical releases (i.e., frequency of evacuations, contributing factors, industries in which incidents occurred, severity of injury, and type of injuries) associated with the top five chemicals that caused injuries. HSEES defined an injured person as a person who experienced at least one documented acute (i.e., occurring in <24 hours) adverse health effect or who died as a consequence of the event; injured persons must have had at least one injury type or symptom, and up to seven could be listed (*5*). Descriptive analyses were performed by using SAS software (version 9.2).

Results

During 1999–2008, of the 57,975 chemical release incidents that were reported in HSEES, 54,989 (95%) involved only one chemical being released. A total of 13,196 persons were reported to have been injured in single chemical releases. Chemicals were ranked by the number of injuries that each chemical caused. The top five chemicals associated with injury were carbon monoxide (2,364), ammonia (1,153), chlorine (763), hydrochloric acid (326), and sulfuric acid (318). These top five chemicals accounted for 1,383 (3%) of total single chemical releases but 4,924 (37%) of all injured persons. Releases of carbon monoxide resulted in the highest number of injured persons (2,364) and also the largest number of incidents that required evacuations (222). However, releases of ammonia resulted in more persons being evacuated (14,536) than the other top five chemicals (Table 1). The majority of the top five chemical releases occurred in fixed facilities (range: 70%–97%). Hydrochloric acid and sulfuric acid had a high frequency of releases occurring during transportation (30% and 15%, respectively) (Table 1).

For each HSEES incident, up to two contributing factors can be reported. The various contributing factors that were involved with the top five chemical releases are summarized (Table 2). Equipment failure was the most commonly reported contributing factor for ammonia (46%), carbon monoxide (45%), and sulfuric acid releases (41%). Human error (defined by HSEES as a mistake made by a person) was the most frequently reported contributing factor for chlorine (37%) and hydrochloric acid releases (41%). Ammonia releases had a high percentage of releases (16%) that involved intentional or illegal acts due to its use in illegal methamphetamine production.

BOX. Case definitions, exclusions, and reporting guidelines — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Case definition for acute chemical release

An acute chemical release is an uncontrolled or illegal spill or release lasting <72 hours of an uncontrolled or illegal spill or release of any hazardous substance meeting specific predefined criteria. Releases of petroleum only (e.g., crude oil or gasoline) were excluded from the Hazardous Substances Emergency Events Surveillance (HSEES) system because the Comprehensive Environmental Response Compensation and Liability Act (Superfund legislation)† excludes it from Agency for Toxic Substances and Disease Registry authority.

Case definition for threatened release

A threatened release is an incident that resulted in a public health action such as an evacuation or road closure.

Changes in reporting guidelines to improve the uniformity of reporting among states and to maximize resources

- Before 2006, HSEES collected information on any chemical release if the amount was required by federal, state, or local law to be cleaned up.
- Starting in 2006, HSEES collected information on chemical releases if the amount was >10 lbs or >1 gallon or in any amount if the chemical was on the HSEES mandatory reporting list of highly toxic chemicals (e.g., anhydrous ammonia, arsenic, hydrazine, methyl isocyanate, nitric acid, and sulfuric acid).

In 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, and nitrogen oxides were excluded because numerous related incidents occurred but rarely resulted in acute public health impact.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

† Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 95 510 (Dec. 11, 1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99 499 (Oct. 17, 1986), 42 U.S.C. 9604(i).

Industries were identified by using the Standardized Industrial Classification (SIC) for 1999—2001 data, and the 2002 North American Industry Classification System NAICS (2002–2008 data) (*6*). The top five chemicals were released in various industries (Table 3). The industry/location that had the highest percentage of injured persons involving carbon monoxide releases was other services (which includes private residences, salons, auto repair, and religious organizations (n = 386 [16%]); most of which occurred in private residences. The industry of real estate, rental, and leasing reported the second highest percentage of injured persons associated with carbon monoxide releases.

In ammonia incidents, the industry with the highest frequency of injured persons was manufacturing of food, textile, and apparel (451 [39%] of 1,153 injured persons). The subsector food manufacturing had the highest number of injured persons and agriculture, forestry, fishing, and hunting had the second highest frequency of persons injured from ammonia releases.

Manufacturing of paper, printing chemicals, petroleum, leather, lumber, and stone resulted in 194 (25%) of 763 injured persons associated with chlorine releases. The subsector paper and chemical manufacturing industries had the most injured persons followed by arts, entertainment, and recreation for chlorine releases.

The transportation and warehousing industry and educational services represented the highest frequencies of the 326 injured persons associated with hydrochloric acid releases. Manufacturing of metal, electrical, transport, and professional and manufacturing of paper, print chemicals, petroleum, leather, lumber, and stone represented the two highest subsectors of the 318 injured persons for sulfuric acid releases.

For all of the top five chemical releases, the majority of injured persons (range: 58%–68%) were treated at a hospital but not admitted. Carbon monoxide had the highest percentage of fatalities; 3% of injured persons died. Chlorine had the lowest frequency of fatalities, less than 1% (Table 4). For sulfuric acid, ammonia, and hydrochloric acid, the majority of injured persons were employees (235 [74%], 716 [62%], and 179 [55%] respectively). For carbon monoxide and chlorine releases, the majority of injured persons were from the general public (49% and 48% respectively) (Table 5).

TABLE 1. Number of incidents, persons injured, evacuations, and shelter-in-place orders, by top five chemicals released — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Characteristic	Carbon monoxide	Ammonia	Chlorine	Hydrochloric acid	Sulfuric acid
Incidents	401	468	192	152	170
Injured persons	2,364	1,153	763	326	318
Evacuations ordered	222	172	70	39	138
Persons evacuated	13,795	14,536	6,164	7,349	2,034
Shelter-in-place orders	5	25	13	10	1

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

TABLE 2. Number and percentage of contributing factors associated with top five chemicals released — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Carbon monoxide		Ammonia		Chlorine		Hydrochloric acid		Sulfuric acid	
Factor†	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Equipment failure	200	(45)	242	(46)	86	(32)	47	(22)	89	(41)
Human error, unspecified	185	(42)	133	(25)	99	(37)	87	(41)	74	(34)
Intentional or illegal acts	5	(1)	87	(16)	2	(1)	19	(9)	9	(4)
Improper filling, loading or packaging	0	(0)	16	(3)	12	(4)	7	(3)	14	(7)
Performing maintenance	4	(1)	19	(4)	15	(6)	3	(1)	4	(2)
Improper mixing	0	(0)	0	(0)	33	(12)	7	(3)	3	(1)
Unauthorized/improper dumping	0	(0)	2	(0)	5	(2)	27	(13)	0	(0)
Vehicle/vessel collision	1	(0)	9	(2)	2	(1)	9	(4)	13	(6)
Fire	24	(5)	3	(1)	3	(1)	1	(1)	0	(0)
Explosion	8	(2)	5	(1)	3	(1)	1	(1)	8	(4)
System/process upset§	2	(0)	7	(1)	6	(2)	2	(1)	0	(0)
Bad weather conditions/natural disasters	7	(2)	4	(1)	1	(0)	0	(0)	0	(0)
Power failure/electrical problems	5	(1)	1	(0)	3	(1)	0	(0)	1	(1)
System start up/shut down	3	(1)	1	(0)	0	(0)	1	(1)	0	(0)
Total	**444**	**(100)**	**529**	**(100)**	**270**	**(100)**	**211**	**(100)**	**215**	**(100)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Some incidents have more than one factor associated with the chemical release.
§ Any glitch in the system that upsets the process such as a chemical-related problem resulting from a chemical reaction that is specific to the facility.

The frequencies of the injuries reported are summarized (Table 6). The most frequently reported injury for ammonia, chlorine, and hydrochloric acid releases was respiratory irritation. Dizziness was the most frequently reported injury for persons exposed to carbon monoxide, and burns were the most frequently reported injury for sulfuric acid releases.

Discussion

Four of the top five chemicals (ammonia, chlorine, hydrochloric acid, and sulfuric acid) have been documented as being the most frequently reported releases involved in injuries and evacuations (*7–9*). One quarter of all 354 deaths during

TABLE 3. Number and percentage of injured persons in incidents with top five chemicals released, by industry/location — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Carbon monoxide		Ammonia		Chlorine		Hydrochloric acid		Sulfuric acid	
Industry/location	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**
Agriculture, Forestry, Fishing and Hunting	151	(6)	196	(17)	24	(3)	0	(0)	9	(3)
Mining	121	(5)	0	(0)	0	(0)	1	(0)	1	(0)
Utilities	67	(3)	12	(1)	51	(7)	22	(7)	11	(3)
Construction	39	(2)	3	(0)	2	(0)	2	(1)	5	(2)
Manufacturing-NAICS 31(Food, Textile, Apparel)	102	(4)	451	(39)	47	(6)	4	(1)	1	(0)
Manufacturing-NAICS 32 (Paper, Printing, Chemicals, Petroleum, Leather, Lumber, Stone)	25	(1)	62	(5)	194	(25)	14	(4)	46	(14)
Manufacturing-NAICS 33 (Metal, Electrical, Transport, Professional)	68	(3)	6	(1)	4	(1)	19	(6)	52	(16)
Wholesale Trade	103	(4)	147	(13)	4	(1)	14	(4)	20	(6)
Retail Trade – I	4	(0)	20	(2)	8	(1)	18	(6)	8	(3)
Retail Trade – II	28	(1)	2	(0)	14	(2)	2	(1)	8	(3)
Transportation and Warehousing – I†	60	(3)	45	(4)	4	(1)	60	(18)	32	(10)
Transportation and Warehousing - II§	9	(0)	31	(3)	0	(0)	0	(0)	5	(2)
Information	35	(1)	0	(0)	0	(0)	7	(2)	1	(0)
Real Estate and Rental and Leasing	349	(15)	0	(0)	2	(0)	3	(1)	11	(3)
Professional, Scientific, and Technical Services	38	(2)	6	(1)	0	(0)	0	(0)	7	(2)
Administrative and Support and Waste Management and Remediation Services	18	(1)	4	(0)	9	(1)	9	(3)	5	(2)
Educational Services	221	(9)	8	(1)	41	(5)	46	(14)	40	(13)
Health Care and Social Assistance	120	(5)	1	(0)	46	(6)	5	(2)	21	(7)
Arts, Entertainment, and Recreation	117	(5)	1	(0)	167	(21)	22	(7)	1	(0)
Accommodation and Food Services	225	(10)	19	(2)	50	(7)	27	(8)	0	(0)
Other Services (except Public Administration)¶	386	(16)	32	(3)	29	(4)	25	(8)	24	(8)
Public Administration	18	(1)	4	(0)	53	(7)	5	(2)	7	(2)
Unknown	60	(3)	103	(9)	14	(2)	21	(6)	3	(1)
Total**	**2,364**	**(100)**	**1,153**	**(101)**	**763**	**(100)**	**326**	**(101)**	**318**	**(100)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Includes air, rail, water, truck, transit and ground passenger, pipeline, and support activities for transportation.
§ Includes postal service, couriers and messengers, and warehousing and storage.
¶ Includes private residences, salons, auto repair shops, and religious organizations.
** Percentages do not equal 100% due to rounding.

TABLE 4. Number and percentage of persons injured by top five chemicals released, by disposition of injured person — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Carbon monoxide		Ammonia		Chlorine		Hydrochloric acid		Sulfuric acid	
Disposition	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**
Treated at hospital (not admitted)	1,608	(68)	715	(62)	450	(59)	204	(63)	184	(58)
Treated on scene with first aid	391	(17)	154	(13)	158	(21)	68	(21)	41	(13)
Treated at hospital (admitted)	199	(8)	96	(8)	41	(5)	14	(4)	29	(9)
Seen by private physician	27	(1)	84	(7)	34	(5)	19	(6)	43	(14)
Injury reported by an official	4	(0)	50	(4)	36	(5)	6	(2)	14	(4)
Observed at hospital (no treatment)	11	(1)	35	(3)	39	(5)	6	(2)	5	(2)
Death	71	(3)	7	(1)	3	(0)	4	(1)	2	(1)
Unknown	53	(2)	12	(1)	2	(0)	4	(1)	0	(0)
Total†	**2,364**	**(100)**	**1,153**	**(99)**	**763**	**(100)**	**326**	**(100)**	**318**	**(101)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Percentages do not equal 100% due to rounding.

TABLE 5. Number and percentage of injured persons for top five chemicals released, by category of injured person — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Carbon monoxide		Ammonia		Chlorine		Hydrochloric acid		Sulfuric acid	
Category	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Employee	892	(37.7)	716	(62.1)	296	(38.8)	179	(54.9)	235	(74)
General public	1,142	(48.3)	269	(23.3)	366	(48.0)	104	(31.9)	49	(15)
Student	258	(10.9)	1	(0.1)	57	(7.5)	20	(6.1)	22	(7)
Firefighter	35	(1.5)	63	(5.5)	24	(3.1)	10	(3.1)	5	(2)
Police officer	13	(0.5)	96	(8.3)	10	(1.3)	9	(2.8)	1	(0)
EMT personnel	7	(0.3)	5	(0.4)	2	(0.3)	0	(0)	4	(1)
Unknown injured persons	13	(0.5)	1	(0.1)	0	(0)	0	(0)	0	(0)
Hospital personnel	4	(0.2)	0	(0)	4	(0.5)	0	(0)	0	(0)
Employee response team	0	(0)	1	(0.1)	3	(0.4)	1	(0.3)	2	(1)
Unknown responder	0	(0)	1	(0.1)	1	(0.1)	3	(0.9)	0	(0)
Total	**2,364**	**(100)**	**1,153**	**(100)**	**763**	**(100)**	**326**	**(100)**	**318**	**(100)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

TABLE 6. Number and percentage of injuries, by top five chemicals released and injury type — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Carbon monoxide		Ammonia		Chlorine		Hydrochloric acid		Sulfuric acid	
Injury type	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Respiratory irritation	211	(10)	805	(44)	607	(50)	249	(62)	112	(32)
Headache	1,400	(68)	169	(9)	38	(3)	20	(5)	5	(1)
Eye irritation	14	(1)	354	(19)	261	(22)	43	(11)	35	(10)
Gastrointestinal problems	105	(5)	138	(8)	92	(8)	6	(2)	30	(8)
Burns	0	(0)	128	(7)	10	(1)	30	(8)	120	(33)
Skin irritation	4	(0)	103	(6)	70	(6)	13	(3)	36	(10)
Other	205	(10)	11	(1)	10	(1)	8	(2)	3	(1)
Dizziness	16	(1)	76	(4)	59	(5)	14	(4)	8	(2)
Shortness of breath	23	(1)	31	(2)	43	(4)	12	(3)	9	(3)
Trauma	49	(2)	3	(0)	0	(0)	0	(0)	1	(0)
Heart problems	34	(2)	7	(0)	5	(0)	3	(1)	0	(0)
Heat stress	0	(0)	3	(0)	5	(0)	1	(0)	0	(0)
Total†	**2,061**	**(100)**	**1,828**	**(100)**	**1,200**	**(100)**	**399**	**(101)**	**359**	**(100)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Percentages do not equal 100% due to rounding.

this time period were attributable to these five chemicals. These five chemicals were also the top five chemicals released in the top five industries that resulted in injuries (*10*). To prevent future adverse public health consequences associated with release of the top five chemicals, public health needs to take a multifaceted approach that focuses on education about proper handling practices of the chemicals, the potential dangers of acute releases, and, when applicable, promotion of the use of safer alternatives.

Carbon Monoxide

CO is an odorless, colorless gas that can cause sudden illness and death. CO fumes are created during combustion and can build up in enclosed or semi-enclosed spaces. The most common symptoms of CO poisoning are headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion (*10*). High levels of CO inhalation can cause loss of consciousness and death (*11*). This analysis indicated that a high frequency of CO releases occur in private residences. The public should receive prevention messages, particularly before and during power outages. To help prevent CO exposure, persons can equip their homes with CO detectors. Some local health agencies, firefighters, and local media outlets have assisted with CO detector distribution and promotion (*12*). More information about preventing CO releases is available at http://www.cdc.gov/co/faqs.htm.

Ammonia

Ammonia is a colorless gas with a very distinct odor that is familiar to many persons because it is used in smelling salts, many household and industrial cleaners, and window-cleaning products. Ammonia gas dissolved in water is called liquid ammonia or aqueous ammonia. Once exposed to open air, liquid ammonia quickly turns into a gas (*13*). Exposure to high levels of ammonia can cause irritation and serious burns on the skin and in the mouth, throat, lungs, and eyes. At very high levels, ammonia can cause death (*14*). In HSEES data, over half of the injured persons in ammonia releases occurred in agriculture and food manufacturing. Ammonia is used as a refrigerant in the food manufacturing; industries could use refrigerant gases that are not as flammable or toxic as ammonia (e.g., carbon dioxide) (*14*,*15*) to reduce morbidity and mortality attributable to future incidents. Ammonia also is applied directly into soil on farm fields and is used to make fertilizers for farm crops, lawns, and plants (*16*). A substantial number of incidents with injuries were caused by illegal acts, most likely ammonia fertilizer tank thefts to produce illegal methamphetamine (*17*). Various substitutions and other theft deterrents for ammonia can be implemented (*17*).

Chlorine

Chlorine is a toxic gas with an irritating odor. Because it is heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. At low levels of exposure (<15 ppm), nose, eye, and throat irritation can occur. Immediate chest pain, coughing, changes in breathing rate, and vomiting might occur at 30 ppm and lung damage at 60 ppm. After a few minutes of exposure to 1,000 ppm, death can occur (*18*). Chlorine is an important industrial chemical used in the production of thousands of products (e.g., vinyl chloride to make polyvinyl chloride plastics, refrigerants, aerosols, silicones, and foams). Chlorine also is used for water disinfection (in water treatment plants and swimming pools) and pulp and paper bleaching (*18*). In this analysis, the majority of injuries in chlorine releases occurred in paper and printing manufacturing and in entertainment and recreation (swimming pools and water parks). Using sodium hydrosulfite and hydrogen peroxide as substitutes can help reduce injuries attributable to chlorine releases in the paper and printing manufacturing industry (*19*). A 2012 study found that, compared with chlorine releases in paper manufacturing, hydrogen peroxide had fewer injured persons per release with injured persons and fewer injured persons for all releases (*20*). Educational initiatives that focus on proper handling and storing procedures for pool chlorine can help reduce injuries (*20*). Because equipment failure represented 37.1% of the incidents that resulted in chlorine releases, routine maintenance of equipment and engineering controls can reduce failure and injuries (*20*).

Hydrochloric Acid

Hydrochloric acid is a clear, colorless solution of hydrogen chloride in water. It is a highly corrosive, strong mineral acid also known as muriatic acid (*21,22*). Hydrochloric acid is used to manufacture fertilizers, dyes, ore refining, rubber and pickling of metal (*23*). It has numerous smaller-scale applications, including household cleaning and commercial pool cleaning. Hydrochloric acid is corrosive to human tissue; upon exposure it can harm respiratory organs, eyes, skin, and intestines irreversibly (*22*). Persons exposed to unsafe levels of hydrochloric acid and have skin or eye irritation need to be decontaminated (*24*). To prevent injuries, persons handling hydrochloric acid should wear skin, eye, and respiratory protection (*20*). Because the majority of the injuries reported in hydrochloric acid releases occurred in transportation and warehousing, persons who work in this industry must be aware of the dangers that are associated with the chemicals they are transporting and know how reactive they are. One method to ensure that workers are following proper protocols for handling hydrochloric acid is to install cameras at warehouses and on transporting vehicles so supervisors can review videos to observe worker handling practices (*24*).

Sulfuric Acid

Sulfuric acid (also called sulphine acid, battery acid, and hydrogen sulfate) is a clear, colorless, oily liquid that is very corrosive. It is used in the manufacture of fertilizers, explosives, other acids, and glue; in the purification of petroleum; in the pickling of metal; and in lead-acid batteries (used in most vehicles) (*25*). Because of its corrosiveness, sulfuric acid at a high concentration can cause very serious damage (e.g., chemical and thermal burns). Sulfuric acid burns the cornea and can lead to permanent blindness if splashed onto eyes. Skin and eye protection should be worn whenever using sulfuric acid. If sulfuric acid gets into the eyes or on a person's skin, the eyes must be irrigated immediately, and skin should be washed with water (*26*). In the HSEES database, the most commonly reported industry for sulfuric acid injuries was manufacturing and these incidents had a high frequency of equipment failures. Ongoing maintenance can prevent releases, in addition to education about proper handling of the chemical.

Limitations

The findings in this report are subject to at least five limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, the results from these nine states might not be representative of the entire United States. Third, inconsistencies within and across states likely exist because reporting capacity (e.g., staffing) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. Fourth, the changes in reporting guidelines in 2006 (e.g., reports of smoke stack emissions above permitted values of carbon monoxide were removed because they rarely resulted in a public health impact) could have led to some chemicals being unreported or bias towards those that cause injuries. Finally, incidents occurring in transportation and warehousing might often be related to a vehicular accidents and, therefore, associated injuries might be related to the trauma of the accident rather than the chemical.

Conclusion

Understanding the nature of the top five chemicals that resulted in injuries can help researchers effectively target reductions in morbidity and mortality. Carbon monoxide and ammonia by far caused the most injuries, deaths, and evacuations and therefore need more attention toward prevention. Three of the chemicals had high reports of releases in various industry settings (ammonia in food manufacturing, chlorine in paper and printing manufacturing, and hydrochloric acid in warehousing). The Occupational Safety and Health Administration (OSHA) regulates worker exposure to chemicals by requiring proper education and training (*27*). In addition, all employers with hazardous chemicals in their workplace must have labels and safety sheets for their exposed workers (*27*). OSHA provides a Hazard Communication Standard that requires that information about chemical hazards in the work setting and associated protective measures are disseminated to workers (*26*). In addition, controlling exposures in the industries that have a high frequency of the top five chemicals released can prevent morbidity and mortality. OSHA has a hierarchy of controls that can determine how to implement feasible and effective controls. The hierarchy (in order of effectiveness) includes elimination, substitution, engineering control, administrative controls, and personal protective equipment (PPE) (*28*). Although these controls can reduce chemical hazards, there are some potential limitations with trying to implement the controls. Elimination and substitution, even though they might be the most effective at reducing hazards, can be difficult to implement. Initial costs for engineering controls (which remove a hazard or place a barrier between a worker and a hazard) can be high; however, long-term operating costs are lower and can be cost saving in other areas of the industry operations. Administrative control and PPE are the least effective of the hierarchy of control and are not well controlled. They are inexpensive to establish but can be costly to sustain (*28*). Overall, proper employee training, implementing the hierarchy of controls, raising awareness among the general public, and in some cases promoting safer alternatives can reduce morbidity and mortality associated with these top five chemicals.

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Top Five Industries Resulting in Injuries from Acute Chemical Incidents — Hazardous Substance Emergency Events Surveillance, Nine States, 1999–2008

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Abstract

Problem/Condition: Because industries using and/or producing chemicals are located in close proximity to populated areas, U.S. residents are at risk for unintentional chemical exposures.

Reporting Period: 1999–2008.

Description of System: The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry during January 1991–September 2009 to collect data that would enable researchers to describe the public health consequences of chemical releases and to develop activities aimed at reducing the harm from such releases. This report summarizes data for the top five industries resulting in injuries from an acute chemical incident (lasting <72 hours) occurring in the nine states (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 full years of data collection (1999–2008).

Results: Five industries (truck transportation, educational services, chemical manufacturing, utilities, and food manufacturing) accounted for approximately one third of all incidents in which persons were injured as a result of unintentional release of chemicals; the same five industries were responsible for approximately one third of all persons injured as a result of such releases.

Interpretation: Acute chemical incidents in these five industries resulted in serious public health implications including the need for evacuations, morbidity, and mortality.

Public Health Implications: Targeting chemical incident prevention and preparedness activities towards these five industries provides an efficient use of resources for reducing chemical exposures. A variety of methods can be used to minimize chemical releases in industries. One example is the Occupational Safety and Health Administration's hierarchy of controls model, which focuses on controlling exposures to occupational hazards. The hierarchy includes elimination, substitution, engineering controls, administrative controls, and use of personal protective equipment.

Introduction

As the United States has become more industrialized and the use of chemicals has increased, the likelihood of unintentional releases of hazardous materials also has increased (*1*,*2*). Hazardous substance releases can occur anywhere, including in private homes, warehouses, and manufacturing facilities. Unintentional releases of hazardous substances can have serious consequences, including adverse health outcomes and in some cases death, need for decontamination, evacuations, environmental degradation, and financial losses. To prevent morbidity and mortality resulting from unintentional releases of chemicals, public health authorities must know where these incidents occur and where the potential exists to prevent harm.

The Hazardous Substances Emergency Events Surveillance (HSEES) system database provides information on the characteristics and spatial and temporal dimensions of hazardous chemical releases within the states that participated in the surveillance system. This report summarizes data for the top five industries resulting in injuries from acute chemical incidents occurring in selected states during 1999–2008 and is a part of a comprehensive surveillance summary (*3*). Public and environmental health and safety practitioners, worker representatives, emergency planners, preparedness coordinators, industry managers, emergency responders, and others who prepare for or respond to chemical incidents can use the findings in this report to prepare for and prevent chemical incidents and injuries.

Methods

This report is based on data reported to HSEES system by health departments in nine states (Colorado, Iowa, Minnesota,

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New York, North Carolina, Oregon, Texas, Washington, and Wisconsin) that participated in HSEES during its last 10 complete calendar years of data collection (1999–2008). Data from 2009 were not included because several states ended data collection mid-year. Case definitions, exclusion criteria, and 2006 changes in reporting guidelines used for this analysis are described (Box 1).

This analysis focuses on the top five industries with injured persons. HSEES defined an injured person as a person who experienced at least one documented acute (i.e., occurring in <24 hours) adverse health effect or who died as a consequence of the event. Injured persons must have had at least one injury type or symptom, and up to seven could be listed (*4*). The top five identified NAICS codes were sectors 311 (food manufacturing), 325 (chemical manufacturing), 484 (truck transportation), 611 (educational services), and 221 (utilities). Information about these sectors is summarized (Box 2).

States obtained data about hazardous substance releases from various sources including state and local environmental protection agencies, police and fire departments, poison control centers, hospitals, local media and federal databases (e.g., the Department of Transportation's Hazardous Material Incident Reporting Systems [HMIRS] and the U.S. Coast Guard's National Response Center [NRC]).

Descriptive analyses were performed by using SAS software (version 9.2) to describe the top industries with injured persons. Industries were identified using the Standardized Industrial Classification (SIC) for 1999–2001 data, and the 2002 North American Industry Classification System (NAICS) for 2002–2008 data. NAICS is the standard used by Federal statistical agencies to classify business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy (*5*). For this analysis, an excel file was used that indicated which SIC codes correspond to NAICS codes so that all were classified the same for consistency. The top five three-digit NAICS industries causing injury were identified, and additional analysis was performed on those incidents.

BOX 1. Case definitions, exclusions, and reporting guidelines — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Case definition for acute chemical release

An acute chemical release is an uncontrolled or illegal spill or release lasting <72 hours of an uncontrolled or illegal spill or release of any hazardous substance meeting specific predefined criteria. Releases of petroleum only (e.g., crude oil or gasoline) were excluded from the Hazardous Substances Emergency Events Surveillance (HSEES) system because the Comprehensive Environmental Response Compensation and Liability Act (Superfund legislation)† excludes it from Agency for Toxic Substances and Disease Registry authority.

Case definition for threatened release

A threatened release is an incident that resulted in a public health action such as an evacuation or road closure.

Changes in reporting guidelines to improve the uniformity of reporting among states and to maximize resources

- Before 2006, HSEES collected information on any chemical release if the amount was required by federal, state, or local law to be cleaned up.
- Starting in 2006, HSEES collected information on chemical releases if the amount was >10 lbs or >1 gallon or in any amount if the chemical was on the HSEES mandatory reporting list of highly toxic chemicals (e.g., anhydrous ammonia, arsenic, hydrazine, methyl isocyanate, nitric acid, and sulfuric acid).

In 2006, reports of smokestack emissions above permitted values of carbon monoxide, sulfur oxides, and nitrogen oxides were excluded because numerous related incidents occurred but rarely resulted in acute public health impact.

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Pub. L. No. 95 510 (Dec. 11, 1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99 499 (Oct. 17, 1986), 42 U.S.C. 9604(i).

Results

During 1999–2008, of the 57,975 hazardous substance incidents that occurred, 4,621 (8%) incidents resulted in 15,506 persons being injured. Incidents at the following top five industries resulted in over one third (36%) of injured persons: chemical manufacturing (1,753 persons), educational services (1,562 persons), truck transportation (869 persons), food manufacturing (760 persons) and utilities (578 persons). These top five industries represented 30% of incidents with injured persons. These top five industries reported 478 evacuations in which 103,530 persons were evacuated. Educational services reported the highest number of evacuations and evacuees (144 and 56,269, respectively). Of the 156 incidents that reported shelter in place, the industry with the highest number of reported a shelter in place (26) was chemical manufacturing (Table 1).

BOX 2. Top five North American Industry Classification System codes associated with injuries from acute chemical incidents

Sector 311 Food Manufacturing

Industries in the Food Manufacturing subsector transform livestock and agricultural products into products for intermediate or final consumption. The industry groups are distinguished by the raw materials (generally of animal or vegetable origin) processed into food products. The food products manufactured in these establishments are typically sold to wholesalers or retailers for distribution to consumers, but establishments primarily engaged in retailing bakery and candy products made on the premises, not for immediate consumption, are included. Establishments primarily engaged in manufacturing beverages are classified elsewhere.

Sector 325 Chemical Manufacturing

The Chemical Manufacturing subsector is based on the transformation of organic and inorganic raw materials by a chemical process and the formulation of products. This subsector distinguishes the production of basic chemicals that comprise the first industry group from the production of intermediate and end products produced by further processing of basic chemicals that make up the remaining industry groups.

Sector 484 Truck Transportation

Industries in the Truck Transportation subsector provide over-the-road transportation of cargo using motor vehicles such as trucks and tractor trailers. The subsector is subdivided into general freight trucking and specialized freight trucking. This distinction reflects differences in equipment used, type of load carried, scheduling, terminal, and other networking services. General freight transportation establishments handle a wide variety of general commodities, generally palletized and transported in a container or van trailer. Specialized freight transportation is the transportation of cargo that, because of size, weight, shape, or other inherent characteristics, requires specialized equipment for transportation.

Sector 611 Educational Services

Educational Services comprises establishments that provide instruction and training in a wide variety of subjects. This instruction and training is provided by specialized establishments such as schools, colleges, universities, and training centers. These establishments might be privately owned and operated for profit or not for profit, or they might be publicly owned and operated. They might also offer food and accommodation services to their students.

Sector 221 Utilities

Industries in the Utilities subsector provide electric power, natural gas, steam supply, water supply, and sewage removal through a permanent infrastructure of lines, mains, and pipes. Establishments are grouped together based on the utility service provided and the particular system or facilities required to perform the service.

TABLE 1. Number of injured persons and frequency of selected incidents, by top five industries compared with all incidents with injured persons — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Number	Chemical manufacturing	Educational services	Food manufacturing	Truck transportation	Utilities	All incidents
Incidents with injured persons	228	241	172	516	218	**4,621**
Injured persons	1,753	1,562	760	869	578	**15,506**
Incidents with evacuations	71	144	104	85	74	**1,439**
Persons evacuated	17,170	56,269	12,781	11,428	5,882	**186,859**
Incidents with shelter-in-place order	26	15	8	9	12	**156**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

In HSEES, up to two contributing causal factors can be reported. The number of persons injured associated with contributing factors reported by the top five industries are summarized (Table 2). Equipment failure was associated with the highest frequency of injured persons for chemical manufacturing (1,272) and food manufacturing (489). Chemical manufacturing also had a high number of injured persons associated with a system or process upset (any glitch in the system that upsets the process; the problem has to be specific to the facility) (386). Human error was associated with the highest frequency of injured persons for educational services (746), truck transportation (629) and utilities (250). For utilities, equipment failure was a close second (242). Educational services also had a high frequency of injured persons associated with intentional or illegal acts (447).

For incidents with only one chemical released, ammonia (141), chlorine (66), carbon monoxide (52), hydrochloric acid (52), and sulfuric acid (44) were the most commonly reported chemicals for the top five industries (Table 3). Ammonia was the most commonly released chemical in chemical manufacturing and food manufacturing. Chlorine was the most commonly reported chemical released in utilities, as was hydrochloric acid for truck transportation and sulfuric acid for educational services.

TABLE 2. Number of persons injured, by associated contributing factors and top five industries — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Factor	Chemical manufacturing	Educational services	Food manufacturing	Truck transportation	Utilities	Total
Equipment failure	1,272	383	489	139	242	**2,525**
Human error	369	746	279	629	250	**2,273**
Intentional or illegal acts	6	447	5	20	31	**509**
System/process upset	386	2	30	0	2	**420**
Vehicle/vessel accident	12	0	5	372	0	**389**
Improper mixing	162	118	42	0	51	**373**
Explosion	161	43	13	10	62	**289**
Fire	115	16	16	8	72	**227**
Improper filling, loading or packaging	57	43	1	105	16	**222**
System start up/shut down	147	55	1	0	8	**211**
Unauthorized/improper dumping	5	6	2	27	118	**158**
Performing maintenance	15	100	25	1	13	**154**
Power failure/electrical problems	86	1	0	0	3	**90**
Bad weather conditions/natural disasters	4	38	0	16	3	**61**
Total†	**2,797**	**1,998**	**908**	**1,327**	**871**	**7,901**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† More than one contributing factor can be reported in the HSEES database; therefore, the total number of injured persons associated with contributing factors is higher than the total number of injured persons.

TABLE 3. Number of top five single chemicals released, by top five industries — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

Chemical	Chemical manufacturing	Educational services	Food manufacturing	Truck transportation	Utilities	Total
Ammonia	19	5	98	14	5	**141**
Chlorine	13	10	8	1	34	**66**
Carbon monoxide	2	11	4	4	31	**52**
Hydrochloric acid	6	11	0	18	17	**52**
Sulfuric acid	7	12	1	16	8	**44**
Total	**47**	**49**	**111**	**53**	**95**	**355**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

Employees represented 51% (2,824) of the injured persons and were the most commonly reported category for all but educational services (Table 4). Students were the most commonly reported category of injured persons for educational services (1,092), followed by employees (412). Students were also the second most commonly reported injured person category for chemical manufacturing (407). The second most commonly reported injured person category for food manufacturing (49), truck transportation (236), and utilities (181) was the general public.

The majority of the injured persons were either treated at the hospital and not admitted (48%) or treated on the scene (31%) (Table 5) Approximately 2% (122) of the injuries resulted in fatalities; the majority (90 [74%]) of the fatalities were reported in the truck transportation industry, which could have been the result of trauma from collisions or rollovers. The most frequently reported symptom overall for the top five industries was respiratory irritation (2,801 [35%]). This was also the most frequently reported symptom for chemical manufacturing (919 [39%]), educational services (763 [28%]), food manufacturing (574 [43%]), and utilities (295 [31%]) and was the second most frequently reported symptom for truck transportation. Nonchemical related traumas were the most frequently reported symptom for truck transportation (299 [33%]), again likely resulting from vehicle collisions or rollovers (Table 6).

Discussion

This analysis described the five industries with the highest frequencies of injured persons associated with acute chemical releases. The top five chemicals identified in this report as occurring most frequently in the top five industries were also the top five chemicals causing injury (*6*). Although chemical releases that occurred in chemical manufacturing resulted in the most injured persons, releases during truck transportation had the most incidents with injured persons and the most fatalities. Many of the injuries and fatalities that occurred during truck transportation were trauma related. Precautions can be taken to ensure safety if a release occurs. To protect the public health and environment, the shipper is responsible for all packaging, labeling, and marking of shipments (*7*). Labeling should be

TABLE 4. Number and percentage of persons injured for top five industries, by category — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Chemical manufacturing		Educational services		Food manufacturing		Truck transportation		Utilities		Total	
Category	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**
Employee	9	(48)	412	(26)	687	(90)	555	(64)	337	(58)	**2,824**	**(51)**
Student	407	(23)	1,092	(70)	0	(0)	3	(0)	0	(0)	**1,502**	**(27)**
General public	391	(22)	40	(3)	49	(6)	236	(27)	181	(31)	**897**	**(16)**
Responders	122	(7)	18	(1)	24	(3)	74	(9)	60	(10)	**298**	**(5)**
Firefighter	74	(4)	14	(1)	17	(2)	22	(3)	30	(5)	**157**	**(3)**
Police officer	17	(1)	2	(0)	6	(1)	35	(4)	20	(3)	**80**	**(1)**
Employee, response team	22	(1)	2	(0)	1	(0)	6	(1)	3	(1)	**34**	**(1)**
EMT personnel	3	(0)	0	(0)	0	(0)	7	(1)	6	(1)	**16**	**(0)**
Responder, unknown type	6	(1)	0	(0)	0	(0)	4	(0)	1	(0)	**11**	**(0)**
Total†,§	**1,753**	**(100)**	**1,562**	**100**	**760**	**(99)**	**868**	**(100)**	**578**	**99**	**5,521**	**(99)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Missing = 1.
§ Not all percentages equal 100 due to rounding.

TABLE 5. Number and percentage of persons injured for top five industries, by disposition of injured person — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Chemical manufacturing		Educational services		Food manufacturing		Truck transportation		Utilities		Total	
Disposition	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**	**No.**	**(%)**
Treated at hospital (not admitted)	531	(30)	790	(51)	533	(70)	456	(53)	341	(59)	**2,651**	**(48)**
Treated on scene (first aid)	862	(49)	542	(35)	102	(13)	85	(10)	123	(21)	**1,714**	**(31)**
Treated at hospital (admitted)	103	(6)	26	(2)	60	(8)	158	(18)	47	(8)	**394**	**(7)**
Injury reported by official	98	(6)	95	(6)	9	(1)	24	(3)	16	(3)	**242**	**(4)**
Seen by private physician within 24 hours	88	(5)	39	(2)	34	(5)	31	(4)	10	(2)	**202**	**(4)**
Observation at hospital, no treatment	59	(3)	58	(4)	10	(1)	23	(3)	21	(4)	**171**	**(3)**
Death	10	(1)	0	(0)	3	(0)	90	(10)	19	(3)	**122**	**(2)**
Unknown	2	(0)	12	(1)	9	(1)	1	(0)	1	(0)	**25**	**(1)**
Total†	**1,753**	**(100)**	**1,562**	**(101)**	**760**	**(99)**	**868**	**(101)**	**578**	**(100)**	**5,521**	**(100)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Not all percentages equal 100 due to rounding.

clear and legible for the transporters. Transporters should be aware of the potential dangers of the chemicals they are transporting and know whom to contact if a release occurs. The contributing factors that resulted in the most injured persons were equipment failure for chemical manufacturing and food manufacturing, and human error for educational services, truck transportation, and utilities. Various measures can be taken to prevent releases associated with equipment failure, including routine equipment inspections and maintenance (*8–10*). To ensure safety of the employees who work in manufacturing industries, the Occupational Safety and Health Administration (OSHA) requires appropriate chemical education and training. Also all employers with hazardous chemicals in their workplace must have labels and safety sheets for chemicals to which their workers might be exposed (*11*). For the transportation industry, the Pipeline and Hazardous Materials Safety Administration (PHMSA) has established policies and standards in addition to providing education to prevent hazardous chemical releases. PHMSA's goal is to prepare the public and first responders to reduce consequences if an incident occurs (*12*).

Because these five industries had a high frequency of students and general public injured, and evacuations, it is important for communities near these facilities to have a strong public health response infrastructure. It is important to include local emergency response, including first responders, hospitals, the manufacturing industry, labor representatives, educational facilities, political entities and the public, so they can develop a plan to respond to and prevent acute chemical releases (*9,13*). With educational services having a high frequency of injured persons associated with human error and intentional or illegal acts, proper chemical use and management (i.e. storing, inventory) is essential to protect the building's occupants (*14*). Proper training and supervision of students and instructors can mitigate school chemical releases (*15*). For releases caused by intentional or illegal acts, a focus on preventing students from illegally or intentionally releasing chemicals in education settings could mitigate adverse public health outcomes. Exploring the implementation of stricter enforcement might discourage students from experimenting with chemicals that can have serious financial and public health consequences.

TABLE 6. Number and percentage of injuries for top five industries, by type of industry — Hazardous Substances Emergency Events Surveillance system, nine states,* 1999–2008

	Chemical manufacturing		Educational services		Food manufacturing		Truck transportation		Utilities		Total	
Type of injury	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Respiratory irritation	919	(39)	763	(28)	574	(43)	250	(28)	295	(31)	**2,801**	**(35)**
Eye irritation	303	(13)	452	(17)	196	(15)	83	(9)	69	(7)	**1,103**	**(14)**
Headache	252	(11)	442	(16)	207	(16)	42	(5)	116	(12)	**1,059**	**(13)**
Gastrointestinal problems	187	(8)	346	(13)	117	(9)	57	(6)	120	(13)	**827**	**(10)**
Dizziness/central nervous system	162	(7)	371	(14)	53	(4)	36	(4)	136	(14)	**758**	**(9)**
Skin irritation	151	(6)	139	(5)	28	(2)	42	(5)	32	(3)	**392**	**(5)**
Short of breath	76	(3)	94	(3)	41	(3)	12	(1)	19	(2)	**242**	**(3)**
Other	120	(5)	31	(1)	24	(2)	16	(2)	49	(5)	**240**	**(3)**
Trauma (nonchemically related)	45	(2)	16	(1)	7	(1)	299	(33)	12	(1)	**206**	**(3)**
Burns (chemically related)	34	(1)	41	(2)	31	(2)	26	(3)	34	(4)	**166**	**(2)**
Trauma (chemically related)	40	(2)	8	(0)	4	(0)	8	(1)	36	(4)	**96**	**(1)**
Burns (thermal)	31	(1)	19	(1)	20	(2)	19	(2)	14	(1)	**86**	**(1)**
Heart problems	12	(1)	5	(0)	17	(1)	2	(0)	11	(1)	**47**	**(1)**
Heat stress	4	(0)	3	(0)	4	(0)	3	(0)	6	(1)	**20**	**(0)**
Total†	**2,336**	**(99)**	**2,730**	**(101)**	**1,323**	**(100)**	**895**	**(99)**	**949**	**(99)**	**8,043**	**(100)**

* Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.
† Total is higher than number of injured persons because persons could report more than one injury.

Also, proper storage of chemicals such as mercury can prevent children from unlawfully obtaining such chemicals and improperly releasing them into the environment. Another safety measure that could reduce injuries is the safe removable of unused, outdated, potentially dangerous chemicals from schools (*16*).

Ammonia was the overall most frequently reported chemical released and the most frequently released for chemical manufacturing and food manufacturing. Ammonia is used as a refrigerant in food manufacturing (*17*) and in many manufacturing processes. Exposure to ammonia can irritate skin, eyes, and the respiratory system and in extreme cases cause death (*17*). To mitigate morbidity and mortality associated with ammonia in food manufacturing, industries could use refrigerants gases that are not as flammable or toxic as ammonia, such as carbon dioxide (*18*,*19*). In additional, education initiatives can raise awareness about the dangers of ammonia, safer alternatives (where applicable) and proper management of ammonia. The Wisconsin HSEES Ammonia Awareness Day was designed to target workers in industries that used ammonia as refrigerant. Wisconsin used electronic mail and a Web page to disseminate information to raise awareness about ammonia (*18*).

Within the utilities industry, chlorine was the most frequently reported chemical released. The utilities industry includes water and sewage. Over 550 water treatment facilities have converted to safer alternatives to chlorine gas. Some safer alternatives to chlorine gas include liquid chlorine bleach (sodium hypochlorite) and ultraviolet light (*20*).

In addition, OSHA's Hierarchy of Controls model to control exposures to occupational hazards includes (in order of effectiveness) elimination, substitution, engineering control, administrative controls, and personal protective equipment (PPE) (*21*). Safer alternatives to some of the chemicals being used in industries exist (e.g., use of ultraviolet light instead of chlorine gas in water treatment facilities and carbon dioxide instead of ammonia in food manufacturing). However, elimination and/or substitution of chemicals can be difficult in implement in industries (*21*). When elimination o substitution is not an option, industries ensure that proper engineering controls are in place that will remove a hazard or implement a barrier to prevent chemical exposure. Although this option can have high initial costs, long-term operating costs can be lower (*21*). Administrative control and PPE are the least effective because they are not well controlled and require a substantial effort by the employees (*22*). These last two controls can be very costly in the long term (*21*). Other potential ways to protect surrounding populations and the general public and to decrease morbidity and mortality include maintaining a sufficient emergency mitigation systems and establishing adequate buffer zone distances to surrounding populations (*22*). Collaboration with industries, surrounding responders, hospitals, and community leaders to ensure that a well devised response plan is in place is important so that if a chemical release occurs, all parties involved are in accord.

Limitations

The findings in this report are subject to at least four limitations. First, despite the attempts to make the case definition the same among states, results are not comparable between states because reporting to HSEES was voluntary and data sources varied by state. Second, the results from these nine states might not be representative of the entire United States. Third, inconsistencies within and across states likely exist because reporting capacity (e.g., staffing) or local requirements varied. Specifically, certain states and localities had more stringent reporting regulations than the federal regulations or had more resources to conduct surveillance, possibly resulting in more reported incidents. These factors might have influenced the quality and number of reports or level of detail provided about the incidents. Finally, the changes in reporting guidelines in 2006 (e.g., the reporting requirement changed based on the amount of the release to >10 pounds or >1 gallon or any release amount for substances on the HSEES mandatory list) could have led to increased reporting of some types of incidents and decreased reporting of others. This also could have affected the reports of industries that had releases.

Conclusion

With thousands of chemicals being released annually and limited resources, it is important to target chemicals with the greatest public health implications. This analysis shows that five industries accounted for approximately one third of all incidents with injuries and 30% of injured persons. The top five chemicals in these five industries are also the top five chemicals causing injury in this time frame for all incidents, making them a good target for prevention efforts. Knowing where chemical releases occur and the magnitude of impact is important as it enables public health authorities to allocate and develop resources and prevention efforts efficiently by using the hierarchy of controls to select the best control methods for the situation and following guidelines and recommendations of OSHA and PHMSA.

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