



## Hazardous substances events associated with the manufacturing of chemicals and allied products

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### Abstract

This report describes events involving the acute release of hazardous substances reported to the Hazardous Substances Emergency Events Surveillance (HSEES) system for 1993–2000. HSEES, maintained by the Agency for Toxic Substances and Disease Registry (ATSDR), collects data on the industries/services associated with events. This analysis focuses on fixed-facility events that occurred during the manufacturing of chemicals and allied products (i.e. categorized according to the 1990 Industrial Classification System (ICS) of the US Bureau of the Census). This is the most frequently reported industry category in the surveillance system, with over 12,000 events (28% of all events and 35% of fixed-facility events). Further classification found that the majority (71%) of these events involved the manufacturing of industrial and miscellaneous chemicals (ICS code 192), and 21% plastics, synthetics, and resins (ICS code 180). A total of 2676 persons reported injuries in 307 fixed-facility events. Most of the injured persons were employees (42%), followed by the general public (38%), students (15%), and responders (5%). Thirty-five percent of all injured persons and 46% of all injured employees had respiratory symptoms. Releases frequently occurred in processing vessels, and the majority was due to equipment failure. A review of the data indicates that manufacturers of chemicals and allied products could help reduce morbidity and mortality by taking preventive actions such as performing regular maintenance of processing equipment, regular training of employees and encouraging them to wear respiratory protection, and educating the public on what to do in the event of a release from these facilities.

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## 1. Introduction

In the United States, tremendous amounts of chemicals are manufactured and used daily, and new chemicals are constantly being introduced. The federal government has classified more than 2000 of these chemicals as hazardous materials [1]. As we become more industrialized and the use of chemicals increases, so does the likelihood of unintentional releases of hazardous materials. The public health consequences of the accidental releases of hazardous materials have thus become a topic of great interest [2]. We analyzed data from the Agency for Toxic Substances and Disease Registry (ATSDR) Hazardous Substances Emergency Events Surveillance (HSEES) system to describe the incidents and consequences of acute releases of hazardous substances in the manufacturing of chemicals and allied products.

Most industrial releases of hazardous substances do not result in severe human health consequences. However, major events (such as the release of methyl isocyanate in Bhopal, India, in 1984 [3]; the dioxin release from a pharmaceutical factory in Seveso, Italy [4]; smaller events such as the pesticide and fertilizer warehouse fire in California in 1985 [3]; or the recent explosion at a chemical fertilizer plant in Toulouse, France, in 2001 [5]) illustrate that the accidental release of hazardous substances from industry can result in dire public health consequences. Evaluating the data for past hazardous substances events, including those not resulting in injuries, can be useful for risk assessment, preparedness and prevention planning, and employee education.

Some industries are more frequently involved in hazardous substances releases and in releases resulting in injury. Identifying the types of facilities and reviewing the mechanisms involved in acute hazardous substances releases can help industries assess their weaknesses and implement changes to reduce the number of future releases and subsequent injuries. The purpose of this report is to characterize the acute releases of hazardous substances reported to HSEES that occurred in chemical and allied products manufacturing industries. We present a retrospective review of these events, focusing on the causes and contributing factors, the chemicals involved, the types of injuries, evacuations, and decontamination activities.

## 2. Methods

Since 1990, ATSDR has developed and maintained HSEES as an active state-based surveillance system for the collection and analyses of emergency events involving hazardous substances. During 1990–1992, data were collected by five states for the pilot phase of the surveillance system. We analyzed data collected from 1993 to 2000. The states of Alabama, Colorado, Iowa, New York, North Carolina, Oregon, Rhode Island, Texas, Washington, and Wisconsin, collected data for this entire time period. Six other states contributed data to a part of this time period: Minnesota (1995–2000), Missouri (1994–2000), Mississippi (1995–2000), New Hampshire (1993–1996), New Jersey (2000), and Utah (2000) (Table 1).

An event is defined by HSEES as the sudden, uncontrolled, or illegal release or threatened release of at least one hazardous substance. Such events are required to meet one of the following criteria to be eligible for inclusion into the HSEES system: (a) release of at least one hazardous substance in an amount that requires it to be removed, cleaned up, or

Table 1  
Number of CAP<sup>a</sup> manufacturing events compared with the number of other fixed-facility events by year and state—HSEES, 1993–2000

State	CAP manufacturing events by year								CAP events		Non-CAP events	
	1993	1994	1995	1996	1997	1998	1999	2000	Total	Percent	Total	Percent
Alabama	30	39	44	42	36	22	35	24	272	2.3	723	3.2
Colorado	5	4	4	5	6	4	5	3	36	0.3	1688	7.6
Iowa	21	21	28	39	43	38	24	20	234	1.9	1362	6.1
Minnesota	–	–	15	33	31	44	45	53	221	1.8	1364	6.1
Mississippi	–	–	22	21	21	32	33	23	152	1.3	386	1.7
Missouri	–	40	43	26	19	31	33	33	225	1.9	816	3.7
North Carolina	39	39	52	29	27	12	22	20	240	2.0	848	3.8
New Hampshire	3	3	3	1	–	–	–	–	10	0.1	142	0.6
New Jersey	–	–	–	–	–	–	–	58	58	0.5	399	1.8
New York	56	66	65	97	81	101	152	101	719	6.0	2701	12.1
Oregon	4	13	6	13	6	8	7	6	63	0.5	968	4.3
Rhode Island	7	4	15	7	5	4	1	1	44	0.4	257	1.2
Texas	685	627	1037	1258	1588	1526	1285	1275	9281	77.0	6717	30.0
Utah	–	–	–	–	–	–	–	3	3	<0.1	137	0.6
Washington	25	23	28	49	34	35	23	21	238	2.0	2185	9.8
Wisconsin	50	30	40	34	34	16	11	22	237	2.0	1641	7.4
Total	925	909	1402	1654	1931	1873	1676	1663	12033	100.0	22334	100.0

<sup>a</sup> Chemicals and allied products.

neutralized in accordance with federal, state, or local law; or (b) a threatened release of at least one hazardous substance in an amount that requires it to be removed, cleaned up, or neutralized in accordance with federal, state, or local law that leads to an action such as evacuation to protect public health [6]. Events involving only the release of petroleum were excluded. The data are collected using a standardized web-based data collection system that is checked routinely for accuracy and completeness.

Surveillance data include the time and place of each event, hazardous substances involved, factors or circumstances contributing to the occurrence of the event, information on persons affected, and whether the event occurred at a fixed facility or is transportation-related.

Victims or injured persons are defined by HSEES as persons who experienced at least one adverse health effect within 24 h after the event or who died as a result of the event. A victim who obtained more than one injury is counted once, but each symptom is recorded according to applicable type. Substances released in an event are coded using the standardized substance name and are further grouped into 11 substance categories (Table 2). For example, ammonia is listed as a standard substance, but it is also a substance category that includes anhydrous ammonia and ammonia not otherwise specified (NOS).

HSEES uses the 1990 ICS established by the US. Bureau of the Census to describe the type of facility or industry at which an event occurred. The manufacturing of chemicals and allied products category includes the following industry codes—180: plastics materials, synthetics and resins; 181: drugs; 182: soaps and cosmetics; 190: paints, varnishes, and related products; 191: agricultural chemicals; and 192: industrial and miscellaneous chemicals [7]. Descriptive analyses of HSEES data were performed using Statistical Analysis

Table 2

Distribution of substances released in CAP<sup>a</sup> related events and events with victims in each substance category—HSEES, 1993–2000

Substance category	All releases		Releases with victims		Percentage of releases with victims percent
	Number	Percent	Number	Percent	
Volatile organic compounds	4249	33.0	62	15.9	1.5
Other inorganic substances	2531	19.7	71	18.2	2.8
Other/unclassified substances	2227	17.3	80	20.5	3.6
Mixture	1757	13.6	34	8.7	1.9
Acids	740	5.8	49	12.6	6.5
Ammonia	616	4.8	29	7.4	4.7
Bases	287	2.2	13	3.3	4.5
Chlorine	211	1.6	46	11.8	21.8
Pesticides	186	1.5	3	0.8	1.6
Paints and dyes	51	0.4	3	0.8	5.9
Polychlorinated biphenyls	6	0.1	0	0.0	0.0
Total <sup>b</sup>	12861	100.0	390	100.0	3.0

<sup>a</sup> Chemicals and allied products.

<sup>b</sup> Total exceeds total number of events because events releasing more than one substance were counted more than once.

System for Windows, Version 8.0 [8]. The analyses were restricted to events occurring in fixed facilities. During the 1993–2000 period, 98% of events involving the manufacturing of chemicals and allied products were fixed-facility events.

### 3. Results

From 1993 to 2000, there were 44,164 hazardous substances emergency events reported to the HSEES system. Approximately 28% ( $n = 12,295$ ) of these events involved the chemicals and allied products manufacturing industry; of this subset, 12,033 (98%) occurred in fixed facilities and 262 (2%) were transportation-related (Table 1). The manufacturing of chemicals and allied products made up 35% of all reported fixed-facility events. Analyses of the 12,033 events by industry subcategories found that 8541 (71%) events involved the manufacturing of industrial and miscellaneous chemicals, 2502 (21%) occurred in plastics, synthetics and resins manufacturing, 569 (4.7%) in agricultural chemicals manufacturing, 187 (1.6%) in pharmaceutical manufacturing, 137 (1%) in soaps and cosmetics manufacturing, and 97 (0.8%) in the manufacturing of paints, varnishes, and related products (Table 3).

The majority of events occurred in Texas ( $n = 9281$ , 77%), followed by New York ( $n = 719$ , 6%) (Table 1). The percentage of fixed-facility events occurring in the chemical and allied products manufacturing category has varied over time, ranging from a low of 27% of all events in 1994 to a high of 44% of reported events in 1997. Twenty-one percent of the events occurred at facilities within a quarter of a mile of private residences, compared with 46% of other fixed-facility events.

Table 3  
Distribution of events and victims by CAP<sup>a</sup> industry subcategories—HSEES, 1993–2000

CAP industry subcategory	All events		Victims	
	Number	Percent	Number	Percent
Manufacturing of industrial and miscellaneous chemicals (ICS <sup>b</sup> code 192)	8541	71.0	1739	65.0
Manufacturing of plastics and resins (ICS code 180)	2502	21.0	241	9.0
Manufacturing of agricultural chemicals (ICS code 191)	569	4.7	107	4.0
Manufacturing of pharmaceuticals (ICS code 181)	187	1.6	508	19.0
Manufacturing of soaps and cosmetics (ICS code 182)	137	1.0	54	2.0
Manufacturing of paints, varnishes, and related products (ICS code 190)	97	0.8	26	1.0
Total <sup>c</sup>	12033	100.1	2675	100.0

<sup>a</sup> Chemicals and allied products.

<sup>b</sup> 1990 Industrial Classification System of the US Bureau of Census.

<sup>c</sup> Percentage exceeds 100 due to rounding.

### 3.1. Contributing factors

Of the 12,033 events occurring in fixed facilities, the type of area within the facility where the event occurred included processing vessel (44.0%,  $n = 5785$ ), piping (15.0%,  $n = 2001$ ), ancillary processing equipment (15.0%,  $n = 1919$ ), storage areas above ground (11.0%,  $n = 1386$ ), loading or unloading of materials areas (5.5%,  $n = 719$ ), transport within the facility (2.0%,  $n = 216$ ), dumping or waste areas (2.0%,  $n = 238$ ), incinerators (1.3%,  $n = 173$ ), and other areas (3%,  $n = 410$ ). The specific area was reported as unknown in 1% ( $n = 187$ ) of events (Table 4).

Table 4  
Distribution of area where events occurred in CAP<sup>a</sup> manufacturing facility—HSEES, 1993–2000

Area of fixed facility	Number	Percent
Processing vessel	5785	44.0
Piping	2001	15.0
Ancillary processing equipment	1919	15.0
Storage area above ground	1386	11.0
Materials loading/unloading area	719	5.5
Transport within the facility	216	1.6
Dumping or waste area	238	2.0
Incinerators	173	1.3
Heating and cooling for facility	42	0.3
Transformer	36	0.2
Storage area below ground	29	0.2
Other areas	410	3.0
Unknown or not report	187	1.0
Total <sup>b</sup>	13141	100.1

<sup>a</sup> Chemicals and allied products.

<sup>b</sup> Total greater than number of events as an event could occur in more than one area. Percentage exceeds 100 due to rounding.

Table 5  
Factors contributing to events in CAP<sup>a</sup> manufacturing—HSEES, 1995–2000

Area of fixed facility	Number	Percent
Equipment failure	6130	63.0
Human error	969	10.0
Equipment maintenance	440	4.5
System process upset	328	3.0
System startup or shutdown	209	2.0
Improper filling	166	2.0
Power failure	157	2.0
Severe weather	115	1.0
Improper mixing	52	0.5
Deliberate damage	12	0.1
Other	569	6.0
Unknown or not reported	551	6.0
Total <sup>b</sup>	9698	100.1

<sup>a</sup> Chemicals and allied products.

<sup>b</sup> Primary contributing factors: based on data for 9697 events as contributing factors were not collected until 1995. Percentage exceeds 100 due to rounding.

Contributing factor information was not collected until mid-year 1995, therefore only 9698 fixed-facility events for this industry category are included in contributing factor analyses. The main factors contributing to a release included, equipment failure ( $n = 6130$ , 63%), human error ( $n = 969$ , 10%), equipment maintenance ( $n = 440$ , 4.5%), system process upset ( $n = 328$ , 3%), system startup or shutdown ( $n = 209$ , 2%), improper filling ( $n = 166$ , 2%), power failure ( $n = 157$ , 2%), severe weather conditions and other uncontrollable factors ( $n = 115$ , 1%), improper mixing ( $n = 52$ , 1%), deliberate damage ( $n = 12$ , <1%), and other ( $n = 569$ , 6%). There were 551 (6%) events for which the contributing factor was unknown or not reported (Table 5).

### 3.2. Victims

During 1993–2000, 20% ( $n = 2675$ ) of the 13,500 victims reported to HSEES were injured in events that occurred in the manufacturing of chemicals and allied products. Injuries were reported in 307 (3%) of the 12,033 events in the manufacturing of chemicals and allied products; in comparison, injuries occurred in 2492 (11%) of the 22,334 events for all other fixed-facility categories combined. In the 307 events with injuries, 146 (48%) had one injured person, 59 (19%) had two, 20 (6%) had three, 19 (6%) had four, and 63 (21%) reported five or more. There were five events with over a 100 victims; three of these occurred at the same plant and are discussed later in the case vignettes. The other events involved 141 employee victims in one event and 583 general public victims in the other. Of the other 2492 fixed-facility events with injuries 1185 (48%) had one victim, 439 (18%) had two, 242 (10%) had three, 141 (6%) had four, and 485 (19%) reported five or more. There were seven events with more than 100 victims (ranging from 102 to 251) in all other fixed-facility events.

The distribution of victims by industry subcategory was 65% in industrial and miscellaneous chemicals manufacturing; 19% pharmaceutical manufacturing; 9% in plastics, synthetics and resins manufacturing; 4% in agricultural chemicals manufacturing; 2% in soaps and cosmetics manufacturing; and 1% in the manufacturing of paints, varnishes and related products (Table 3). The majority of injured persons were employees (42%,  $n = 1125$ ), followed by the general public (38%,  $n = 996$ ), students (15%,  $n = 407$ ), and emergency responders (including company responders) (5%,  $n = 126$ ). The victim category was unknown or not reported for 21 persons. In fixed-facility events occurring in all other industries, a greater proportion of victims were employees (59%) and responders (10%).

Symptoms or injuries most commonly reported were respiratory irritation (35%,  $n = 1452$ ), eye irritation (15%,  $n = 621$ ), gastrointestinal effects (12%,  $n = 482$ ), and headaches (12%,  $n = 475$ ) (Table 6). The distribution of reported injuries was similar to that of non-chemical and allied products manufacturing industries events, except for trauma. Of the 4142 injuries reported in chemical and allied products related events, 175 (4%) were trauma, compared with 310 (2%) of the 19,464 injuries in all other fixed-facility events (Table 6). Most injured persons were taken to a hospital (55%,  $n = 1482$ ), of which 1208 (45%) were treated and released, 140 (5%) were admitted, and 134 (5%) were kept for observation but not treated. Other victims were either: (a) treated at the scene of the event (35%,  $n = 925$ ), (b) were examined by a private physician (5%,  $n = 141$ ), or (c) had their injuries reported to an official within 24 h after the event (3%,  $n = 89$ ).

Table 6  
Distribution of injuries among victims by industry type—HSEES, 1993–2000

Injury category	CAP <sup>a</sup> manufacturing events				Other fixed-facility events			
	All victims	Percent	Employees	Percent	All Victims	Percent	Employees	Percent
Respiratory irritation	1452	35.0	756	46.0	6958	35.7	3950	35.0
Eye irritation	621	15.0	162	9.9	2705	13.9	1626	14.4
Gastrointestinal effects	482	11.6	88	5.4	2323	11.9	1353	12.0
Headaches	475	11.5	70	4.3	2278	11.7	1409	12.5
Dizziness/CNS <sup>b</sup> symptoms	262	6.3	133	8.1	1795	9.2	1163	10.3
Skin irritation	246	5.9	84	5.1	1159	6.0	593	5.2
Trauma	175	4.2	126	7.7	310	1.6	123	1.1
Other	161	3.9	76	4.6	465	2.4	207	1.8
Thermal burns	78	1.9	66	4.0	254	1.3	118	1.0
Heart problems	67	1.6	9	0.5	221	1.1	131	1.2
Chemical burns	65	1.6	54	3.3	649	3.3	450	4.0
Shortness of breath	31	0.7	14	0.9	221	1.1	174	1.5
Heat stress	27	0.7	4	0.2	126	0.6	5	0.0
Total <sup>c</sup>	4142	100.0	1642	100.0	19464	100.0	11302	100.0

<sup>a</sup> Chemicals and allied products.

<sup>b</sup> Central nervous system.

<sup>c</sup> Total number of injuries exceeds number of victims because some victims had multiple injuries.

Twenty-three (1%) persons died (20 employees, two persons from the general public, and a responder).

### 3.3. Injuries among employees

Forty-two percent ( $n = 1125$ ) of the 2676 persons injured in chemicals and allied products related events were employees. Commonly reported injuries among employees were respiratory irritation (46%), eye irritation (10%), dizziness (8%), trauma (8%), and gastrointestinal effects (5%) (Table 6). Of the injured employees, 27% reported wearing no form of personal protective equipment (PPE) at the time of injury. Among those who reported wearing PPE, eye protection (48%), level D (19%), and gloves (19%) were most often worn.

### 3.4. Control actions

A greater proportion of chemicals and allied products related events followed an emergency contingency plan, 97% compared with 90% for other fixed-facility industry categories. The type of contingency plan followed was reported for most of the 12,033 events (97%,  $n = 11,710$ ), with the company's standard operating procedure (40%) and an incident-specific, ad hoc plan (37%) being the most common contingency plans followed.

Orders to evacuate were issued in 443 (4%) of the 12,033 events, which is less than for events in other industry categories (15%,  $n = 3347$ ). Evacuations entailed mainly the building or the affected part of the building (57%), the downwind or downstream plume (19%), or within a determined radius of the event location (16%). The median evacuation period (2 h, range from 1 h to 75 days) was similar to that of other fixed-facility industry events. The median number of persons evacuated was slightly larger (25 persons for chemical and allied products related events vs. 20 persons for other industries).

### 3.5. Substances released

In most ( $n = 11,976$ , 99.5%) events substances were actually released. In 18 (0.2%) events, hazardous substances were threatened to be released; in 38 (0.3%) events there were both actual and threatened releases of substances. There was a slightly lower percentage of actual releases in other fixed-facility events (97.0%), and a higher proportion of threatened releases (1.2%) or a combination of actual and threatened releases (1.9%). Ninety-six percent ( $n = 11,571$ ) of events involved the release of a single substance. The most frequently released categories of substances in events were volatile organic compounds (33%), other inorganic substances (20%), mixtures between categories (14%), acids (6%), and ammonia (5%) (Table 2). Seventeen percent of substances could not be classified into an existing substance category. The most frequently released substances in events with victims were other inorganic substances (18%), volatile organic compounds (16%), acids (13%), chlorine (12%), mixtures (9%), and ammonia (7%) (Table 2). Twenty-one percent of events with victims involved substances that could not be classified into an existing substance category. Air emissions (65%), spills (31%), fire (2.0%), and explosions (<1%) were the most frequent types of releases reported. Spills (48%), air emissions (38%), fire (9%), and explosions (2%) were the reported types of releases in other fixed-facility events.



#### 4. Case vignettes

The following briefly summarizes examples of actual events that occurred in facilities classified under the manufacturing of chemicals and allied products industry codes.

One pharmaceutical manufacturing facility accounted for three of the events resulting in injuries and evacuations. This was an older facility, located in an industrial/commercial area with a school and private residences built nearby. Factors contributing to these three events were equipment failure and system process upset, which caused air emission of pyridine and ammonia into the environment. The events occurred on weekdays between the hours of 8:30 a.m. and 4:30 p.m. and were responded to by a HAZMAT team. Actions were taken to mitigate or control the events. Two of the events resulted in the evacuation of more than 4400 persons on each occasion, including students at a neighboring high school, for periods of 3–4 h. One event resulted in injuries to 118 students and 10 members of the general public. Another event at this facility resulted in injury to 98 students and nine members of the general public, and a third resulted in injury to 191 students and 68 members of the general public. No responders or employees were injured. The reported injuries were gastrointestinal effects, respiratory irritation, eye irritation, headaches, dizziness, and shortness of breath. All injured persons were treated at the scene.

An explosion at a fertilizer manufacturing facility located in an industrial complex resulted in the deaths of four employees and injured 19 other employees and one responder. Three of the four employees died because of trauma-related injuries. The fourth employee broke his leg after falling from a catwalk and was overcome by ammonia fumes. The other injured employees suffered trauma and respiratory irritation. All were transported to and treated at a hospital, and eight were admitted. The injured responder received treatment at a hospital for respiratory irritation. The plant produces four basic products, urea, anhydrous ammonia, ammonium nitrate, and urea ammonium nitrate. The explosion occurred inside the ammonium nitrate production area of the facility at approximately 6:00 a.m. on a weekday. A combination of equipment failure, system process upset, and human error were cited as contributing to the explosion. More than 2500 residents (in two states) within a 5-mile radius of the facility were immediately evacuated for more than 24 h. It took 6 days for the facility to effectively secure the material.

#### 5. Discussion

Facilities involved in the manufacturing of chemicals and allied products were the most frequently reported industry category in the surveillance system during 1993–2000, accounting for more than a quarter of all events and over a third of fixed-facility events. It is likely that more incidents occurred in the manufacturing of chemicals and allied products industries because they involve the use and production of large amounts of chemicals [4].

Previous reports that included facility types or industries in their analyses of hazardous materials incidents have cited transportation-related events as the most frequently reported type of event [9–11]. These reports were based on data from individual states and consisted of a smaller number of events. The proportion of events in the HSEES database that were

from the transportation industry was 20%, compared with 28% from the chemical and allied products industry.

Identification and assessment of factors frequently associated with releases are important to prevent future releases. The processes involved in manufacturing, the equipment used, and human factors are among the list of possible factors contributing to the accidental release of hazardous substances [12]. The analyses of HSEES data found that releases frequently occurred in processing vessels and that most releases resulted from equipment failure. Of the five events that had the most victims, two resulted from failure of the pressure release valves. The other three resulted from equipment failure and system process upset. The HSEES results for 1993–2000 support Beddows suggestion that frequent and systematic hazard and risk analysis, along with engineered devices and controls and improved maintenance, can prevent accidental releases in the chemical manufacturing process. This could include frequently updating equipment, replacing parts, having devices for automatic detection and relief of equipment stress, or backup devices for the containment of releases [12]. In addition, the Chemical Safety and Hazard Investigation Board in the Morton Specialty Chemical Investigation Report recommended many ways to prevent runaway chemical reactions [13].

Evacuations during manufacturing of chemical and allied products related events were less frequently required than for other fixed-facility events, but the median number of persons requiring evacuation was greater. The proximity of chemicals and allied products manufacturing facilities at which events occurred in relation to private residences (21% within a 1/4 mile of a residence) compared with all industries (46% within a 1/4 mile of a residence) could explain the lesser frequency of ordered evacuations. A smaller percentage of events resulted in victims than with other fixed-facility events (2.6% vs. 11.2%). However, the largest proportion of injured persons (20%,  $n = 2675$ ) in fixed-facility events captured by the HSEES database resulted from events in the manufacturing of chemicals and allied products. A significant proportion (20%) of events with injuries involved five or more persons. This suggests that while a smaller proportion of events are resulting in injuries and evacuations, a larger number of persons are being affected. This is valuable information for emergency planners and industry to consider in the assessment of the consequences of routine events and the potential for larger scale events.

Only acute adverse health effects (i.e., those occurring within 24 h after the event) are collected by the HSEES system. Respiratory and eye irritation, gastrointestinal effects, and headache were the most frequently reported health effects. This is similar to the distribution of adverse health effects for other fixed-facility events captured by the HSEES system. The frequency of releases by air emissions (65%) is a likely explanation for the majority of reported adverse effects related to the respiratory system and eyes. Trauma-related injuries, though less frequently reported, were a more likely adverse effect of events in chemical and allied products manufacturing than events in other fixed facilities (4.2% vs. 1.6%). It is not clear how the type of releases are associated with the greater proportion of trauma-related injuries, because releases resulting from fires and explosions were more frequently reported in other fixed-facility events.

Events in chemicals and allied products manufacturing occurred less frequently in facilities within a quarter mile of private residences. However, events in such facilities may have the potential for greater public health impact, as seen by the disproportionate number of injured persons who were students and members of the general public.

As with other industry categories, the majority of victims were employees (42%,  $n = 1125$ ), but a smaller proportion of injured persons were classified as emergency responders, which includes company responders. Respiratory irritation, eye irritation, dizziness, trauma, gastrointestinal effects, and skin irritation were the injuries most often reported by employees. Employees were more likely to suffer trauma than injured employees in other fixed-facility events (8% vs. 1%). Of the injured employees, a significant proportion (27%) reported wearing no form of PPE at the time of injury. Among those who reported wearing PPE, eye protection, level D, and gloves were most often worn. These forms of PPE offer little or no respiratory and skin protection. As previously discussed, air emissions were the most frequent types of release reported, and respiratory irritation was the most common adverse health effect reported by injured employees. Providing and promoting the use of effective PPE, which offers inhalation protection for employees who are the most likely to sustain injuries, may be a way of improving awareness and decreasing injuries in employees.

Volatile organic compounds and other inorganic substances were the most commonly released categories of substances. Some categories of substances, such as acids, ammonia, and chlorine were less frequently released; however, these substances are potentially more likely to cause adverse health effects (Table 2). There is an abundance of new chemicals that are being manufactured and used, and not all of them are covered under the Environmental Protection Agency Accidental Release Prevention Requirements Risk Management Plans [14]. Additional preparation and preventive measures may be required for communities and employees at risk. Routine evaluation of past releases within a particular industry is important to creating individualized prevention plans.

Data on releases of hazardous materials are available from several federal databases, such as the National Response Center, the Emergency Response Notification System, and the Hazardous Material Incident Reporting System. The HSEES system is unique in that it is the only federally supported database with the goal to decrease morbidity and mortality from hazardous substances releases. Since HSEES is not a regulatory program, participating state health departments actively investigate releases through various reporting sources rather than relying on the use of mandatory reporting or sanctions. These sources include, but are not limited to, records and oral reports of state environmental protection agencies, police and fire departments, the US Department of Transportation, the National Response Center, and hospitals. While ATSDR provides a case definition for inclusion of events in the HSEES system, each participating state has different state and local reporting laws. States with no threshold reporting requirements are allowed to exclude events involving less than 10 lb or 1 gal of a substance not considered extremely hazardous. This may lead to the uneven reporting of releases involving small amounts of substances. The surveillance system is currently in almost a third of the fifty states. There is a wide geographic distribution of states and industry, making HSEES a fairly representative sample of events involving hazardous substances that occur across the US. Despite its limitation, the HSEES system, through the use of multiple sources for both national and local reporting of events and thorough data verification, provides a comprehensive and representative database for assessing the consequences of acute releases of hazardous substances.

## 6. Conclusion

Identifying industries that frequently report hazardous substance incidents and injuries is just one of the many effective ways of utilizing the HSEES database. Facilities classified as manufacturers of chemicals and allied products are frequently involved in acute releases of hazardous substances. More than a third of the events reported to HSEES occurred at facilities in this industry category. Each of these events should be viewed as having the potential to be a catastrophic accident. By periodically assessing these events, the facilities involved can formulate safety plans specific to their needs. Although these facility types are less frequently in close proximity to private residences than other types of facilities, a significant proportion of reported injuries were among students and the general public. This implies the potential for accidental releases in industry to affect surrounding communities. The safety plans developed by these facilities should not only meet the industry and environmental regulations, but also take into account the general public.

Reviewing events in the HSEES database enabled the identification of factors contributing to releases and the mechanism of releases. Equipment failure was the most common contributing factor to releases, suggesting a need for safer design and engineering controls and regular maintenance to improve process safety in industry. If not already in place, safety programs that include the regular evaluation and upgrading of equipment, updating material safety data sheets, and adhering to industry operating regulations should be considered.

Though relatively few events resulted in injuries, a large number of persons were injured per event. Given the large number of events and number of employees sustaining injuries, the hazard of substances as well as the risk to workers should be regularly evaluated. Adhering to the regulatory requirements of the Occupational Safety and Health Administration and the Environmental Protection Agency for regular process hazard analyses could minimize injuries and protect employees. Regularly providing safety training for employees and supplying them with effective PPE, particularly respiratory protection, could improve and maintain awareness regarding chemical safety.

Reviewing data from past events is one way facilities at which accidental releases frequently occur can assess the effectiveness of their current safety plans. Findings from reviews of databases such as HSEES should be communicated to employees and community emergency planners to assist in prevention and response preparation.

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