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Acute public health consequences associated with hazardous substances released during transit, 1993–2000

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Abstract

Massive quantities of hazardous substances are transported each day throughout the United States. While most arrive safely at their destination, uncontrolled releases of substances in transit do occur and have the potential of causing acute public health consequences for those individuals at or near the release. Data from 16 state health departments participating in the Agency for Toxic Substances and Disease Registry's (ATSDR) Hazardous Substances Emergency Events Surveillance (HSEES) system were analyzed to determine the public health consequences that occurred from actual releases in transit. Of the 9392 transportation events analyzed, 9.1% resulted in 2008 victims, including 115 deaths. The population groups injured most often were employees and the general public. The most common injury sustained was respiratory irritation. Evacuations were ordered in 5.5% of events effecting at least 63,686 people. Human error and equipment failure were the most common factors leading to events. These findings underscore the importance of job safety training, community planning, and effective emergency response to prevent adverse public health consequences from occurring or lessen their effect on the public.

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Keywords: Transportation; Hazardous substances; Chemical releases; Adverse public health consequences

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1. Introduction

Hazardous materials transported in the US exceed 800,000 shipments per day and result in the transport of more than 3.1 billion tons annually via air, ground, rail, and water [1]. An estimated 63% of the shipments involve chemical and allied products, while the remaining portions involve petroleum products, medical wastes, and various other hazardous materials [1]. Among the hazardous materials transported include substances such as fuel, solvents, fertilizers, pesticides, paints, and household cleaning disinfectants that are commonly used by US consumers and industry. Although some of these materials are ubiquitous to daily life, many are often corrosive, explosive, flammable, and toxic and can be extremely dangerous when improperly released. These materials are frequently transported over, through, and under densely populated or sensitive areas where the consequences of an emergency release—i.e. overturned truck, derailed tanker car, barge spill, pipeline leak, crop-duster misapplication—could result in environmental damage, severe injury, or loss of life [2]. While most of these materials reach their destination safely [2], emergency releases during transit do occur and have the potential to cause substantial adverse public health consequences. A recent high profile example was the derailment of a freight train, in a downtown Baltimore tunnel, that caused the release of hazardous substances, injuries to first responders, and wide-scale evacuations of the surrounding area [3,4].

Data from the Agency for Toxic Substances and Disease Registry's (ATSDR) Hazardous Substances Emergency Events Surveillance (HSEES) system were used to conduct a descriptive analysis on transportation events involving actual releases of hazardous substances in 16 states during 1993–2000. Transportation-related events were chosen for this analysis because of the lack of information available in the literature detailing how and where these events occur and who can be effected. The objectives of the analysis were to (a) describe the distribution and characteristics of transportation-related emergency events and the acute public health consequences associated, (b) present examples of transportation-related emergency events, and (c) identify strategies that might help reduce future morbidity and mortality resulting from transportation-related emergency events.

2. Methods

Since 1990, ATSDR has maintained the active, state-based HSEES system to reduce the morbidity and mortality associated with hazardous substances releases (transportation and fixed-facility related). While information on hazardous substance releases are available from other federal databases, such as DOT's Hazardous Materials Incident Reporting System (HMIS) and the US Coast Guard's National Response Center (NRC) database, HSEES is the only federal database designed specifically to assess and record the public health consequences of these hazardous substance releases. The other federal databases are designed primarily for emergency response or regulation and do not necessarily seek out and verify information on all injuries [5].

During 1993–2000, 10 state health departments participated in HSEES for the entire time period: Alabama, Colorado, Iowa, New York, North Carolina, Oregon, Rhode Island, Texas, Washington, and Wisconsin. Six states participated during portions of this period:

Minnesota (1995–2000), Mississippi (1995–2000), Missouri (1994–2000), New Hampshire (from 1993 to 1996 only), New Jersey (2000), and Utah (2000). Data collected from 1993 to 2000 were used for this analysis because (a) the initial years of data (1990–1992) are considered pilot data, and (b) 2000 data were the most recent data available at the time of analysis.

States used multiple data sources available to capture complete event information. These sources included, but were not limited to, state environmental protection agencies, police and fire departments, poison control centers, hospitals, local media, and other federal databases (i.e. HMIS, NRC). Information collected (i.e. substance(s) released, victims, injuries, and evacuations) was recorded on standardized data forms and entered into a computerized database. This information was then sent quarterly by the states to ATSDR where it was uploaded into the central HSEES database for analysis. Beginning in 2000, ATSDR ceased using the quarterly data submission system and deployed a real-time, web-based surveillance system. Descriptive analyses on events were conducted using the statistical analysis software SAS, version 8.01 [6].

HSEES defines hazardous substances emergency events as uncontrolled or illegal releases or threatened releases of hazardous substances, or the hazardous by-products of substances that have to be removed, cleaned up, or neutralized according to federal, state, or local law [7]. Events where the release of substances was threatened but, in fact, did not occur, were excluded from this analysis. HSEES defines a hazardous substance as any substance that can cause an adverse health effect. For this analysis, the HSEES database was queried for all events that were categorized as transportation-related events (versus fixed-facility events). Transportation-related emergency events (hereafter referred to as transportation events) were defined as any event in which a hazardous substance release occurred during transit. To establish greater specificity, these transportation events were analyzed by the five primary modes: ground, rail, air, water, and pipeline. Pipeline is a mode used to transport substances long distances, particularly from one fixed-facility to another (i.e. ammonia for farming). Events where the transport mode was unknown or coded strictly as “other” were excluded from the analysis.

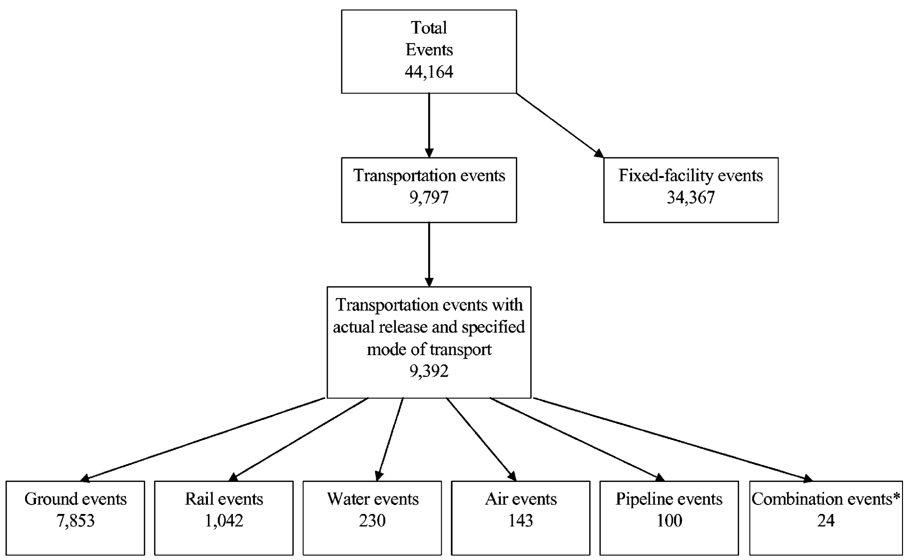
Substances were grouped into 11 categories: acids, ammonia, bases, chlorine, mixtures across categories, other, other organic substances, paints and dyes, pesticides, polychlorinated biphenyls (PCBs), and volatile organic compounds (VOCs). The category *other inorganic substances* is comprised of all inorganic substances, except for *acids*, *bases*, *ammonia*, and *chlorine*. The category *mixtures across categories* consists of substances that were mixed prior to release. The category *other* consists of substances that could not be placed in one of the other substance categories. For data analysis of events by substance category, these 11 categories are used for events where only one substance was released or where multiple substances were released, but all substances released are from the same substance category (i.e. all acids, or all pesticides). An additional *multiple category* was created for those events where multiple substances are released from at least two or more different substance categories. An example of a *multiple category* event would be an event where both an acid and a VOC were released. Events involving petroleum exclusively or events where substances cannot be identified are excluded by HSEES. Petroleum releases were captured however, if one or more non-petroleum hazardous substances were also released during an event.

Victims were defined as persons sustaining at least one injury or symptom (i.e. respiratory irritation) or died as a result of the event. First responders included emergency medical technicians (EMTs), hospital personnel (i.e. emergency department [ED] physicians and nurses), police officers, professional firefighters, responders of unknown type, and volunteer firefighters. Evacuations were defined as events in which people left their home or place of work because of the release. Decontamination was defined as any cleaning procedure that was not considered routine (i.e. washing hands and clothing).

3. Results

3.1. Events

A total of 44,164 events (transportation and fixed-facility related) was reported to the HSEES system from 1 January 1993 to 31 December 2000. Transportation events comprised 22.2% ($n = 9797$) of the events, versus 77.8% ($n = 34,367$) of fixed-facility events (Fig. 1). Of all transportation events, 95.9% ($n = 9392$) had categorized transport modes and involved actual releases. Of these 9392 events, most involved ground transportation (83.6%) and rail transportation (11.1%) (Table 1). The number of transportation events for the 16 participating states (which includes the six states that participated for only portions of the period analyzed) increased more than three-fold, from 598 events in 1993 to 1961 events in 2000. During this period, increases occurred for all known single transportation modes; ground (249.4%), rail (98.7%), air (127.3%), water (325.0%), and pipeline events



* Multiple transport types involved (e.g., collision of a freight train carrying hazardous substances with a tanker truck carrying hazardous substances).

Fig. 1. Distribution of all HSEES events. Hazardous Substances Emergency Events Surveillance, 1993–2000.

Table 1
Distribution of acute public health consequences associated with transportation events, by transport type

Type of transport[a]	Events		Hazardous substances involved[b]		Events with victims[c]		Victims[c]		Deaths		Evacuees		Persons decontaminated	
	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)
Ground[d]	7853	83.6	8539	83.5	724	84.7	1511	75.2	92	80.0	35174	55.2	2083	76.7
Rail	1042	11.1	1150	11.2	66	7.7	271	13.5	4	3.5	24134	37.9	506	18.6
Water	230	2.4	243	2.4	7	0.8	102	5.1	1	0.9	2918	4.6	15	0.6
Air	143	1.5	166	1.6	52	6.1	104	5.2	18	15.7	30	0.0	86	3.2
Pipeline	100	1.1	107	1.0	1	0.1	12	0.6	0	0.0	1430	2.2	10	0.4
Combination[e]	24	0.3	24	0.2	5	0.6	8	0.4	0	0.0	0	0.0	17	0.6
Total	9392	100.0	10229	100.0	855	100.0	2008	100.0	115	100.0	63686	100.0	2717	100.0

Source: Hazardous Substances Emergency Events Surveillance, 1993–2000.

[a] Events with threatened releases only and where mode of transport was unknown or coded strictly as “other” were excluded from analysis ($n = 405$).

[b] The number of hazardous substances involved ($n = 10,229$) exceeds the number of events ($n = 9392$) because more than one substance can be involved per event.

[c] Includes deaths.

[d] For example transport in a truck, van, tractor, automobile.

[e] Multiple transport types involved (e.g. collision of a freight train with a tanker truck).

(460.0%). A separate analysis was conducted for the 10 states that participated for the entire period to determine how much of an increase occurred without the addition of new HSEES states. The number of transportation events for these 10 states increased more than two-fold, from 592 events in 1993 to 1420 events in 2000. For these 10 states, increases occurred in all known single transportation modes; ground (151.0%), rail (60.5%), air (81.8%), water (250.0%), and pipeline events (400.0%).

The three states accounting for the most transportation events were Texas (19.0%), Wisconsin (13.9%), and Colorado (9.7%). Events were more likely to occur in rural/agricultural areas (19.9%), followed by commercial areas (16.2%). More than half of the transportation events (54.8%) occurred during the 5-month period of April through August. Of events when the time and day of occurrence were recorded, 71.4% occurred during the hours of 06:01 and 18:00, and 86.3% occurred during a weekday.

3.2. Substances

A total of 10,229 substances was involved in 9392 transportation events (Table 1). In 94.5% of the transportation events, only one substance was involved. The number of substances per event ranged from 1 to 11. Most substances, where the unit of measure was known, were reported in gallons (72.9%). Of these, 99.5% had a known quantity that ranged from 1 to 98,000 gal (median = 10.0). Most of these amounts (75.0%) were 55 gal or less.

Of the categories into which substances were grouped, the largest percentage of events involved *other* (27.7%), *acids* (13.1%), and VOCs (12.3%) (Table 2). From all substance categories, the individual substances most frequently involved were hydrochloric acid (3.9%) and paint or coating NOS (not otherwise specified) (3.8%) (Table 3). The individual substances most frequently involved by single transport mode were paint or coating NOS (ground), sulfuric acid (rail), paint or coating NOS (water), malathion (air), and ammonia (pipeline). Most of the substances involved spills (85.3%).

3.3. Victims, injuries, and personal protective equipment (PPE) usage

In the 9392 transportation events, 855 (9.1%) resulted in 2008 victims, including 115 deaths (Table 1). Of the 855 events with victims, 67.4% involved one victim and 32.6% involved two or more victims. Of these events with victims, the number of victims per event ranged from 1 to 136. Most of the victims were injured during ground (75.2%) and rail (13.5%) transport. The largest percentage of events with victims involved the substance categories *other* (21.5%), *multiple categories* (15.4%), and *other inorganic substances* (13.7%). The substances most frequently involved with victims were ammonia (4.8%) and diesel fuel (4.7%).

The population groups injured most frequently were employees (46.4%) and the general public (37.3%) (Table 4). Of all of the victims where age and sex were recorded (66.9 and 91.3%, respectively), the age range was less than 1–89 years old (mean = 35.5, median = 35.0) and 78.2% were male. The 2008 victims injured sustained a total of 2986 injuries (Table 5). Overall, the single most commonly reported injuries were respiratory irritation (27.1%) and trauma (20.4%). The number of injuries sustained per victim ranged from 1 to 6, with 33.0% of victims sustaining more than one injury. Most victims (61.1%) were

Table 2
Distribution of acute public health consequences associated with transportation events, by substance category

Hazardous substance category	Events[a]		Events with victims[b]		Victims[b]		Deaths		Evacuees		Persons decontaminated	
	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)	No.	Total (%)
Other	2601	27.7	184	21.5	512	25.5	14	12.2	11909	18.7	631	23.2
Acids	1235	13.1	113	13.2	180	9.0	5	4.3	9509	14.9	495	18.2
Volatile organic compounds	1158	12.3	67	7.8	113	5.6	4	3.5	7008	11.0	258	9.5
Other inorganic substances	1023	10.9	117	13.7	265	13.2	19	16.5	15897	25.0	296	10.9
Pesticides	989	10.5	92	10.8	310	15.4	17	14.8	5803	9.1	234	8.6
Bases	619	6.6	35	4.1	54	2.7	2	1.7	167	0.3	167	6.1
Mixtures across categories	505	5.4	38	4.4	65	3.2	5	4.3	1039	1.6	131	4.8
Paints and dyes	466	5.0	19	2.2	31	1.5	3	2.6	31	0.0	39	1.4
Multiple categories	379	4.0	132	15.4	291	14.5	39	33.9	9016	14.2	334	12.3
Ammonia	327	3.5	48	5.6	169	8.4	5	4.3	3157	5.0	111	4.1
Polychlorinated biphenyls	66	0.7	4	0.5	5	0.2	2	1.7	0	0.0	10	0.4
Chlorine	24	0.3	6	0.7	13	0.6	0	0.0	150	0.2	11	0.4
Total	9392	100.0	855	100.0	2008	100.0	115	100.0	63686	100.0	2717	100.0

Source: Hazardous Substances Emergency Events Surveillance, 1993–2000.

[a] Events with threatened releases only and where mode of transport was unknown or coded strictly as “other” were excluded from analysis ($n = 405$).

[b] Includes deaths.

Table 3
The top five substances released in transit involving acute public health consequences

Rank	Total substances involved ($n = 10{,}299$)		Substances involved with victims ($n = 1147$)		Substances involved with deaths ($n = 126$)		Substances involved with evacuations ($n = 525$)		Substances involved with decontaminations ($n = 898$)	
	Substance	Total (%)	Substance	Total (%)	Substance	Total (%)	Substance	Total (%)	Substance	Total (%)
1	Hydrochloric acid	3.9	Ammonia	4.8	Diesel fuel	11.9	Ammonia	8.9	Sulfuric acid	8.0
2	Paint or coating NOS[a]	3.8	Diesel fuel	4.7	Ammonia	5.6	Hydrochloric acid	5.3	Hydrochloric acid	6.3
	Sulfuric acid[b]	3.8	Hydrochloric acid	4.4	Aviation fuel NOS/ hydrochloric acid[b]	4.0	Sulfuric acid	3.4	Sodium hydroxide	5.3
3	Sodium hydroxide	3.6	Sulfuric acid	3.8	Sulfuric acid	3.2	Sodium hydroxide	3.0	Ammonia	3.7
4	Ammonia	3.2	Sodium hydroxide	3.7	Carbon dioxide/ paint or coating NOS/sodium hydroxide/sodium hypochlorite/sulfur[b]	2.4	Nitric acid	2.9	Phosphoric acid/ corrosive NOS[b]	2.0
5	Ethylene glycol	2.1								

Source: Hazardous Substances Emergency Events Surveillance, 1993–2000.

[a] Not otherwise specified.

[b] Tie.

Table 4
Distribution of transportation victims and deaths, by population group

Population group	Victims[a]		Deaths[b]	
	No.	Percentage	No.	Percentage
Employee	932	46.4	69	60.0
General Public	748	37.3	45	39.1
Responder, unknown type[c]	132	6.6	0	0.0
Police officer[c]	92	4.6	0	0.0
Professional firefighter[c]	32	1.6	0	0.0
Student	31	1.5	0	0.0
EMT personnel[c]	20	1.0	0	0.0
Firefighter, unknown type[c]	11	0.5	0	0.0
Volunteer firefighter[c]	7	0.3	0	0.0
Hospital personnel[c]	2	0.1	0	0.0
Unknown	1	0.0	1	0.9
Total	2008	100.0	115	100.0

Source: Hazardous Substances Emergency Events Surveillance, 1993–2000.

[a] Includes deaths.

[b] Death may have been due to the sequence of events (i.e. motor vehicle accident), which lead to the release of a hazardous substance, and not necessarily by exposure to the hazardous substance itself.

[c] First responders were not categorized by responder type before 1995; therefore, responder victims from 1993 to 1994 were grouped in "Responder, unknown type."

treated at a hospital, but not admitted, while 12.6% were admitted to a hospital and 11.6% were treated on the scene.

Of the victims for which PPE status at the time of injury was known (92.5%), most (84.8%) were not wearing any form of PPE, including 80.8% of employees and 58.6% of first responders. Of the known injured responder types who did not wear PPE, most (44.8%) were police officers and emergency medical technicians (EMTs) (7.7%). The most frequently worn PPE among injured responders was firefighter turn-out gear (18.3%). Firefighter turn-out gear—which includes a self-contained breathing apparatus (SCBA), coat, pants, boots, and gloves—provides limited protection during fires only and is not effective in chemical spill situations [8].

3.4. Evacuations and decontaminations

Of the 9392 transportation events, 518 involved ordered evacuations, of which, 409 had a known number of evacuees. There were 63,686 known people evacuated ranging from 1 to 8700 people per event (median = 20). The length of these evacuations ranged from 1 to 426 h (median = 4.0). The largest percentage of events with evacuations involved the substance categories *other* (24.0%), *acids* (15.4%), and VOCs (13.0%). The substances most frequently involved with evacuations were ammonia (8.9%) and hydrochloric acid (5.3%).

Decontamination of potentially exposed individuals was necessary in 728 (7.8%) known events. A total of 2717 individuals underwent decontamination; 79.1% were emergency responders, 16.9% were employees, and 4.0% were members of the general population.

Table 5
Distribution of transportation injuries sustained

Injury type	Transportation injuries	
	No.	Percentage
Respiratory irritation	808	27.1
Trauma[a]	610	20.4
Gastrointestinal problems[b]	331	11.1
Eye irritation	298	10.0
Headache	256	8.6
Dizziness/CNS[c] symptoms	222	7.4
Skin irritation	139	4.7
Chemical burns	116	3.9
Shortness of breath	52	1.7
Thermal burns	47	1.6
Heat stress	30	1.0
Heart problems	17	0.6
Other	60	2.0
Total	2986[d]	100.0

Source: Hazardous Substances Emergency Events Surveillance, 1993–2000.
[a] Trauma may have been caused by the sequence of events (i.e. motor vehicle accident) leading to the release of a hazardous substance, and not necessarily by exposure to the hazardous substance itself.
[b] e.g. nausea, vomiting.
[c] Central nervous system.
[d] The number of injuries ($n = 2986$) exceeds the number of victims ($n = 2008$) because a victim can have multiple injuries.

The largest percentage of decontamination events involved the substance categories *other* (22.8%), *acids* (20.3%), and VOCs (10.6%). The substances most frequently involved with decontaminations were sulfuric acid (8.0%) and hydrochloric acid (6.3%).

4. Case vignettes

4.1. Ground event

In April 1994, an 18-wheel tanker truck released 43,000 gal of the pesticide aldicarb when it struck an overhanging interstate highway sign and exploded near a residential area in Texas. The driver, who fell asleep at the wheel, died and 136 other people sustained injuries. Most of those injured (81.6%) were members of the general public, and 18.4% were first responders. The single most commonly sustained injury was respiratory irritation (25.0%). Eight people were decontaminated and 5200 people were evacuated for 10 h from their place of work or residence.

4.2. Rail event

In February 1996, an 82 car freight train derailed while descending too rapidly down a steep Colorado mountain pass. It spilled approximately 53,000 gal of sulfuric acid, 20,000 gal of triethylene glycol, and 15,000 gal of diesel fuel. Two train engineers died and a third engineer was admitted to the hospital with trauma-related injuries. Twenty members of the general public were treated at a local hospital for respiratory and eye irritation. Fifty people were decontaminated and 20 people were evacuated from their place of work or residence for 40 h.

4.3. Water event

In March 1993, a fish processing vessel caught fire off the coast of Washington state, releasing 50 pounds of ammonia and 650 gal of mixed hydraulic fluid and diesel fuel. No one was injured; however, four crew members were forced to evacuate after securing the fuel lines to the engine. After burning for 9 h, the vessel eventually capsized and was towed into port.

4.4. Air event

In June 2000, a crop-dusting aircraft crashed in a rural Oregon corn field while spraying pesticide. The pilot was the only person injured and was able to walk away from the crash. After undergoing decontamination, the pilot was treated at a hospital for eye irritation, but not admitted. A 500 gal mixture of the pesticides mancozeb and methamidophos and 70 gal of aviation fuel were released upon impact.

4.5. Pipeline event

In October 1997, employees in a rural agricultural area of Iowa ruptured an ammonia pipeline with digging equipment while conducting routine maintenance at a pumping station. Propane burners were set up to flare off the ammonia and the line was emptied for repairs. A total of 80 t of ammonia was released during the event. No one was injured; however, three people from nearby farm houses were evacuated for 3 h.

5. Discussion

Both the HSEES and the DOT's HMIS data appear to reflect an upward trend in the occurrence of transportation events involving hazardous substances. However, it is difficult to definitively conclude whether this trend is due to more events actually occurring or from other factors. Although, a possible explanation for why the number of HSEES transportation events may be increasing includes additional states joining HSEES during the period analyzed. However, an increase in events was also seen for the 10 states that participated during the entire analysis period. Another possible reason for the increase in HSEES transportation events is better source reporting. For example, beginning in 1998, HSEES states started using the DOT's HMIS database as a primary notification source for transportation events [9]. This access may explain why similar increases occurred in HSEES transportation events compared with HMIS transportation incidents. Other possible reasons for increases in overall transportation events (i.e. HSEES and HMIS) include growth in the hazardous materials sector and the US economy in the 1990s, due to consumer demands and industrial needs; changes in national and global distribution practices; and overcrowded transportation routes (i.e. roadways) [1,10,11].

Collection of causal factor information for transportation events began in late 1999; therefore, only causal factor data for 2000 were analyzed. Human error, followed by equipment failure, were the most frequent single factors leading to the event, which is consistent with DOT data [12]. Other specific factors or secondary factors included: improper filling or loading leading to load shifts, tipping or spillage; vehicle accidents or rollovers; intentional and/or illegal activities including dumping; loose caps, lids or valves; and punctures by forklifts or other pointy objects. These data suggest that job safety training, preventive equipment/vehicle maintenance, and improved container designs and shipping procedures could prevent or reduce the occurrence of events and injuries.

As noted in other HSEES analyses [13,14], many events (transportation and fixed-facility related) appear to follow seasonal agricultural activities (i.e. fertilizing, pesticide application). The frequency of transportation events during 1993 through 2000 was highest from April through August, with a peak occurring in May. This peak coincides with the planting season, when demand for agricultural chemicals is high [13]. Given the large number of agricultural substances released (i.e. pesticides, ammonia), agricultural employee education on safe transport and substance handling appear to be appropriate targets for preventive interventions.

Extremely hazardous substances such as ammonia, hydrochloric acid, sulfuric acid, and sodium hydroxide were the substances most frequently involved where there were victims, deaths, evacuations, and decontaminations. Therefore, it is critical for first responders—specifically, hospital emergency department [ED] personnel and EMTs—to have the training and resources to treat contaminated patients with these and other hazardous substance exposures. Interestingly, the substances released most often were not necessarily the most likely to result in victims. For example, acids, the second most released substance category, was released during 1235 events; however, only 113 (9.1%) of these events resulted in injury. Conversely, chlorine, the least released substance category, was released in only 24 events, yet 6 (25.0%) of these events resulted in injury, indicating its greater potential for harm. Additionally, because there were so many events involving substances from the *other* category, ATSDR toxicologists are currently examining this substance category to determine if these chemicals can be further distributed into definitive categories. Refining this *other* substance category should give greater chemical specificity for future analyses.

Most of the transportation events did not have victims, probably because many events occurred in less populated areas (i.e. rural/agricultural areas). Events with victims tend to happen without warning affecting those in the immediate vicinity of the release. The employee category had the highest percentage of victims, most likely due to their direct transport involvement. Of particular concern is that 52.8% of general public victims were injured in either residential areas—presumably where they lived—or a combination of residential and other areas near the release. Of the students who were injured, many were being transported to or from school and were present when the release occurred (i.e. pepper spray released on a school bus/carbon monoxide release from a malfunctioning school bus). First responders tended to be injured as they secured the event area or provided rapid on-site emergency care to victims during and immediately after releases.

Respiratory irritation and gastrointestinal problems (i.e. nausea) ranked first and third, respectively, for injuries sustained, indicating that victims likely inhaled airborne substances that were released. Trauma, the second most frequently sustained injury, was most likely due to the actual transport collision/impact and not necessarily to the exposure of the substance released. An argument can be made that those victims who died or were injured from transport collision and not from a hazardous substance exposure should be omitted from the victim count because their inclusion may overstate the public health consequences. During the period analyzed, HSEES did not have the ability to differentiate between those who died or were injured due to impact or those who died or were injured due to actual substance exposure. However, as of 1 January 2002, revisions to the system should help clarify this issue. For example, for victims sustaining trauma, the choices of *trauma-chemical related*, *trauma-not chemical related*, and *trauma-not specified* can now be selected.

HSEES does not capture PPE usage for those individuals who were not injured. However, analyzing PPE usage for injured victims can help determine human exposure. PPE usage was analyzed for victim groups that were more inclined to wear PPE as part of their job (i.e. employees, first responders). While those victims in the employee category numbered the most, less than 20% of employee victims were wearing some type of PPE at the time of injury. As a group, first responders were injured less frequently than employees and members of the general public. Reasons for this may include being forewarned of releases en route to an event by a dispatcher and having access to PPE (41.4% wore PPE at the time of injury). Some first responder groups, however, wear PPE more frequently than others. Firefighters, for example, tend to wear turn-out gear during routine responses and are more likely to have limited chemical and respiratory protection. Police officers, who often arrive first on the scene, tend to wear standard uniforms that offer little or no protection, which may explain why they were the largest number of responder victims injured. Similarly, the two hospital employee victims, who wore no PPE, were secondarily contaminated from injured persons who were not properly decontaminated before entering the ED. Injuries sustained by any individuals who were wearing PPE most likely resulted from inappropriate or inadequate PPE for the substance released or from heat-related effects of wearing PPE for prolonged periods of time.

HSEES is a useful tool for capturing information on the public health impact from hazardous substance releases; however, there are some limitations to the system. First, the reporting of events to participating HSEES states is not mandatory. Therefore, events that are not reported from traditional reporting sources may be under reported. HSEES does however capture more public health information on hazardous substances released than other federal databases [15]. Second, the data for this report are from 16 participating states and may not adequately reflect the epidemiology of hazardous substance injuries in other states; however, HSEES coverage is approximately one third of the US landmass and population and has wide geographic distribution. Third, each state has different minimum substance quantity reporting guidelines; therefore, small releases in some states may go unreported. Finally, HSEES excludes all events where petroleum is released exclusively. Had these petroleum events been eligible for inclusion, the number of HSEES events would have increased remarkably, and may have effected the findings presented.

6. Conclusion

The HSEES data suggest that the numbers of events where hazardous substances are released in transit are increasing. While most releases are small scale releases, adverse public health consequences such as injuries, deaths, and evacuations do occur. These injuries primarily affect employees, members of the general public, and first responders. The occurrence of these events underscores the importance of employee training to help prevent future events from occurring and the importance of effective emergency planning and response to events at the community level, once a release has occurred. As the total tons of hazardous materials produced is forecasted to grow, the risk to the public's health could increase unless effective safeguards are in place [12].

6.1. Injury prevention strategies

Some possible public health actions that can be taken by local government, employers, and first responders to help reduce the potential for hazardous substances released in transit and associated injuries are to:

- Use HSEES, and other federal, state, and local databases to determine—for planning purposes—where the highest numbers of releases are occurring;
- Develop emergency response plans before hazardous substances events occur;
- Ensure that employees and first responders who work with or around hazardous substances or contaminated victims undergo continuous job safety training (i.e. HazMat training) and have access to appropriate PPE, where necessary;
- Emphasize the importance of preventive maintenance on equipment and vehicles used in transport, and;
- Route the transport of hazardous materials away from densely populated areas, where feasible.

6.2. Existing federal transportation regulations and safety recommendations

Adherence to the federal regulations set forth by DOT and heeding the safety recommendations of NTSB should also help prevent or lessen the adverse public health consequences of hazardous substances released in transit. These federal regulations and safety recommendations can be found at URLs: http://hazmat.dot.gov/rules.htm for DOT and http://hazmat.dot.gov/ntsb_safety.htm for NTSB. In addition, the National Response Team, composed of 16 Federal agencies, has recently updated its guide for developing state and local emergency response plans to hazardous material releases [16]. This guide can be found at URL: http://www.epa.gov/swercepp/p-new.htm#fact.

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