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New York hazardous substances emergency events surveillance: learning from hazardous substances releases to improve safety

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Abstract

Since 1993, the New York State Department of Health, funded by the Agency for Toxic Substances and Disease Registry, has collected data about non-petroleum hazardous substances releases through the Hazardous Substances Emergency Events Surveillance (NYHSEES) project. This study investigates risk factors for hazardous substances releases that may result in public health consequences such as injury or reported health effects. The 6428 qualifying events that occurred during the 10-year-period of 1993–2002 involved 8838 hazardous substances, 842 evacuations, more than 75,419 people evacuated, and more than 3120 people decontaminated. These events occurred both at fixed facilities (79%) and during transport (21%). The causative factors most frequently contributing to reported events were equipment failure (39%) and human error (33%). Five of the 10 chemicals most frequently associated with injuries were also among the 10 chemicals most frequently involved in reported events: sulfuric acid, hydrochloric acid, ammonia, sodium hypochlorite, and carbon monoxide. The chemical categories most frequently associated with events, and with events with adverse health effects were volatile organic compounds (VOCs) and solvents, and acids. Events with releases of hazardous substances were associated with injuries to 3089 people including employees (37%), responders (12%), the general public (29%) and students (22%). The most frequently reported adverse health effects were respiratory irritation, headache, and nausea or vomiting. Most of the injured were transported to the hospital, treated, and released (55%) or treated at the scene (29%). These data have been used for emergency response training, planning, and prevention activities to reduce morbidity and mortality from future events.

Keywords: Hazardous substances; Chemicals; Emergency response; Chemical releases; Responder injuries

1. Introduction

The Hazardous Substances Emergency Events Surveillance (HSEES) is a state-based project funded by the Agency for Toxic Substances and Disease Registry (ATSDR) to describe and evaluate the public health consequences of incidents involving non-petroleum hazardous substances [1]. Since 1993, the New York State Department of Health (NYSDOH) has participated in the project that currently includes 15 states[1] [2].

The goal of the HSEES project is to reduce morbidity (injury) and mortality (death) resulting from hazardous substance events by identifying risk factors [3] in the incident data and providing the information to appropriate audiences such as industrial hygienists, safety engineers, emergency responders, and response planners, who can implement preventative and corrective measures. Efforts to reduce morbidity and mortality may include a process change that eliminates problematic conditions or reactions, better equipment maintenance, improved employee training, or appropriate uses of personal protective equipment by employees and responders. The surveillance objectives are:

- Describe the distribution and characteristics of acute hazardous substance(s) events in New York State.
- Describe the morbidity and mortality experienced by employees, responders, and the general public that result from hazardous substance events.
- Identify risk factors associated with morbidity and mortality from the release of hazardous substances.
- Identify or develop prevention strategies that might reduce future morbidity and mortality associated with hazardous substance releases.

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[1] Other states participating in the study are Alabama, Colorado, Iowa, Louisiana, Minnesota, Mississippi, Missouri, New Jersey, North Carolina, Oregon, Texas, Utah, Washington and Wisconsin.

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During the 10-year-period of 1 January 1993 through 31 December 2002, project staff characterized 6428 events involving more than 8838 hazardous substances in New York State.

2. Methods

2.1. Definition of a reportable event

For the HSEES project, a reportable event is defined as an uncontrolled, illegal or threatened release of hazardous substances (excluding petroleum products) that need to be removed, cleaned up or neutralized according to federal, state or local law. Includable hazardous substances are chemical, biological, and radiological. If a spill includes the release of petroleum products with other hazardous substances that meet event criteria, then the spill qualifies as a reportable event, and those petroleum products are included in the database for completeness. A threatened release which qualifies for inclusion in the study is defined as an incident that requires an emergency response and leads to a public health action such as an evacuation, access restriction or traffic re-routing.

Spills are determined to be non-events for any of several reasons such as: the chemicals involved are petroleum and excluded by case definition, the amounts released are small quantities excluded from regulation, the release is legal or permitted, the spill is not a recent incident but rather a discovery of substances such as waste barrels dumped more than 3 days earlier, or the threatened incident does not involve any action to protect public health such as a road losure or an evacuation.

2.2. Definition of fixed facility and transportation events

Fixed facility events are those which occur outdoors or inside a building on the premises of a facility or site. Some examples of fixed facilities are manufacturing plants; businesses; industrial, construction, and excavation sites; farms; schools; hospitals and private residences. Transportation events involve ground, rail, water, air or pipeline transport and often occur outside the boundaries of a fixed facility.

2.3. Types of data collected

Project staff collected data using a 66-question computerized survey tool developed by ATSDR and approved by the Office of Management and Budget. The data collection system is maintained by ATSDR in Atlanta, GA. Data were entered and edited online, via a secure Internet connection. Each event was given a unique record identification code for tracking purposes.

Categories of information collected during investigation included the following:

- chemical name and quantity released;
- time, date, weather conditions, and location of event;
- type of release (e.g., spill, air emission, fire, explosion, radiation, threatened, etc.) and factors contributing to the release (e.g., equipment failure, operator error, improper mixing, etc.);
- injury-related information including victim category (employee, responder, general public or student), injury type (e.g., trauma; eye, respiratory or skin irritation; chemical burns), treatment provided, and use of personal protective equipment;
- information on the number of persons (employees, responders, members of the general public, and students) decontaminated;
- estimated size of the potentially exposed residential population within one-quarter mile, one-half mile, and one mile of the event;
- evacuation and in-place sheltering activities; and
- control actions, types of responders, and health follow-up activities.

Victims were categorized as students if they were at school or participating in a school function (e.g., field trip), when the exposure occurred; and as general public, if they were in any other location.

2.4. Data collection methods

Incidents were identified through two main sources; the New York State Department of Environmental Conservation (NYSDEC) Spill Hotline and the New York City Department of Environmental Protection. Additional event identification was obtained from the NYSDOH Bureau of Environmental Radiation Protection, the New York State Emergency Management Office, the New York State Office of Fire Prevention and Control, the New York State Police, the New York State Department of Transportation, the NYSDEC Division of Law Enforcement, the US Department of Transportation Hazardous Materials Incident System (HMIS), and the federal National Response Center. These agency sources of information were supplemented by incident reports from county health departments, the news media, and from the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) Section 6(a)(2) Reports obtained from NYSDEC. During recent years, staff has scanned the online newspapers of all major metropolitan areas in New York State to identify additional qualifying events.

Each spill was investigated promptly and thoroughly through telephone and written inquiries to appropriate sources including local, county, and state emergency response personnel such as firefighters, emergency medical services, and HazMat staff; county health departments; industrial health and safety or environmental personnel; hospital staff; plant managers and employees; and private citizens. Prior to closing, the records in each year's data set were reviewed for quality assurance/quality control

(QA/QC). After QA/QC, data were analyzed using Statistical Analysis System (SAS®).

2.5. Chemical categorization

Chemicals were categorized using a hierarchical structure of specific functional classes such as acids, bases, solvents, salts, with several default categories such as "other organic" or "other inorganic." The data necessitated additional categories such as chemical mixes and chemical reactions. Several individual chemicals including ammonia, carbon monoxide, and chlorine were not merged into chemical categories. These hazardous substances were retained separately because the elevated numbers of events and/or injuries involving these chemicals provide valuable information that can be used to improve the quality of future education and outreach activities.

3. Results and discussion

3.1. Summary of events

During the 10-year-period of 1993–2002, project staff reviewed approximately 200,000 hazardous substances incidents reported in New York State and selected events involving non-petroleum compounds. Investigation of these actual or threatened releases indicated that 6428 (3.2%) met the HSEES criteria for an eligible event, and these were entered into the project database.

The 6428 qualifying events (Table 1) involved 8838 chemicals, 3089 injured people, 842 events with evacuations, and more than 3120 people who were decontaminated. The numbers of people evacuated or decontaminated and the duration of evacuations are underestimated because information on these parameters was collected and entered only when reported with certainty. In some instances, circumstances indicated that the actual numbers may have been considerably higher, but these numbers were not collected because they could not be confirmed. Data on the populations injured indicate not only the incidence of injured employees (37%) and injured responders (12%) but also of injured people outside the workforce, namely, the general public (29%) and students (22%).

Table 1
Event summary information, New York Hazardous Substances Emergency Events Surveillance, 1993–2002

	Number (%)
Events	6428
Fixed facility	5080 (79)
Transportation	1348 (21)
Chemicals released	8838
Events with injuries	745 (12)
Injured people	3089
Employees	1137 (37)
Responders	359 (12)
General public	885 (29)
Students	695 (22)
Unknown	13 (<1)
Events with ordered evacuations	842 (13)
Fixed facility	761 (90)
Transportation	81 (10)
People evacuated	>75419
Time lost in evacuations (person-hours)[a]	>830057
People decontaminated	>3120

[a] Person-hours equal the number of people evacuated multiplied by the length of the evacuation in hours for all events.

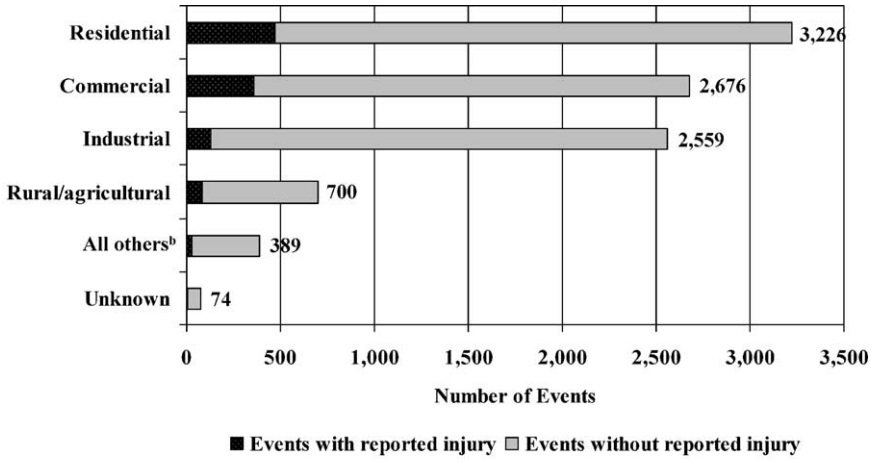
For this project, hazardous substances releases could be described by as many as two descriptors from the following list: spill, volatilization to air, fire, explosion, radiation or not applicable (threatened release). A total of 9338 release types were recorded for the 8838 chemicals involved in these events. Most of the releases involved spills (5063/8838, 57%) or air releases (1703/8838, 19%). Six percent of chemical releases (498/8838) involved two release types. Four percent of events (273 events involving 874 chemicals) had an emergency response but did not result in an actual hazardous substance release and were captured as threatened events.

> An employee at an industrial laundry mistakenly confused two chemical hoses and pumped the wrong solutions into two chemical containers. The containers held solutions of sodium hypochlorite and a bisulfite salt. Upon mixing, a chemical reaction occurred releasing smoke and fumes. The building with 35 people was evacuated for 1 h; HazMat responded. Two employees complained of shortness of breath. They were transported to the hospital, treated, and released. Both employees were wearing Level D at the time of the incident.

3.2. Event areas

Five of the 62 counties in New York State had more than 10 events per 10,000 population each using US Census 2000 [4] data. Two of these counties (Niagara and Saratoga) have areas that are highly industrialized or commercial, but three counties (Essex, Livingston, and Tioga) include less populous areas of New York State and one of the three counties (Essex) is a sparsely populated area totally contained within the Adirondack Park. The census-standardized data indicate that although populated, industrialized areas have the majority of events, the rural and agricultural areas are not immune from these incidents. Industries and transportation routes drive the number of events in rural counties, and as a result, these counties have event rates that, based on census data, are proportional.

Reported events occurred in a variety of land areas defined by the survey tool as vacant, industrial (manufacturing), commercial (includes retail, apartments, hotels, etc.),



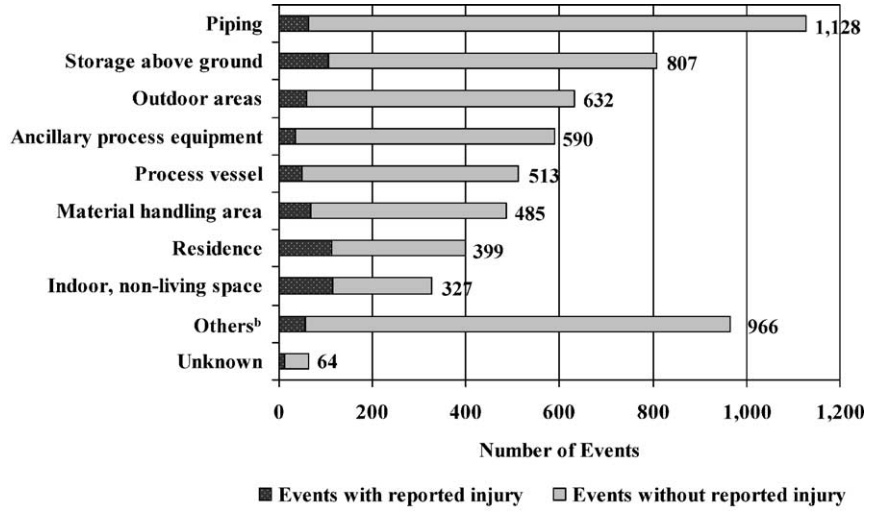
[a]Each event may involve up to two area types.
[b]This category includes road, railway, Department of Energy/Department of Defense, surface water, recreational area, vacant plain, forest, wetlands, and the category 'other'.

Fig. 1. Type of land area[a].

residential, rural/agricultural, forested, wetlands or coastal, surface water or other (e.g., airport, hospital, jail or university). According to the project's design, each event was identified by one or two area types; thus, land areas for any event are not mutually exclusive. The data in Fig. 1 indicate that many events occurred in commercial (2676 events, 42%) or industrial (2559 events, 40%) areas. However, 50% of events (3226 events) were in areas identified as residential, indicating a potential for impacts to the general public. Geo-coding of event locations indicated that 72% (4628 events) occurred within one-quarter mile of a residence.

3.3. Location of events at fixed facilities

Many events at fixed facilities involved piping (1128, 18%), storage above ground (807, 12%) or outdoor areas (632, 10%). Fig. 2 depicts event locations with each bar shaded to indicate the relative proportion of events with reported injuries followed by the events without reported injuries. The highest number of events with injuries occurred in indoor non-living space (e.g., offices, hallways, cafeterias, or restrooms) (114); in residences, including basements (112); and in storage above ground (106). Locations with the highest percentage of events with injury were indoor and non-living spaces such as offices or retail establishments (35%) or residences (28%). Prior to the year 2000, events that occurred within a residence were coded based on specific location such as piping or storage rather than to the residence. Thus, events in the database that are coded to the location "residence" are underestimated for the 10-year-period. However, all events that were coded to residences actually occurred there and were not indoor air



[a]Each fixed facility event may involve up to two locations.
[b]This category includes dump/waste areas; heating, ventilation, and air conditioning (HVAC); transport within a fixed facility; transformer; storage areas below ground; laboratory; incinerator; secondary contamination (office building); and the category 'other'.

Fig. 2. Location of events at fixed facilities[a].

Table 2
Types of industry in reported events[a]

Industry type	Events (%)	Events with injury (%)	Injured persons (%)
Transportation	1046 (16)	97 (13)	238 (8)
Chemical manufacturing	936 (14)	50 (7)	638 (21)
Utilities and sanitation	923 (14)	57 (8)	179 (6)
Durable goods manufacturing	907 (14)	43 (6)	208 (7)
Private residence	450 (7)	145 (19)	209 (7)
Professional services[b]	352 (5)	58 (8)	221 (7)
Retail trade	181 (3)	51 (7)	239 (8)
Paper and printing	128 (2)	10 (1)	57 (2)
Agriculture	120 (2)	15 (2)	31 (1)
Food manufacturing	105 (2)	22 (3)	79 (2)
Other	861 (13)	158 (21)	924 (30)
Unknown	419 (7)	39 (5)	66 (2)

[a] The 6428 total events included 745 events with injuries to 3089 people.

[b] Professional services include medical and health care facilities, schools, libraries, child day care services, religious organizations, engineering services, and research and development services.

quality impacts from nearby manufacturing or commercial establishments.

The data in Figs. 1 and 2 describe types of land areas and locations within fixed facilities associated with hazardous substances events. Many incidents occurred in areas of manufacturing or commerce, but others occurred near or in residential areas and could potentially impact the public who are rarely aware of the potential health impacts or prepared to minimize exposures.

3.4. Industries in reported events

The industries with the highest number of reported events were transportation (16%) followed by 14% each in chemical manufacturing, utilities and sanitation, and durable goods manufacturing (Table 2). Comparing the numbers of events to the number of events with injuries indicates that private residences had proportionately more events with injuries (145/450 events, 32%) than any other category. For the 450 events in which the industry was coded as a private residence, 264 events (61%) were caused by human error. These events occurred during residential use of hazardous substances and were not the result of cottage industries. However, these numbers do not include all events that occurred in residences. For residential events in which the cause of the release was a utility or a contractor on residential property, the event and any resulting injuries were coded to that industry and not captured as the industry "residence."

Other industries with the highest percentage of injuries were retail trade (51/181 events, 28%) and food manufacturing (22/105 events, 21%). The industries with the three lowest percentages of events with injuries were durable goods manufacturing (43/907 events, 5%), chemical manufacturing (50/936 events, 5%) and utilities and sanitation (57/923 events, 6%).

A reaction vessel at a photographic equipment manufacturing company overfilled with ethylene glycol when the limit switches on the control system failed. As the reaction began and heat was applied, the vessel contents were pushed up the distillation column where dimethyl terephthalate cooled and solidified. The distillation column became completely blocked by the solid causing a rapid pressure increase in the reaction vessel. Both pressure disks ruptured releasing a plume of hazardous material that traveled about one-half mile into a residential area. The release deposited a mildly irritating white powder on all surfaces. Access roads and other adjacent streets were closed. Forty-nine people, identified as being exposed to the substance, were decontaminated onsite. All exposed persons were medically evaluated and released. The manufacturing company contracted with a car wash company for decontamination of all affected vehicles including cars on a nearby dealer's lot.

3.5. Contributing factors

The predominant contributing factors in HSEES events (Fig. 3) were equipment failure (2483, 39%) and human error (2152, 33%). When human error was the primary or secondary contributing factor, a larger percentage of the events involved injury (24%) when compared to events in which equipment failure was the primary or secondary contributing factor (6%). The higher proportion of events caused by human error indicates a need for emphasis on engineering controls to decrease the consequences of human error and the need for education and training to prevent future incidents.

3.6. Chemical frequency

Ninety-two percent of all events involved one hazardous substance and 7% of all events involved combinations of two to four hazardous substances (Table 3). Seventeen events involved between 11 and 72 hazardous substances. The four events with the highest number of hazardous substances involved more than 100 hazardous substances each; three of

Table 3
Number of chemicals involved in reported events

Chemicals per event	Number of events	Total (cumulative %)
1	5927	5927 (92)
2	285	570 (96)
3	104	312 (98)
4	44	176 (99)
5	22	110 (99)
6–10	25	185 (99)
>10	21	1558 (99)
Total	6428	8838 (100)

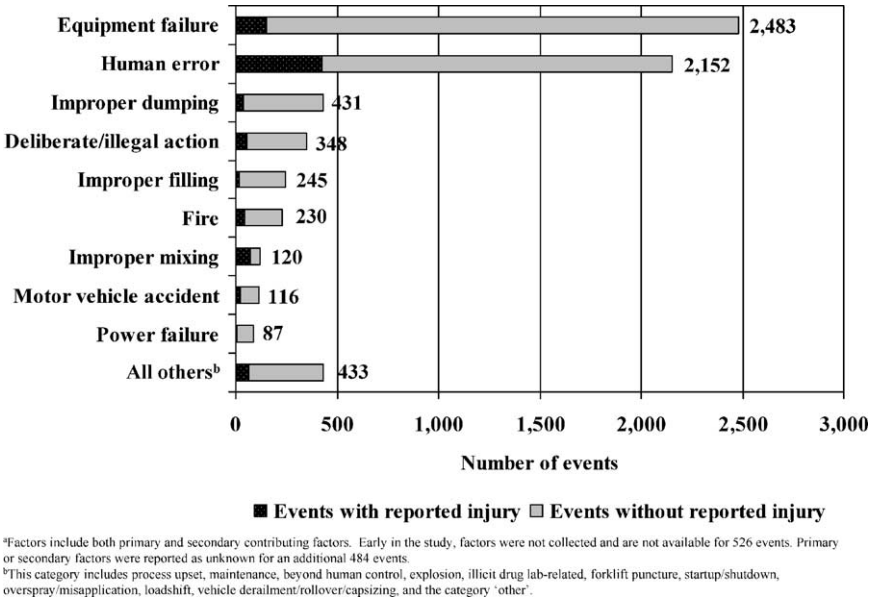


Fig. 3. Factors contributing to reported events[a].

these were fires. The event with the largest number of chemicals (more than 750) was a complex event that involved two warehouses, one of which burned. The release in the second warehouse was threatened and the hazardous substances were identified by an actual inventory taken after the fire. Many of the same chemicals were stored in the first warehouse but no inventory was available.

In general, the majority of events that involve one hazardous substance may be easier for responders to handle and may pose less of a physical and/or toxicological hazard because the possibility of chemical reaction(s) is eliminated. However, even in an event with one hazardous substance, risks of exposure and potential health effects remain. These depend on the inherent physical and toxicological properties of the single hazardous substance released.

3.7. Chemicals involved in spills and injuries

The 10 chemicals most frequently involved in reported events (Table 4) included a coolant and antifreeze (ethylene glycol); a refrigerant (chlorodifluoromethane); a heavy metal (mercury); five corrosive substances (sulfuric acid, hydrochloric acid, sodium hydroxide, ammonia, and sodium hypochlorite); oils (heat transfer fluids) that typically contained low concentrations (50–500 ppm) of polychlorinated biphenyls (PCBs); and an odorless, colorless, tasteless toxic gas (carbon monoxide). These 10 chemicals were involved in 2716 events, 42% of the total of 6428 events.

The 10 chemicals most frequently associated with injury accounted for 54% of the injured people (1680/3089). Table 5 lists the 10 chemicals most frequently associated with adverse health effects and their corresponding victim frequencies. For events with more than one chemical released, each victim is counted with each chemical. Five of the hazardous substances are corrosive or caustic materials:

Table 4
Chemicals most frequently involved in reported events

Chemical	*N* (%)
Ethylene glycol	437 (7)
Chlorodifluoromethane	399 (6)
Mercury	370 (6)
Sulfuric acid	300 (5)
Hydrochloric acid	262 (4)
Oils contaminated with PCBs[a]	228 (4)
Sodium hydroxide	204 (3)
Ammonia	202 (3)
Sodium hypochlorite	167 (3)
Carbon monoxide[b]	146 (2)

[a] PCB, polychlorinated biphenyl; concentrations, typically, 50–500 ppm.
[b] Data collection for events involving carbon monoxide began in 2000.

Table 5
Chemicals most frequently associated with injuries[a,b]

Chemical	No. of victims (%)
Ammonia	524 (17)
Pyridine	496 (16)
Carbon monoxide[c]	326 (11)
Hydrochloric acid	190 (6)
Sodium hypochlorite	175 (6)
Sulfuric acid	173 (6)
Propane	86 (3)
Chlorine	79 (3)
Malathion	71 (2)
Xylene	70 (2)

[a] Mixtures of two or more chemicals were excluded from the table.
[b] If a person is injured by more than one chemical, she or he is counted under each chemical. The total of 2190 injuries corresponds to 1680 injured people.
[c] Data collection for events involving carbon monoxide began in 2000.

ammonia, hydrochloric acid, sodium hypochlorite, sulfuric acid, and chlorine. Pyridine, a solvent with a distinctive disagreeable odor, is used in the manufacture of pharmaceuticals. Carbon monoxide is a poisonous gas produced from the combustion of fossil fuels. Propane is a fuel gas that was included only for events with other hazardous substances releases which qualified the event for capture in the database. Xylene is a solvent and raw material for organic syntheses. Malathion is an organophosphate insecticide. Five of the 10 chemicals most frequently associated with injuries were also among the 10 chemicals most frequently involved in reported events: sulfuric acid, hydrochloric acid, ammonia, sodium hypochlorite, and carbon monoxide.

Injuries to employees were caused by a wide variety of hazardous substances but the chemical that predominated was hydrochloric acid which was associated with injuries to 102 (9%) injured employees. Responders were most frequently injured during releases involving three chemicals: propane (23%), ammonia (19%), and sulfuric acid (15%). Injuries sustained by the general public occurred most frequently in events involving three chemicals: ammonia (15%), carbon monoxide (15%), and pyridine (7%). The hazardous substances most frequently involved in events with injuries to students were pyridine (45%), ammonia (23%), and carbon monoxide (7%). The data on pyridine releases which caused adverse health effects to students and adults originated at one manufacturing facility that is located about 1 mile upwind of three schools with students from elementary, middle, and high school. Recent measures to control releases at this facility have been effective as measured by decreased numbers of reported events in the past 2 years.

Analysis of the chemicals most frequently involved in an evacuation order by an official showed that 334 of the 842 evacuations (40%) were associated with five hazardous substances: carbon monoxide (15%), ammonia (10%), hydrochloric acid (5%), mercury (5%), and sulfuric acid (5%).

> Employees installing a new MRI (magnetic resonance imaging) machine at a hospital were overcome when a liquid nitrogen tank leaked. The released nitrogen displaced the room's oxygen and resulted in the death of a 22-year-old male. Three others were overcome and were treated with oxygen in the emergency room. Two employees were put under medical observation, but did not require treatment. Ten people in the vicinity were evacuated for 2 h.

3.8. Chemical categories involved in events and injuries

Data on the 10 chemical categories most frequently associated with reported events (Table 6) indicate that 20% were associated with volatile organic compounds (VOCs) and solvents. The next highest categories were acids (15%), other inorganic compounds (14%), other organic compounds (12%), and freons (10%). Seventy-one percent of events involved hazardous substances from these five categories. Three of these categories describe distinct chemical categories and the information has been used for outreach, education, and training of employees and responders to prevent future events. Two of the chemical categories, "other inorganic compounds" and "other organic compounds," are default categorizations for compounds that could not be assigned to a more explicit category.

Table 6
Chemical categories most frequently involved in reported events

Chemical category	*N* (%)
VOCs[a] and solvents	1293 (20)
Acids	988 (15)
Other inorganic compounds	925 (14)
Other organic compounds	746 (12)
Freons	642 (10)
Glycols	481 (7)
Heavy metals	467 (7)
Bases	361 (6)
Pesticides	360 (6)
Oils contaminated with PCBs[b]	228 (4)

[a] VOC, volatile organic compound; defined as any compound of carbon with vapor pressure greater than 0.1 mmHg.
[b] PCB, polychlorinated biphenyl; concentrations, typically, 50–500 ppm.

Analysis of the chemical categories associated with adverse health effects (Fig. 4) indicates that nearly half of injuries sustained by victims (45%) were attributable to releases of VOCs and solvents, acids or ammonia. One-third of events in the NYHSEES database that involved exposure to ammonia and had reported injuries (15/45) occurred during the manufacture of food. Forty-seven percent of ammonia events with injuries involved piping.

Another chemical that was not merged into the chemical categories was carbon monoxide. Events in the NYHSEES database which involved exposure to carbon monoxide resulted from combustion processes such as heating, equipment fires and engine exhaust. Frequent sources of carbon monoxide events were fires in underground utility lines that generated high levels of carbon monoxide due to inadequate oxygen. The gases from these fires migrated through the conduits to aboveground locations including occupied apartments.

> Fire control received a call that an employee was experiencing chest pain. Upon arriving at the scene, the responders found six employees with headache, nausea, and central nervous system symptoms. The fire department noticed a chemist doing onsite work at this laminates manufacturing facility. The building was evacuated and HazMat was called. Hospital staff later identified the chemical exposure as carbon monoxide from an undetermined source.

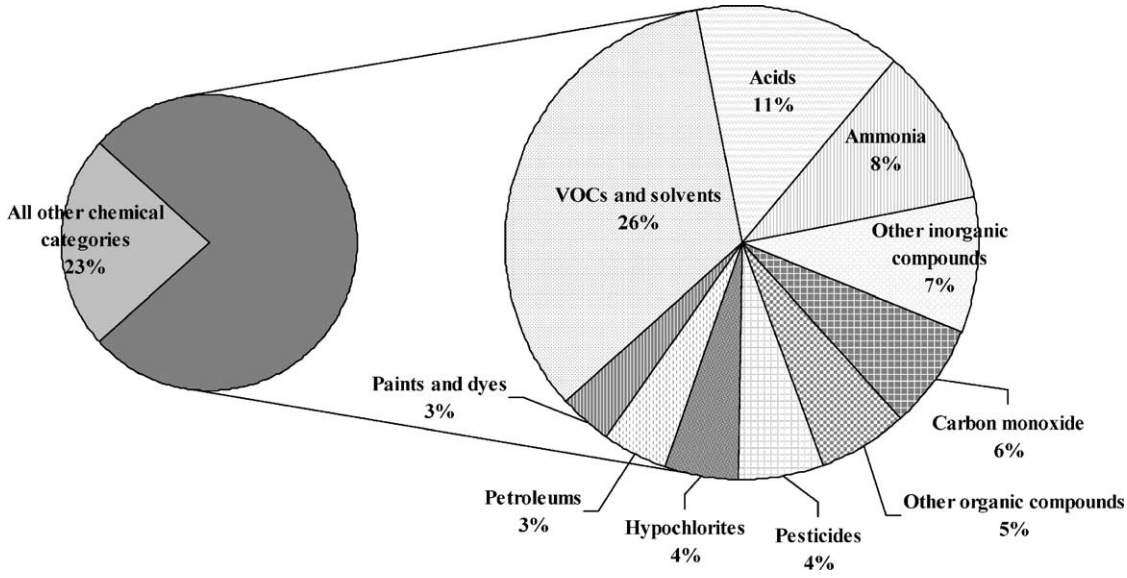
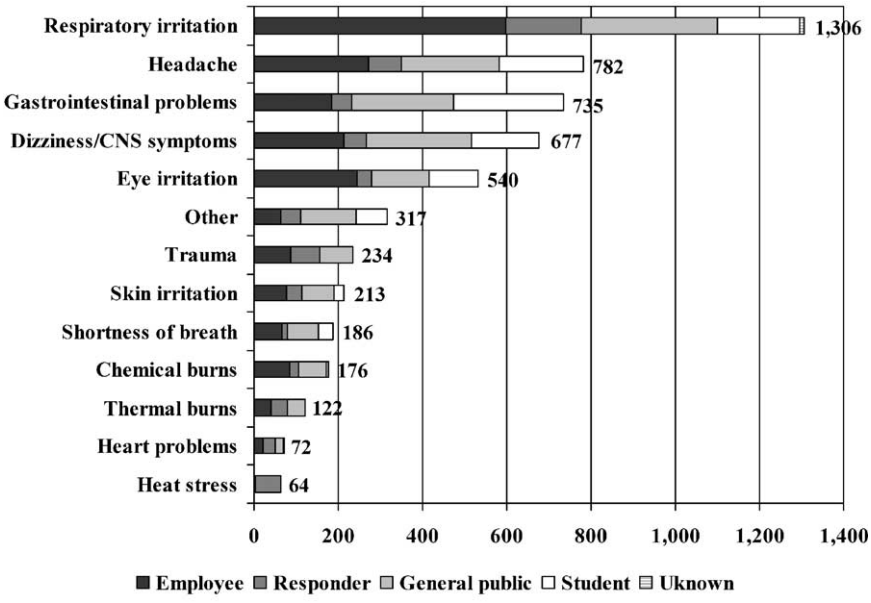


Fig. 4. Ten chemical categories most frequently associated with adverse health effects.

3.9. Victims, injuries and, medical outcomes

Data on adverse health effects (Fig. 5) indicate that the most frequent symptoms were respiratory irritation (42% of victims), headache (25%), nausea or vomiting (24%), dizziness/central nervous system symptoms (22%), and eye irritation (17%). For employees, the predominant injuries were respiratory irritation (597 victims, 52%) and headache (272 victims, 24%). For responders, the predominant injuries were also respiratory irritation (179 victims, 50%) and headache (78 victims, 22%). For the general public, the predominant injuries were respiratory irritation (323 victims, 36%) and dizziness/central nervous system symptoms (249 victims, 28%). For students, the predominant injuries were gastrointestinal problems (260 victims, 37%) and headache (200 victims, 29%).

Data on the medical outcomes for injured people (Table 7) indicate that some injured people were treated on the scene (29%), but more than half of the injured people (55%) were transported to the hospital and released after treatment. Rel-



[a]Some victims sustained more than one type of injury.

Fig. 5. Distribution of adverse health effects by victim category[a].

Table 7
Medical disposition of injured people[a]

Medical disposition	Total (%)
Seen by a private physician[b]	40 (1)
Delayed symptoms reported later[b]	173 (6)
Treated at the scene	891 (29)
Transported to the hospital for observation	70 (2)
Transported to the hospital, treated, and released	1710 (55)
Transported to the hospital and admitted	171 (6)
Fatality	33 (1)
Unknown	1 (<1)
Total	3089 (100)

[a] Out of total, 2783 were injured during fixed facility events and 306 were injured during transportation events.
[b] Within 24 h.

atively small numbers of injured people were seen by a private physician (1%), kept at the hospital for observation (2%), or admitted (6%) to the hospital. One percent of injuries resulted in fatalities.

Water rinses containing residual methyltrichlorosilane and toluene were accidentally mixed in an onsite waste trailer. During onsite transport to the incinerator, the residuals reacted in the waste trailer. While the trailer was parked next to the incinerator, the safety gasket on the trailer blew releasing 34 lb of hydrogen chloride. The company HazMat team responded and evacuated seven people for 3 h from the immediate and downwind areas. Two employees were treated on the scene for respiratory, skin, and eye irritation.

3.10. Personal protective equipment

Data were collected on the levels of personal protective equipment (PPE) worn by injured employees and responders (Table 8). Most injured responders were wearing firefighter turnout gear although some injured responders and employees wore Levels A or B. The most frequently reported injury among responders in turnout gear was respiratory irritation (108/204, 53%). Injured responders in Level A most frequently reported heat stress (68%), and injured responders in Level B most frequently reported chemical burns (63%). Three injured employees wearing Level A reported respiratory irritation (3), headache (2), dizziness/CNS symptoms (2), gastrointestinal problems (2), and eye irritation. Five injured employees wearing Level B reported respiratory irritation (2), dizziness/CNS symptoms (2), gastrointestinal problems (1), skin irritation (1), and chemical burns (2).

Data on injuries sustained among employees and responders wearing Levels A or B protection indicate that symptoms such as chemical burns and respiratory irritation could have been prevented by appropriate use of PPE. Other symptoms, such as heat stress and heart problems, may have resulted from the taxing demands of PPE. Symptoms caused by demanding circumstances such as high ambient temperatures can be prevented by appropriate medical screening and scene management. The surveillance system is unable to ascertain whether the avoidable symptoms, such as respiratory irritation or chemical burns, occurred because the PPE was worn incorrectly, was damaged or compromised or because it was removed prematurely. Other symptoms, such as dizziness and central nervous symptoms,

Table 8
Adverse health effects sustained by employees and responders wearing levels A or B protection, or firefighter turnout gear

	Type of personal protective equipment worn					
	Level A[a]	Level B[a]	Level A[b]	Level B[b]	FFTOG[b,c]	Total
Number of injured persons	3	5	19	8	204	239
Type of injury[d]						
Respiratory irritation	3	2		2	108	115
Headache	2				61	63
Trauma					57	57
Heat stress			13	1	37	51
Dizziness/CNS[e] symptoms	2	2			39	43
Thermal burns					37	37
Other[f]					35	35
Gastrointestinal problems	2	1			26	29
Heart problems			1		26	27
Skin irritation		1	4		13	18
Chemical burns		2	1	5	9	17
Shortness of breath					9	9
Eye irritation	1				6	7

[a] Category of victim: employee.
[b] Category of victim: responder.
[c] FFTOG, firefighter turnout gear.
[d] Some people sustained more than one type of injury.
[e] CNS, central nervous system.
[f] Other includes hypertension (31) and altered taste (4).

cannot be attributed a specific cause. These symptoms could have resulted from exposure to hazardous substances; from the demands of wearing PPE in stressful, taxing circumstances; from inadequate medical monitoring; or because the PPE was worn for excessive periods of time for the given site or weather conditions. The symptoms could also have been caused because personnel were tired, dehydrated or undernourished at the beginning of the response and were, therefore, more susceptible to developing related symptoms.

Conversations with both career and volunteer firefighters in New York State have revealed some reluctance to wear respiratory protection during all phases of firefighting. The reasons offered have included that respiratory protection impedes communication, sometimes in critical circumstances, and that it is not necessary except in the area of visible flames. The latter behavior is partly based on a sense of invincibility adopted by some older firefighters and transferred almost as tradition to newer members. Additionally, some firefighters have indicated a lack of understanding of the chemical hazards and the potential health effects of exposure to hazardous substances, particularly during the later stages of firefighting including "overhaul" when there is little or no visible smoke, or during HazMat events which may involve exposure to respiratory irritants but do not include combustion. Data support the need for respiratory protection [5,6] and more recent conversations indicate that the attitudes/behaviors are changing.

3.11. Decontamination

Decontamination (Table 9) in most events occurred on-scene (90%) and most frequently involved responders (77%). Although only 10% of victims (318/3120) received decontamination at a medical facility, the group decontaminated most often at a medical facility was the general public (34%). Emergency department staff need to be prepared and trained to provide decontamination for those rare events where persons exposed to hazardous substances may walk in and potentially contaminate hospital staff and/or equipment. Examples of such demanding events were the sarin attack in Tokyo in 1995 [7] and the attacks of 11 September 2001 in New York City and other US locations.

> A hose used to offload polyaluminum chloride overpressurized spraying the chemical in the immediate area. Three employees and the truck driver reported eye irritation and chemical burns. The three employees were decontaminated at the scene and transported to the hospital, treated, and released. None of the injured were wearing personal protective equipment which was in violation of company policy.

Table 9
Decontamination by victim category

Victim category	Location of decontamination		Total persons decontaminated[a]
	Scene	Medical facility	
Employee	337	89	426
Responder	2288	119	2407
General public	165	110	275
Student[b]	12	0	12
Total	2802	318	3120

[a] If a person was decontaminated at both the scene and a medical facility, that person was counted twice.

[b] Decontamination information for students was not collected until 2002.

4. Conclusions and recommendations

These results summarize the incidence and public health consequences of hazardous substance releases or threatened releases for 6428 events reported in New York State from 1993 to 2002. In terms of public health impacts, the data show the incidence and types of adverse health effects not only to the workforce (employees and responders) but also to non-workforce populations: the general public and students. Events occurred in residences or in other adjacent or nearby areas that may impact residential sites. Equipment failure and human error contributed to reported events in similar numbers, but human error was nearly three times more likely than equipment failure to result in injuries. During the period of this surveillance, the events with the highest number of injured people occurred in chemical manufacturing or in professional services. However, the percentage of events that involved injury in residences was more than double the percentage of events that involved injury in industries such as utilities and sanitation, chemical manufacture, or durable goods manufacture.

In addition to recording the number of evacuations and the loss of time from these disruptions, the data provide an estimate of the number of people decontaminated and thus the need for training and resources to accomplish this task. The data identify the chemicals and the chemical categories most frequently involved in reported events and document injuries to employee and responder populations, all of which can be used for activities such as occupational safety and health training, risk management planning, and emergency response training.

The findings that the highest number of events with injuries occurred in non-industrialized locations, such as indoor non-living spaces and residences, indicate the need to educate not only people who work in industrial facilities but also other audiences about the hazards of using chemical products and about the importance of following label instructions. These audiences include people in commercial and retail establishments, school staffs, students, and members of the general public. Particular emphasis should be given to using adequate ventilation, not mixing incompatible materials and wearing protective equipment such as gloves.

For workplace settings, these findings can provide the basis for future preventative measures in occupational safety and health. The summarized data can guide decision-making and the case studies can serve as the basis for discussions of lessons learned. To reduce the frequency and consequences of events, facilities can improve or install engineering controls in areas where highly hazardous chemicals are used or stored. These include measures such as automatic shut-off capabilities, automatic emergency shunting systems, liquid containment systems, automated or manual vapor entrapment systems, emergency panic buttons, ventilation, and remotely located control stations to reduce the potential for employee injuries or off-site migration of toxic or corrosive materials. Facilities can also review and improve existing equipment maintenance programs, particularly of piping systems that carry pressurized or corrosive chemicals.

In summary, these data substantiate the need for awareness training, education, planning, and preparedness activities in all types of locations (industrial, commercial, and residential) where hazardous substances are manufactured, used or transported. The data substantiate the need to educate people not only in the workforce but also in residential locations about the hazards of chemicals and about their proper use. Lastly, these data can and have been used to train and prepare responders for likely future events.

A drum of hydrochloric acid at a manufacturing facility was mislabeled as sulfuric acid. An employee added sulfuric acid to the mislabeled drum. As the sulfuric and hydrochloric acids began reacting, the employees noticed the bulging drum and ran. The drum exploded. Ten people were evacuated for 70 h until clean-up could be completed.

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