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Surveillance of hazardous substances releases due to system interruptions, 2002

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Abstract

The Hazardous Substances Emergency Events Surveillance (HSEES) system collected information on 9014 acute hazardous substance releases in 15 participating states in 2002. There were 3749 fixed-facility manufacturing events, of which 2100 involved "interruptions" to normal processing and 1649 "comparisons" that did not involve interruption. Equipment failure (69%) or intentional acts (20%) were the main root factor. Many events occurred in October and November in three states (Texas, Louisiana, and New Jersey), in three manufacturing industries (industrial and miscellaneous chemicals; petroleum refining; and plastics, synthetics, and resins). In interruption events, the substance categories most often released were mixtures, other inorganic substances, and volatile organic compounds and those most often causing injury were acids, chlorine, bases, and ammonia. Comparison events resulted in more acutely injured persons (408 versus 59) and more evacuees (11,318 versus 335) than interruption events and therefore may receive more public health attention. Because of the large number of interruption events, targeted prevention activities, including management of change procedures, lessons-learned implementation, process hazards analysis, and appropriate protection for workers could be economically advantageous and improve environmental quality. Efforts should focus on the identified areas of greater occurrence. The relationship of weather and equipment failure with interruption events needs further investigation.

Keywords: Hazardous substances; Chemical release; System interruption; Spill; Toxic spill

1. Introduction

The Hazardous Substances Emergency Events Surveillance (HSEES) system, established by the Agency for Toxic Substances and Disease Registry (ATSDR) in 1990, collects and analyzes information about acute releases of hazardous substances. An HSEES event is any acute hazardous substance release that needs to be cleaned up or neutralized according to federal, state, or local law. Threatened releases that result in a public health action, such as an evacuation, are also included in the system. A substance is considered hazardous if it might reasonably be expected to cause an adverse human health effect. Releases of petroleum only are excluded from HSEES. The overall goal of HSEES is to reduce the number of injuries and deaths experienced by first responders, employees, and the general public that result from acute hazardous substances events. This analysis looks specifically at fixed-facility HSEES events involving an interruption to normal chemical processing procedures in manufacturing industries. It compares interruption events with other HSEES fixed-facility events in manufacturing industries that do not involve interruption, comparison events, in an attempt to describe the problem and identify areas that can be targeted for prevention or investigated further.

2. Methods

In 2002, 15 participating State Health Departments (Alabama, Colorado, Iowa, Louisiana, Minnesota, Missouri, Mississippi, New Jersey, New York, North Carolina, Oregon, Texas, Utah, Washington, and Wisconsin) collected data on each hazardous substance release event. Data, including the location and industry involved in the release, factors contributing to the release, chemicals released, victim, injury, and evacuation information, were entered into the standardized web-based application maintained by ATSDR. A variety of sources (e.g., records and oral reports of state environmental agencies, police and fire departments, and hospitals) were used to collect information about the hazardous substances releases.

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For the analyses, we grouped the substances released into 14 categories: acids, ammonia, bases, chlorine, hetero-organics, hydrocarbons, mixture across categories, oxy-organics, pesticides, polychlorinated biphenyls, polymers, volatile organic compounds, other inorganic substances, and other substances. Mixture across categories consisted of chemicals from at least two different chemical categories mixed prior to release. If the mixture had components from the same category, we placed it in the component's category (e.g., a mixture of hydrochloric acid and sulfuric acid would be in the category acid). Other inorganic substances are comprised of all inorganic substances, except for acids, bases, ammonia, and chlorine, and included chemicals such as mercury and hydrogen sulfide. Oxy-organics consisted mainly of carbon monoxide, ethylene glycol (antifreeze), and alcohols; hydrocarbons consisted mainly of hydraulic and transformer oils and other oils. The "other" category consisted of chemicals such as asbestos and carbon dioxide that could not be classified into any one of the other 13 chemical categories.

We defined a "victim" as a person experiencing at least one documented injury. An "injury" is any adverse health effect (such as respiratory irritation or chemical burns) that likely resulted from the event and occurred within 24 h of the release.

Data from the HSEES system were analyzed to describe the characteristics of uncontrolled releases of chemicals during the manufacturing process due to system interruption, and to identify opportunities for preventive strategies. The HSEES system collects data on the root factor and the immediate contributing factor of an event. "Interruption" was considered any immediate contributing factor coded as either system or process upset, system start up or shutdown, system maintenance, or power disruptions. Excluded from this analysis were 173 events where the immediate cause of the event was unknown. Fixed-facility events that occurred in manufacturing industries (Standard Industrial Classification (SIC) 201-399) were classified as either "interruption" events or "comparison" events based on their immediate contributing factor. Descriptive statistics are presented for the number of events involving system interruptions, industry and chemicals involved in the releases, contributing factors of the releases, seasonality of the releases, types of victims, types of adverse health effects, severity and disposition of the victims, and evacuations.

3. Results

During 2002, HSEES captured 9014 events, of which 3904 happened in a manufacturing industry (Fig. 1). There were 100 transportation manufacturing events that were excluded, leaving 3804 fixed-facility manufacturing events. Of the 3804 there were 2100 interruption events and 1649 comparison events (55 events that did not specify a contributing factor were excluded).

3.1. Contributing factors

More than half ($n = 2100$, 55.0%) of the known immediate contributing factors in fixed-facility manufacturing events were attributable to interruption of normal chemical processing

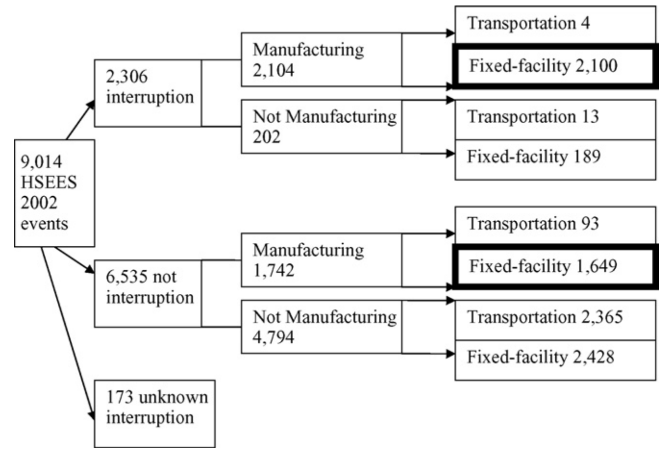

Fig. 1. 2002 Hazardous Substances Emergency Events Surveillance (HSEES) events involved in the analysis.

including: system or process upset ($n = 861$, 41.0%) (Table 1). The immediate contributing factor was reported for 540 (32.7%) of the comparison events (Table 1); equipment failure ($n = 235$, 43.5%) was most frequently cited. There was no immediate contributing factor in 1109 (67.3%) comparison events. The initial (root) factor in both system interruptions and comparison events was mainly equipment failure (69.0% and 74.4%, respectively). Other root factors of the system interruption events included intentional or illegal acts ($n = 341$, 20.2%), human error ($n = 90$, 5.3%), bad weather ($n = 758$, 4.4%), and other factors ($n = 17$, 1.0%). No root factor was listed for 411 events. Human error was the root factor in more comparison events (18.2%), while intentional acts was a root factor in less events (3.1%) compared with interruption events. Bad weather was cited as a root factor in 758 interruption events.

Table 1
Immediate contributing factors in interruption and comparison events, hazardous substances emergency events surveillance (HSEES) system, 2002

	No.	Percentage (%)
Interruption events		
Power disruptions	175	8.3
System maintenance	415	19.8
System/process upset	861	41.0
System start up and shutdown	649	30.9
Total	2100	100.0
Comparison events		
Equipment failure	235	43.5
Explosion	19	3.5
Fire	67	12.4
Forklift puncture	13	2.4
Human error	17	3.1
Illicit drug production related	14	2.6
Improper filling, loading, or packing	126	23.3
Improper mixing	21	3.9
Other	14	2.6
Unauthorized/improper dumping	14	2.6
Total[a]	540	99.9

[a] Percentages do not total 100% due to rounding.

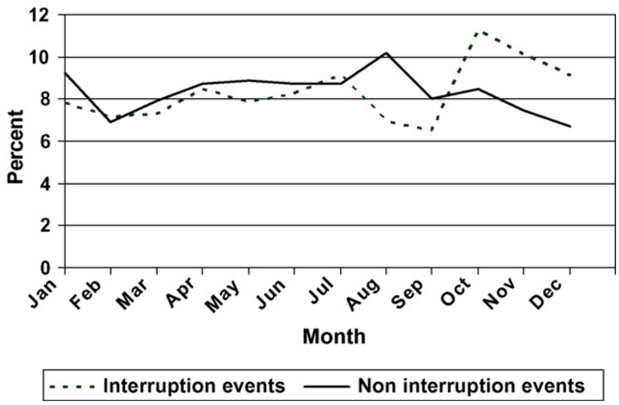

Fig. 2. Fixed-facility manufacturing industry system interruption events compared to not system interruption events by month, 2002.

When examining the weather conditions in the 2100 interruption events, of note were 20 events involving weather disasters and 16 involving lightening, mostly occurring in Texas or Louisiana.

3.2. Spatial and time distribution

Among the 15 participating states, the majority (93.4%) of interruption events occurred in Texas ($n = 1587$, 75.6%), Louisiana ($n = 314$, 15.0%), and New Jersey ($n = 60$, 2.9%). Texas, Louisiana, and New York had the most comparison events ($n = 1040$, 63.1%).

System interruption events peaked during October and November; comparison events peaked in the warmer month of August (Fig. 2).

3.3. Industry distribution

Most interruption events ($n = 1960$, 93.3%) occurred in three industry categories:

- SIC 281, 286, 289 industrial and miscellaneous chemicals manufacturing ($n = 839$, 40.0%),
- SIC 291 petroleum refining ($n = 717$, 34.1%), and
- SIC 282 plastic, synthetics, and resin manufacturing ($n = 404$, 19.2%).

These same three industries were the top industries involved in comparison events, but to a lesser percent ($n = 1033$, 62.6%).

3.4. Victim and injury distribution

There were 59 victims in 19 (0.9%) interruption events, compared with 408 victims in 92 (5.6%) comparison events. Employees were the most frequent victim category in both interruption events ($n = 43$, 72.9%) and comparison events ($n = 316$, 77.5%). One interruption event employee and two comparison event employees were trained responders. The remaining victim categories for interruption events were police officers ($n = 9$, 15.3%), followed by emergency medical technicians (EMTs) ($n = 6$, 10.2%, all injured in the same event), and the general public ($n = 1$, 1.7%). For comparison events the remaining victim categories were general public ($n = 72$, 15.4%), followed by professional and volunteer firefighters ($n = 19$, 4.7%), and a police officer ($n = 1$, 0.3%). Among both interruption and comparison events, the most commonly experienced adverse health effect was respiratory irritation; however, it was more frequent in interruption events ($n = 47$, 79.7% and $n = 178$, 43.6% of victims respectively) (Table 2).

In both interruption events and comparison events, most victims were treated or observed at a hospital and released ($n = 26$, 44.1% and $n = 265$, 65.6%, respectively). In interruption events, 15 (25.4%) were admitted to the hospital, 12 (20.3%) received first aid on scene, 3 (5.1%) were seen by a personal physician or had their adverse health effects reported by an official within 24 h of the event, and 2 (3.4%) died on scene. Both fatalities occurred

Table 2
Adverse health effects experienced during interruption and comparison events, hazardous substances emergency events surveillance (HSEES) system, 2002

Adverse health effect	Interruption		Comparison	
	No.	% of victims with adverse health effect[a]	No.	% with adverse health effect[a]
Burns	7	11.9	94	23.0
Dizziness/central nervous system effects	1	1.7	77	18.9
Eye irritation	10	16.9	52	12.7
Gastrointestinal problems	5	8.5	47	11.5
Headache	0	–	71	17.4
Heart problems	0	–	3	0.7
Heat stress	0	–	1	0.2
Other/unknown	0	–	14	3.4
Respiratory irritation	47	79.7	178	43.6
Shortness of breath	1	1.7	1	0.2
Skin irritation	2	3.4	30	7.3
Trauma	1	1.7	68	16.7
Total[b]	74	–	636	–

[a] Percentage calculated using 59 victims in interruption events and 408 victims in comparison events.
[b] Total greater than the number of victims because each victim could have more than one health effect reported.

Table 3
Chemicals released in system interruption and comparison events by chemical category, hazardous substances emergency events surveillance (HSEES) system, 2002

Chemical category	Interruption			Comparison		
	No.	Percentage (%)	% with victims[b]	No.	Percentage (%)	% with victims[b]
Mixture across categories	1024	42.7	0.3	312	14.9	2.9
Other inorganic substances	767	32.0	0.5	388	18.6	4.4
Volatile organic compounds	349	14.6	0.6	471	22.5	5.7
Pesticides	50	2.1	2.0	61	2.9	13.1
Oxy-organics	47	2.0	0.0	195	9.3	55.3
Ammonia	47	2.0	8.5	178	8.5	12.4
Other	22	0.9	0.0	74	3.5	10.8
Acids	21	0.9	19.0	125	6.0	15.2
Hydrocarbons	21	0.9	0.0	35	1.7	14.3
Polymers	13	0.5	0.0	61	2.9	8.2
Chlorine	12	0.5	16.7	56	2.7	3.4
Hetero-organics	11	0.5	9.1	36	1.7	5.6
Bases	10	0.4	15.4	59	2.8	8.5
Paints and dyes	2	0.1	0.0	32	1.5	9.4
PCBs and formulations	0	0.0	0.0	9	0.4	0.0
Total	2396	100.1[a]	0.9	2092[c]	99.9	11.5

PCBs = polychlorinated biphenyls.
[a] Percentages do not total 100% due to rounding.
[b] Calculated by dividing the number of events with victims for that category by the number of events in that category times 100.
[c] Does not include six substances that could not to be categorized.

in the same event involving a hydrogen sulfide release in a paper mill. There were 14 other victims in this event, including 8 employees and 6 EMTs who experienced secondary contamination from treating employee-victims. In comparison events, 60 (14.9%) received first aid on scene, 51 (12.6%) were admitted to a hospital, 10 were seen by a personal physician or had their adverse health effects reported by an official within 24 h of the event (2.5%), 8 (2.0%) were observed at a hospital without treatment, and 10 persons (2.5%) died (five on scene and five at the hospital).

3.5. Chemical distribution

A total of 2396 substances were released in the 2100 events caused by system interruptions. As many as nine chemicals were released per event, but most events involved the release of only one substance ($n = 1924$, 91.6%). In comparison events, there were 2098 substances released. The number of substances per event ranged from 1 to 119, with 91.0% having only one substance released.

The categories of chemicals most frequently released in interruption events were mixtures across chemical categories (42.7%), other inorganic substances (32.0%), and volatile organic compounds (14.6%) (Table 3). These same three categories were also the most frequently released in comparison events, but the distribution was different (14.9%, 18.6%, and 22.5%, respectively). In interruption events, acids, chlorine, and bases were the categories of substances most likely to result in events with victims (19.0%, 16.7%, and 15.4% of releases in their respective categories). However, in the comparison group, oxy-organics, acids, hydrocarbons, and pesticides were the categories most likely to result in events with victims (55.3%, 15.2%, 14.3%, and 13.1%, respectively). Only 0.9% of the substance releases in interruption events caused injury, whereas, 11.5% of the substance releases in the comparison events harmed humans.

When looking at individual substances rather than categories, sulfur dioxide, nitric oxide, nitrogen oxides (nitrogen oxide, nitrogen dioxide, oxides of nitrogen not specified), benzene, hydrogen sulfide, ammonia, butadiene, ethylene, carbon monoxide, and various mixtures containing these substances were the top substances released in interruption events. With the exception of ethylene, all of these substances (singly, not mixed) were also most frequently released in comparison events; additionally, sulfuric acid, chlorine, and fluorocarbon 22 were frequently released in comparison events.

The substance release type was “explosion” for none of the interruption events, compared to 17 comparison events.

3.6. Evacuation distribution

Evacuations were ordered in 13 (0.62%) interruption events, involving more than 335 people (median = 17.5 people, largest = 101 people). Evacuations were ordered in a greater percentage of comparison events ($n = 119$, 7.4%), requiring more than 11,318 people to be evacuated (median = 35 people, largest = 1500 people). Most of the evacuations in both interruption and comparison events were from a building or affected part of a building (69.2% and 77.8%, respectively). The evacuation status was unknown for 13 systems interruption and 42 non-system interruption events.

The percent of events with residences within 1/4 mile was lower for events involving interruptions than the comparison events: $n = 514$ (29.4%) versus $n = 478$ (36.8%). There were 349 interruption and 351 comparison events for which it was unknown whether there was a residence within 1/4 mile.

4. Discussion

In 2002, approximately a quarter of all HSEES events were interruption events. Fewer of the events involving interruption had evacuation or injury than the comparison group. One reason may be that many of these were planned releases above permitted quantities that generally occur through pollution control devices to the atmosphere and have no acute affects on public health. Another reason may be that there were no explosions in interruption events, compared with 17 during comparison events. Fewer of the interruption events (29.4% versus 36.8%) had residences within 1/4 mile, which may also account for some of this difference.

In interruption events, a large percentage of injuries occurred among workers and involved respiratory irritation. That points to a need to stress the importance of using appropriate respiratory protection in the workplace and taking extra safety precautions during system interruption situations, especially when working with acids, chlorine, and bases (the substances most likely to result in injury in interruption events). Interruption events predominately occurred in three states (Texas, Louisiana, and New Jersey) and three industries (industrial and miscellaneous chemicals manufacturing; petroleum refining; and plastic, synthetics, and resin manufacturing). Prevention efforts should focus on these states and industries. Such efforts should also target processes that involve mixtures of the most common substances released in interruption events (sulfur dioxide, nitric oxide, nitrogen oxides, benzene, hydrogen sulfide, ammonia, butadiene, ethylene, carbon monoxide). The large percent of mixtures, particularly those from different chemical categories, may allude to a chemical reactivity issue, or may just be the nature of mixtures involved in stack emissions. Areas for further investigation include equipment failure as the major root factor of the release and the reason for spikes in the cooler months of October and November. A more rigorous quantitative analysis of predictors of interruption events is also suggested. It should be noted that while HSEES makes an attempt to identify a root and contributing immediate cause for every release, it relies on preexisting sources for this information and this data may not be available or accurate, particularly at the early stages when the event is investigated. While follow-up attempts to gather better information are usually made, it may not become available before an event is finalized.

Several industry organizations representing the affected industries, including the American Chemistry Council (ACC) [1] and the Synthetic Organic Chemical Manufacturers Association (SOCMA) [2], have taken the initiative to promote voluntary safety measures to protect workers and the environment with their Responsible Care Program. The American Institute of Chemical Engineers, Center for Chemical Process Safety, has many free resources on its website to promote industry safety, including a free book on essential practices for managing chemical reactivity hazards [3].

The Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) Standard, if properly followed, would help to prevent many of these interruption events. However, PSM is only required in industries that store substances on the highly hazardous list over a specified amount [4]. Even if the PSM is applicable, it is not always properly followed. Five SIC codes (291, 281, 286, 289, and 282) stood out in the top three industries involved in events captured by HSEES where system interruption was an immediate contributing factor. Those were among the top nine most-often cited industries for violations of PSM standard during October 2002 through September 2003 [5].

Lastly, warnings from smaller incidents, near misses, or situations where some precursor conditions of an incident were present went unheeded [6]. In August 2001, the Chemical Safety and Hazard Investigation Board (CSB) published a safety bulletin on management of change. The bulletin recommends that all facilities have systematic methods for handling system changes, which should cover operational variances in addition to physical alterations [7]. This seems particularly relevant to interruption events because they often involve a system startup, shutdown, or maintenance activity. The CSB reviewed safety incidents involving maintenance and found that failure to evacuate material before performing maintenance, inadequate monitoring of conditions or lack of hazard recognition contributed to the releases. CSB concluded, “during the equipment preparation phase and the actual maintenance operations, hazards may exist in the equipment or in proximity to the maintenance work. Therefore, careful planning and monitoring should accompany any maintenance work scheme. Hazards should be identified in advance and a plan developed to proceed safely if precautions cannot be met. If, during the course of work, it is discovered that hazards may be present, it is important to stop work and conduct a hazards analysis” [8].

CSB also has issued a safety bulletin targeting oil and chemical facilities that were affected by Hurricane Katrina. Hurricanes are a particular problem in Texas and Louisiana, where there were more interruption events and more events caused by weather disasters. CSB recommendations for startup of processes, made in light of the three catastrophic incidents that CSB investigated that involved startup, include follow established startup procedures and checklists and carefully perform prestartup safety reviews; use appropriate management of change processes before modifying anything; make sure that adequate staffing and expertise are available beforehand; use up-to-date startup procedures and ensure that the staff are trained in them; evacuate non-essential personnel; and thoroughly evaluate equipment, tanks and instrumentation for damage prior to startup (see bulletin for details) [9]. The EPA also has a safety alert on hazardous substance release incidents caused by power outages that may assist in prevention for this type of release [10].

5. Conclusion

While many of the system interruption events have a lower chance of immediate harm to public health, as measured by the number of victims or evacuees, the sheer volume of these releases has associated economic costs and an effect on environmental quality. Improved management of change procedures, lessons-learned implementations, evaluation of near misses and low-level failures, process hazards analysis, and worker protection could help in preventing future events and their resultant pubic health consequences (injuries and evacuations) in the identified industries. Further investigation of the role of mixtures, weather, and equipment failure in these releases is needed.

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