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The role of adverse weather conditions in acute releases of hazardous substances, Texas, 2000–2001

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Abstract

High winds, flooding, lightning, and other phenomena associated with adverse weather can cause power failures, equipment damage, and process upsets resulting in chemical releases. Of the 5000 events in Texas that were reported to the Hazardous Substances Emergency Events Surveillance (HSEES) system during 2000–2001, adverse weather conditions contributed to 110 (2%) events. Rain was the most frequent adverse weather condition. Most events to which adverse weather conditions contributed occurred during June or September; these months correspond with the high temperature and hurricane season in Texas. Most events occurred in coastal counties with large numbers of industrial facilities. Three industries reported the majority of events: industrial and miscellaneous chemicals manufacturing; petroleum refining; and plastics, synthetics, and resin manufacturing. Power failures were associated more often with adverse weather-related events than with nonweather-related events. Releases occurred most commonly from ancillary process equipment and process vessels. Events associated with adverse weather-related conditions involved nine victims. System and process design improvements, such as improved backup power generation and redesigned secondary containment systems, could be explored to reduce the potential negative effects of severe weather.
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1. Introduction

Texas weather can be volatile. High winds, flooding, and lightning associated with adverse weather events such as tropical storms and tornados can cause power failures, equipment damage, and process upsets that result in the release of hazardous substances. The potential effect of weather on the release of hazardous substances was demonstrated dramatically during Tropical Storm Allison (STA). This storm battered Texas during June 5–9, 2001, causing severe flooding. Twenty-eight counties, including many of the heavily industrialized counties, were declared disaster areas [1]. During the storm, pilot lights were extinguished, power and equipment failed, and plants shut down. More than 200,000 pounds of chemical mixtures were released into the air. Heavy rains and flooding resulted in the release of more than 15,000,000 gallons of phosphoric acid and 850,000 gallons of sulfuric acid into the Houston Ship Channel. The flooding also resulted in the release of 1000 tons of urea fertilizer, 3600 gallons of ammonium nitrate fertilizer, and smaller quantities of various chemical mixtures consisting of substances such as alcohol, toluene, xylene, carbon tetrachloride, chloroform, and other halogenated solvents. One person received chemical burns while trying to remove a drum containing “Corrosive Liquid NOS” that flood waters had deposited in a relative’s front yard.

Most releases of industrial chemicals do not involve direct human exposure; however, when they do, the results can be catastrophic [2,3]. The unanticipated release of hazardous substances can negatively impact public health, resulting in injuries, fatalities, emergency decontaminations, in-place sheltering, or evacuations. Identifying the circumstances under which releases occur can help in developing processes to reduce the likelihood of future releases, improve plant safety, and reduce the likelihood of injuries. This article summarizes the characteristics of hazardous sub-

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stances releases in Texas associated with adverse weather conditions reported to the Agency for Toxic Substances and Disease Registry's (ATSDR's) Hazardous Substances Emergency Events Surveillance (HSEES) system during 2000–2001.

2. Methods

Since 1990, ATSDR has maintained an active, state-based surveillance system to describe the public health consequences of acute releases of hazardous substances. The surveillance system, known as HSEES, collects and analyzes data on acute releases of hazardous substances to prevent future events, reduce the public health impact of events, and provide information for improving preparedness efforts. The Texas Department of Health (TDH) has participated in this surveillance system since 1993.

Releases are eligible for inclusion in the HSEES system if they are uncontrolled or illegal and require removal, cleanup, or neutralization according to federal, state, or local law. Threatened releases also are included if they result in a public health action, such as an evacuation. Events involving only petroleum are excluded. TDH also applies a size criterion to all events meeting the surveillance definition. The quantity must be greater than 10 pounds or 1 gallon (unless the event involves a chemical whose Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) reportable quantity is 1 pound) [4].

A variety of sources were used to obtain information about events described in this paper. These sources included the National Response Center (NRC), the Texas Commission on Environmental Quality (TCEQ) (formerly known as the Texas Natural Resource Conservation Commission [TNRCC]), the U.S. Department of Transportation's Hazardous Materials Information System (HMIS) database, and run sheets from local fire department hazardous materials units.

For each event, information was collected about the type of event (fixed-facility or transportation-related); the industry involved in the event; substance(s) released (identity, chemical form, type of release, and quantity released); victim(s) including population group, type of injury sustained, medical outcome, demographics, personal protective equipment worn, and distance from the event; the type of area in which the event occurred; date and time of occurrence; numbers of people potentially affected; evacuations; response plans; and causal factors. Fixed-facility events included releases at industrial sites, schools, farms, or other permanent structures; while transportation-related events occurred during transport by surface, air, or water. Victims were defined as people with symptoms (including psychological stress) or injuries (such as respiratory irritation or burns) that probably resulted from the event and occurred within 24 h after the release. In addition, all victims were counted who died as a result of the event, regardless of the interval between event occurrence and death. HSEES records up to two factors identified as contributing to the cause of the release.

Data were submitted to ATSDR through a web-based data entry system. ATSDR provided quality assured/quality controlled data for analysis. Data were analyzed using SAS for Windows version 8 [5]. For analysis, substances were grouped into nine categories: acids, ammonia, bases, mixture across categories, paints and dyes, polychlorinated biphenyls, volatile organic compounds, other inorganic substances, and other substances. Mixture across categories consisted of chemicals that were mixed before release, including chemicals from more than one of the other eight chemical categories used. "Other inorganic substances" is comprised of all inorganic substances, except for acids, bases, and ammonia, and included chemicals such as mercury, carbon monoxide, and sodium hypochlorite. The "other" category consisted of chemicals such as asbestos, ethylene glycol, and styrene, that could not be classified into any of the other chemical categories.

Data for 2000–2001 were analyzed to describe events for which adverse weather conditions were a contributing factor (i.e., adverse weather-related events) in the release of hazardous substances. Adverse weather was defined as selecting either "bad weather conditions/natural disasters" or "factors beyond human control" as the causal factor. "Bad weather conditions/natural disasters" included heavy rain, snow/ice, fog, high winds, extreme temperatures, lightning, floods, tornados, hurricanes, earthquakes, and wild fires. The years 2000–2001 were chosen for analysis because "bad weather conditions/natural disasters" was not available as a choice until mid-2000. Before that, adverse weather conditions were included in "factors beyond human control"; this category also included other acts of God and animal interference. For events where "factors beyond human control" was selected, we checked responses to the question "What were the general weather conditions at the time of the event?" If the response was rain, snow, ice, sleet, fog, high winds, weather disasters, or extreme temperature and "factors beyond human control" was selected as the causal factor, we included the event in our analysis. Where appropriate, adverse weather-related events were compared with events for which adverse weather conditions were not a contributing factor (i.e., nonweather- related events) to determine whether any major differences existed between the two types of events.

3. Results

During 2000–2001, TDH reported 5000 acute hazardous substances events to the HSEES system; 4355 (87%) of the events occurred at fixed facilities and 645 (13%) were transportation-related. Adverse weather conditions were identified as a causal factor in 110 events (2% of all events). Of the 110 events, 103 (94%) occurred at fixed facilities and 7 (6%) were transportation-related. The most frequent type of adverse weather was rain ($n = 60$, 44%) followed by

Table 1
Types of adverse weather reported in events in which adverse weather conditions were a causal factor, Texas Hazardous Substances Emergency Events Surveillance (HSEES) system, 2000–2001

Type of adverse weather	Number	Percent
Rain	60	43.8
Weather disaster (flood, tornado, hurricane)	27	19.7
Lightning	21	15.3
High winds	13	9.5
Extreme temperature	12	8.8
Snow/sleet/ice	1	0.7
Fog	1	0.7
Unknown	2	1.5
Total[a]	137	100.0

[a] Total number of adverse weather conditions exceeds total number of events ($n = 110$) because up to two types of weather could be reported for each event.

weather disasters (flood, tornado, hurricane) ($n = 27$, 20%) (Table 1). The frequency of adverse weather-related events was highest during June and September. Nonweather-related events ($n = 4890$) did not occur more frequently during any particular month.

In addition to adverse weather conditions, power failure/electrical problems ($n = 27$, 25%) including power outage, short in equipment, and problems with an electrical device, such as a circuit breaker, also were identified as a major factor contributing to the releases. Equipment failure ($n = 26$, 24%) defined as failure of process or storage vessels, valves, pipes, pumps, or other types of equipment that allow the release of hazardous substances, and system/process upset ($n = 17$, 15%) including any glitch in the system that upsets the process, such as a chemical-related problem or an upset from a chemical reaction, were other major factors identified as contributing to the releases. Power failure/electrical problems were identified as a contributing factor in only 3% of nonweather-related events. Equipment failure (36%), system start-up and shutdown problems (13%), and human error (13%) defined as a mistake made by a person (such as leaving a valve open or inappropriate use of equipment) that results in a release or threatened release of hazardous substances were the most frequent causal factors in nonweather-related events.

For the 103 adverse weather-related events in fixed facilities, ancillary process equipment ($n = 58$, 56%), including any equipment besides the process vessel and piping used in making a product such as a compressor or pump, was the most common location within the fixed facility where the events occurred. Process vessel ($n = 17$, 17%), a chemical reaction chamber where chemicals are processed, blended to form a mixture, or reacted to convert them to some other product or form such as a tank or vat, and dump/waste area ($n = 12$, 12%) such waste sites at industrial facilities, municipal landfills, and sewer/storm drains where wastewater is dumped, also were major locations within the fixed facility where the events occurred. Nine (75%) of the 12 events in dump/waste areas involved secondary containment overflows or sinking of floating roofs on storage tanks. Ancillary process equipment (47%) and process vessel (20%) were also the most common locations for nonweather-related fixed-facility events; however, the third most common location for these events was piping (11%) which included any type of lines, tubing, joints, valves, and flanges.

Adverse weather-related events occurred most frequently in Harris ($n = 52$, 47%), Brazoria ($n = 10$, 9%), and Jefferson ($n = 9$, 8%) counties; nonweather-related events also occurred most frequently in these three coastal counties. These counties also have the most industrial facilities. Three industries were more likely to experience adverse weather-related events during the 2000–2001 reporting period: industrial and miscellaneous chemicals manufacturing ($n = 41$, 37%); petroleum refining ($n = 25$, 23%); and plastics, synthetics, and resins manufacturing ($n = 11$, 10%). Together, these three industries accounted for more than two-thirds of adverse weather-related events. These three industries also accounted for the same percentage of nonweather-related events during 2000–2001.

A total of 123 chemicals were released in the 110 adverse weather-related events. The number of chemicals released per event ranged from 1 to 6, but most events had only one chemical ($n = 104$, 95%) released. The category of chemicals most frequently released in adverse weather-related events was “other inorganic substances”, such as oxides of nitrogen ($n = 37$, 30%) (Table 2). Mixtures across chemical categories accounted for 32 (26%) releases. Benzene, butadiene, and oxides of nitrogen were components in several of the mixtures. Most releases were air emissions (55%) or spills (31%). The top chemical categories released and the types of releases were the same for nonweather-related events.

Nine people were injured in three adverse weather-related events (3% of all adverse weather-related events); a similar percentage of persons were injured in nonweather-related events. Eight people were members of the general public, and one was an employee. Seven persons reported gastroin-

Table 2
Number of chemicals released in events in which adverse weather conditions were a causal factor, by chemical category, Texas Hazardous Substances Emergency Events Surveillance (HSEES) system, 2000–2001

Chemical category	Number	Percent
Other inorganic substances	37	30.1
Mixture across chemical categories	32	26.0
Volatile organic compounds	26	21.1
Other substances	17	13.8
Acids	4	3.3
Ammonia	2	1.6
Polychlorinated biphenyls	2	1.6
Paints and dyes	2	1.6
Bases	1	0.8
Total[a,b]	123	99.9

[a] Total number of chemicals exceeds total number of events ($n = 110$) because more than one chemical was released in some events.
[b] Total percentage does not equal to 100 because of rounding.

testinal problems, one person reported trauma, and one person reported skin irritation. The person who experienced trauma was admitted to the hospital; the other injuries were experienced within 24 h of the event and reported by an official (e.g., fire department, emergency medical technician, police, or poison control center). Seven people were injured in one event caused by extreme temperature and fire in a petroleum refinery. A mixture of 70 pounds of mercaptan, alkyl sulfides, cyclic sulfides, alkyl disulfides, di-alkyl disulfides, and tetrahydrofuran was released in this event. An evacuation was ordered for 16 h for 30 people downwind of the release.

Two other evacuations were ordered in adverse weather-related events. One event resulted in evacuation of 600 people for 8 h after an overheated tanker truck threatened to release monoethanolamine; the overheating resulted from extreme temperature. The other event involved the evacuation of ten people from a medical center research laboratory that was flooded during TSA. This event involved the actual and threatened release of 30 gallons of halogenated solvent waste, 30 gallons of nonhalogenated solvent waste, and medical and biological wastes. The length of the evacuation was not reported.

4. Discussion

Adverse weather-related events were similar to nonweather-related events with respect to geographic distribution, location within the fixed facility where the releases occurred, industries, the most frequently released categories of chemicals, and the percentage of events involving victims. However, adverse weather-related events were more likely to occur in June or September, and nonweather-related events showed no temporal pattern. June and September coincide with hurricane season in Texas, and temperatures generally exceed 90 °F [6]. Several of the events in 2001 were related to TSA, and in 2001, Texas had above-average levels of precipitation [6]. Additionally, power failure/electrical problems were identified more often as a contributing factor in adverse weather-related events compared with nonweather-related events (25% versus 3%, respectively). Power failure/electrical problems can result from lightning, high winds, ice storms, or hot weather power demands [7]. In 2000, 240 chemical release incidents resulted from an electric power interruption [8].

The frequency of releases during adverse weather conditions highlights the need for improved systems and process operations. Redesigning secondary containment and storage tank floating roofs would be one step in preparing for torrential rains and flooding [9,10]. System and process design also needs to include better backup power generation in preparation for adverse weather conditions that trigger power failures and equipment failures [7]. Additionally, processes and equipment failure associated with power failure should be identified, maintained, tested, and kept in a ready-to-operate state [7]. Industry should consider directing more resources toward solutions to prepare for the negative effects of severe weather so costs can be reduced and injuries avoided.

The HSEES system is useful for collecting data regarding negative public health impacts caused by hazardous substance releases. However, there are limitations to the system. First, no legal mandate exists to report acute hazardous substance releases directly to the TDH HSEES system; therefore, not every qualifying release is captured. Still, HSEES captures more public health information about hazardous substances releases than any other federal database [11]. Second, the HSEES events presented in this article occurred only in Texas. However, the patterns and trends of hazardous substance releases and public health impacts may be similar to other states because Texas cover a large, diverse geographic area. Third, Texas does not collect information for events in which the hazardous substance released is <1 gallon or <10 pounds unless the substance is extremely hazardous. However, during 2000–2001, TDH HSEES investigated 5000 events and contributed 30% of the data for the entire HSEES system.

5. Conclusions

Adverse weather conditions occur regularly in some of the most industrialized areas of Texas. Whenever hazardous substances are released, the potential exists for negative public health impact. Nine people were injured in events where adverse weather contributed to the releases, and several hundred people were evacuated in these events. Additionally, acute chemical releases could potentially contribute to lost product, reduced employee productivity, injuries, and negative financial impacts. Industries, such as industrial and miscellaneous chemicals manufacturing, and geographic areas, such as Harris County, where there are a large number of adverse weather-related events could benefit from targeted design modifications.

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