

# Hazardous substances releases associated with Hurricanes Katrina and Rita in industrial settings, Louisiana and Texas<sup>☆</sup>

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## Abstract

The scientific literature concerning the public health response to the unprecedented hurricanes striking the Gulf Coast in August and September 2005 has focused mainly on assessing health-related needs and surveillance of injuries, infectious diseases, and other illnesses. However, the hurricanes also resulted in unintended hazardous substances releases in the affected states. Data from two states (Louisiana and Texas) participating in the Hazardous Substances Emergency Events Surveillance (HSEES) system were analyzed to describe the characteristics of hazardous substances releases in industrial settings associated with Hurricanes Katrina and Rita. HSEES is an active multi-state Web-based surveillance system maintained by the Agency for Toxic Substances and Disease Registry (ATSDR). In 2005, 166 hurricane-related hazardous substances events in industrial settings in Louisiana and Texas were reported. Most (72.3%) releases were due to emergency shut downs in preparation for the hurricanes and start-ups after the hurricanes. Emphasis is given to the contributing causal factors, hazardous substances released, and event scenarios. Recommendations are made to prevent or minimize acute releases of hazardous substances during future hurricanes, including installing backup power generation, securing equipment and piping to withstand high winds, establishing procedures to shutdown process operations safely, following established and up-to-date start-up procedures and checklists, and carefully performing pre-start-up safety reviews.

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## 1. Introduction

After crossing southern Florida and entering the Gulf of Mexico, Hurricane Katrina strengthened and struck southeastern Louisiana on August 29, 2005, as a Category 3 hurricane [1]. Hurricane Katrina, one of the worst natural disasters to ever strike the United States, resulted in an estimated 1336 deaths, numerous illnesses and injuries, and extensive damage [1–3]. Hurricane Rita was also classified as a Category 3 hurricane when it struck the Louisiana–Texas border on September 24, 2005 [4]. Although the impact from Hurricane Rita was not as severe as that from Hurricane Katrina, the approach of Hurri-

cane Rita generated one of the largest evacuations in US history; estimates exceed 2 million evacuees in Texas [4].

The scientific literature concerning the public health response to these unprecedented hurricanes has focused mainly on assessing health-related needs and surveillance of injuries, infectious diseases, and other illnesses [5–10]. However, the hurricanes also resulted in unintended hazardous substances releases in the affected states. Data from two states (Louisiana and Texas) participating in the Hazardous Substances Emergency Events Surveillance (HSEES) system were analyzed to describe the characteristics of hazardous substances releases in industrial settings associated with Hurricanes Katrina and Rita. Recommendations are made to prevent or minimize acute releases of hazardous substances during future hurricanes

## 2. Methods

HSEES is maintained by the Agency for Toxic Substances and Disease Registry (ATSDR). Since 1990, HSEES has col-

<sup>☆</sup> *Disclaimer:* The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Agency for Toxic Substances and Disease Registry.

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lected data on acute releases of hazardous substances and their associated injuries and evacuations. HSEES is an active, state-based surveillance system that enables identification of factors related to the public health impact of these acute events and promotion of activities to lessen the impact. A HSEES event is an uncontrolled or illegal acute release of any hazardous substance in any amount for substances listed on the HSEES Mandatory Chemical Reporting List. For substances not on the list, events are included if the amount released is  $\geq 10$  lbs or 1 gallon. Threatened releases of qualifying amounts are included if the threat led to an action (e.g., evacuation) to protect the public health. Events involving only petroleum are excluded. The Petroleum Exclusion clause of the CERCLA legislation excludes any forms of petroleum that have not been refined to the point of becoming single-chemical products such as pure xylene [11]. However, HSEES does record information about petroleum if it is released with a qualifying substance.

State health department personnel used a variety of sources (e.g., records and oral reports of state environmental agencies, police and fire departments, and hospitals) to collect information about the acute hazardous substances events. Data were entered into a Web-based application that enabled ATSDR to instantly access the data. Information collected for each event included the location and industry involved in the event, hazardous substances released, number of victims, evacuations, and contributing causal factors for the event. Information on contributing causal factors was either reported by the notification source or determined by the state HSEES coordinator using various reports.

The 2002 North American Industry Classification System (NAICS) was used to categorize the industries [12]. A victim is defined as a person experiencing at least one documented adverse health effect (such as respiratory irritation or chemical burns) that was likely associated with the event and occurred within 24 h after the release.

For the analyses, the hazardous substances released were grouped into 13 categories: acids, ammonia, bases, chlorine, hetero-organics, hydrocarbons, mixture across categories, oxy-organics, pesticides, polymers, volatile organic compounds (VOCs), other inorganic substances, and other substances. Mixture across categories consisted of hazardous substances that were mixed before release, including hazardous substances from more than one of the other 12 categories used. The category “other inorganic substances” comprised all inorganic substances—except for acids, bases, ammonia, and chlorine—and includes hazardous substances such as nitrogen oxide and hydrogen sulfide. The “other” category consisted of hazardous substances, such as asbestos, that could not be classified into any of the other 12 categories.

Fifteen states participated in HSEES in 2005: Colorado, Florida, Iowa, Louisiana, Michigan, Minnesota, Missouri, New Jersey, New York, North Carolina, Oregon, Texas, Utah, Washington, and Wisconsin. Data from two states (Louisiana and Texas) were analyzed to describe the characteristics of hazardous substances releases associated with Hurricanes Katrina and Rita. Events were identified as hurricane-related based on

state reports. Events were restricted to the following NAICS codes because the focus of this analysis was releases in industrial settings: 21 Mining, 22 Utilities, 23 Construction, and 31–33 Manufacturing. Descriptive statistics are presented including contributing causal factors, hazardous substances and industries involved in the releases, release type, amount of hazardous substance released, and event scenarios.

### 3. Results

A total of 166 hurricane-related events occurred in industrial settings in Louisiana and Texas in 2005; 131 (78.9%) events occurred in Texas and 35 (21.1%) occurred in Louisiana. These events represented 5.2% of all HSEES events in Louisiana and Texas in 2005. Most (74.7%) of the events occurred in September; 13.3% were in October and 12.0% were in August. Twenty-five (15.1%) events were related to Hurricane Katrina and 140 (84.3%) events were related to Hurricane Rita. One (0.6%) event was related to both hurricanes and occurred when a third-party clean-up contractor caused a release while cleaning up after both hurricanes. All of the Hurricane Katrina-related events occurred in Louisiana, and 93.6% of the Hurricane Rita-related events occurred in Texas.

Hurricane-related events in industrial settings involved the manufacturing (151 [91.0%]), mining (11 [6.6%]), utilities (3 [1.8%]), and construction (1 [0.6%]) industries. Chemical manufacturing (115 [76.2%]) and petroleum and coal manufacturing (34 [22.5%]) accounted for most of the manufacturing events.

#### 3.1. Contributing causal factors

The most common immediate contributing causal factor was system start-up or shutdown (120 [72.3%]) (Table 1). Of the 120 events where system start-up or shutdown was an immediate contributing causal factor, 6 (5.0%) were shutdowns in preparation for Hurricane Katrina, 59 (49.2%) were shutdowns in preparation for Hurricane Rita, and 55 (45.8%) were start-ups after Hurricane Rita.

Table 1  
Immediate contributing causal factors in events related to Hurricanes Katrina and Rita in Louisiana and Texas, Hazardous Substances Emergency Events Surveillance (HSEES) System, 2005

Immediate causal factors	No.	%
Equipment failure	17	10.2
Fire	2	1.2
Human error	1	0.6
Improper filling, loading, or packing	2	1.2
None	10	6.2
Other	1	0.6
Power failure	6	3.6
System/process upset	7	4.2
System start-up/shut down	120	72.3
Total <sup>a</sup>	166	100.1

<sup>a</sup> Percentages do not total 100% due to rounding.

Table 2

Category of hazardous substances released in events related to Hurricanes Katrina and Rita in Louisiana and Texas, Hazardous Substances Emergency Events Surveillance (HSEES) System, 2005

Hazardous substances category	No.	%
Mixture across categories	95	48.2
Volatile organic compounds	42	21.3
Other inorganic substances	31	15.7
Ammonia	7	3.6
Other	5	2.5
Pesticides	4	2.0
Hydrocarbons	3	1.5
Acids	2	1.0
Chlorine	2	1.0
Oxy-organics	2	1.0
Polymers	2	1.0
Hetero-organics	1	0.5
Bases	1	0.5
Total <sup>a</sup>	197	99.8

<sup>a</sup> Percentages do not total 100% due to rounding.

### 3.2. Hazardous substances

A total of 197 hazardous substances were released in the 166 hurricane-related events. The number of hazardous substances released per event ranged from 1 to 8, but in most events ( $n=155$ , 78.7%), only one hazardous substance was released. The categories of hazardous substances most frequently released in these events were mixture across categories (48.2%) and VOCs (21.3%) (Table 2). The most frequently released individual hazardous substances were nitrogen oxide (10 [5.1%]) and a mixture of carbon monoxide, nitrogen dioxide, and propylene (8 [4.1%]) (Table 3). Most releases were air releases (91.4%); 8.1% were spills, and 0.5% involved both an air release and a fire. The amount of hazardous substances released ranged from less than one pound to 501,200 pounds (median = approximately 1000 pounds; mean = approximately 17,000 pounds). Almost a third (29.2%) of releases were between 1000 and 9999 pounds. The amount released was unknown for 19 (9.6%) hazardous substances.

Table 3

Individual hazardous substances released in five or more events related to Hurricanes Katrina and Rita in Louisiana and Texas, Hazardous Substances Emergency Events Surveillance (HSEES) System, 2005

Hazardous substance	No.	%
Nitrogen oxide <sup>a</sup>	10	5.1
Mixture: CO/NO <sub>2</sub> /propylene	8	4.1
Mixture: benzene/butadiene/CO/NO <sub>2</sub> /VOCs	7	3.6
Ammonia	7	3.6
Sulfur dioxide	7	3.6
Benzene	6	3.1
Mixture: CO/ethylene/NO <sub>2</sub>	6	3.1
Asbestos	5	2.5
Ethylene	5	2.5
Nitric oxide	5	2.5

<sup>a</sup> Includes nitrogen oxide, nitrogen oxides, oxides of nitrogen, NO<sub>x</sub>.

### 3.3. Response

The personnel responding to events were most frequently the company's emergency response team (127 [76.5%]). Third-party clean-up contractors responded in 2 (1.2%) events, and no one responded in 37 (22.3%) events. One event required response from law enforcement, a fire department, and a department of public works in addition to the company's response team. Environmental sampling was conducted in 7 (4.2%) events.

### 3.4. Events involving nearby populations, evacuations, and victims

In six (3.6%) events, the plume extended beyond the facility. In one event, a power failure caused by Hurricane Katrina at a nitrogen fertilizer manufacturer resulted in a loss of refrigeration to ammonia storage tanks causing an emergency release of ammonia to a flare. However, the ammonia was only partially combusted by the flare. Approximately 980 pounds of ammonia were not combusted and released and 490 pounds of oxides of nitrogen were released in this event. In another event, 759 pounds of zinc bromide were released from storage tanks that were washed away from an oil and gas support operation during Hurricane Katrina. Ten pounds of nitrogen oxide and 500 pounds of sulfur dioxide were released when a petroleum refinery shut down its plant in preparation for Hurricane Katrina. A chemical product and preparation manufacturer released 270 pounds of ammonia and 75 pounds of nitrogen oxides when the ammonia storage tank routed to the flare after the compressors were shut down. Seven hundred eighty pounds of ammonia were released from a nitrogen fertilizer manufacturer when a power outage caused the loss of key monitoring equipment. The flare on the ammonia tank was blown out by the high winds sustained during Hurricane Rita. These events occurred in industrial areas, and not near residences, nursing homes, schools, or day cares.

Because of Hurricane Rita, 1082 pounds of chlorine were released from an alkali and chlorine manufacturing plant when a power failure caused excess pressure in the chlorine tank. The tank had to be manually vented to reduce pressure and protect the tank integrity. Approximately 493 persons lived within 1/4 mile, and a licensed daycare center was within 1/4 mile of the release; no information was available about whether anyone was at home or in the daycare center when the release occurred.

One (0.6%) building was evacuated because of hurricane-related events; the evacuation lasted 2 h. One employee was injured in a hurricane-related event. The employee was injured while opening a valve with an air-operated device during a shut-down of a polyethylene resins manufacturing plant. The pressure released with a mixture of benzene, butadiene, carbon monoxide, and VOCs caused the employee to flip over and hit her head on the grating.

## 4. Discussion

HSEES recorded 166 hurricane-related events in industrial settings in Louisiana and Texas in 2005. Texas did not have

any Hurricane Katrina-related events because of the path of the hurricane. Texas reported most of the Hurricane Rita-related events because Beaumont and Port Arthur, as well as several other areas in the state, shutdown their plants in preparation for Hurricane Rita; Louisiana reported less events from Hurricane Rita because of the path of the hurricane and many of their plants were still not operating when Hurricane Rita struck. Most events occurred in the manufacturing industry (91.0%), and the immediate contributing causal factor in most (72.3%) of these events was system start-up or shutdown. Most releases were air releases (91.4%), and the category of hazardous substances (21.9%) most frequently released was mixtures. HSEES only recorded one injury associated with hurricane-related events in industrial settings. This is likely because most facilities were already shut down when the hurricanes hit and were operating with reduced crews. Also, many people evacuated the areas before the hurricanes hit [1,4].

Almost 40% of the events were caused when complex industrial processes were shutdown in preparation for the hurricanes. The shutdowns that resulted in preparation for Hurricanes Katrina and Rita were more massive and involved numerous simultaneous activities and rapidly changing process conditions compared with one process or unit during normal shutdowns. Additionally, these large massive shutdowns had not been done before. There is a need for different shutdown procedures that involve massive shutdowns of entire plants, such as those that occur during hurricanes. One lesson learned from Hurricanes Katrina and Rita is that it is critical for chemical facilities to better coordinate with state and local emergency preparedness agencies, especially for decisions concerning mandatory evacuation orders which can directly impact plant shutdown sequence and timing [13]. The U.S. Environmental Protection Agency (EPA) advises that all industry sectors review past events associated with shutdowns during hazardous weather conditions and make administrative/procedural, operational/process equipment and hardware/software safety improvements as needed [14]. Chemical facilities should also establish staff responsibilities and procedures to shutdown process operations safely [15].

About a third of the events were caused when major industrial processes started up after the hurricanes. The startups that occurred following the large massive shutdowns in preparation for the hurricanes were also large-scale. Many plants also used this opportunity to conduct massive maintenance or repairs on the shutdown plants which resulted in releases. Additionally, releases are more likely to occur when processes are shutdown for more than one day, and equipment in some facilities in Texas dates back to the 1940s. The U.S. Chemical Safety and Hazard Investigation Board (CSB) issued a safety bulletin for precautions needed during oil and chemical facility start-up following hurricanes [16]. CSB recommends that as facilities resume operations, established and up-to-date start-up procedures and checklists should be followed and pre-start-up safety reviews should be carefully performed. Specific recommendations include using appropriate management-of change (MOC) processes before making any modifications; having adequate staffing and expertise available before starting up; and evacuating nonessential personnel from nearby process units that are

starting up. CSB also recommends that equipment, tanks, and instrumentation be thoroughly evaluated for damage. Particular attention should be given to examining large bulk storage tanks and pressure vessels for evidence of floating displacement or damage, and examining sewers, drains, furnace systems, electric motors and drives, switchgear, conduit, electrical boxes, electronic and pneumatic instrumentation, emergency warning systems, emergency equipment, and insulation systems for piping, vessels, and tanks for trapped floodwater and debris-impact damage.

Releases resulting from power failures may benefit from improved backup power generation [17]. Generators and backup lights should be tested in preparation for a hurricane, extra fuel should be on-hand, and generators should be located in areas of the facility that are not likely to be flooded [18]. Other efforts include filling all storage tanks to prevent floating or falling during hurricane-force winds, adequately securing equipment and piping to withstand high winds, and properly labeling all chemical bulk storage tanks to aid identification if these items are washed or wind-blown away [18].

Although HSEES tries to identify contributing causal factors for every release, it relies on preexisting sources for information and these data may not be available or accurate, particularly at the early stages of the event investigation. Data are reported according to general categories so that data can be aggregated and analyzed to observe trends and make general conclusions. A more in-depth analysis of causal factors would require more specific data to be collected. Local and state public health and emergency response infrastructure was severely disrupted by the hurricanes; therefore, some events may not have been reported and some data may not have been captured during follow-up. In Louisiana, agencies were only notified about major releases that resulted from Hurricane Katrina. Furthermore, HSEES collects information on acute, not chronic, releases, and releases of only petroleum are excluded.

## 5. Conclusion

Because preventing hurricanes is not possible, attention must be focused on preventing and minimizing acute releases of hazardous substances when hurricanes make landfall. Industries should consider acquiring backup power generation, securing equipment and piping to withstand high winds, establishing staff responsibilities and procedures to shutdown process operations safely, following established and up-to-date start-up procedures and checklists, and carefully performing pre-start-up safety reviews to prevent or minimize acute hazardous substances releases during future hurricanes.

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