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A release of nitrogen oxides in Bogalusa, Louisiana and similarities of causation to the Bhopal MIC release[☆]

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Abstract

The causes of a release of nitrogen oxides and nitric acid that occurred in Bogalusa, Louisiana in 1995 resembled those of the MIC release in Bhopal, India. The initiating event in both accidents was the entry of water into a storage vessel, which started a series of chemical reactions. An analysis of the underlying causes of these accidents shows some striking similarities (e.g. large quantities of a toxic chemical in storage, lack of instrumentation, inadequate mechanical systems, inadequate operating and maintenance procedures). Further, in both incidents a similar pattern of previous incidents, ignored warnings and ignored safety recommendations existed. Several layers of administrative and engineering options that could have prevented or mitigated these incidents are discussed. It is hoped that the identification of recurring root and contributing causes will help to prevent future accidents. © 2001 Published by Elsevier Science Ltd.

Keywords: Accident; Accident prevention; Recurring causes; Nitrogen tetroxide; Bogalusa

1. Introduction

Many chemical companies in US have adopted codes and standards above and beyond the ones required by regulations to assure that their operations are safe. Other facilities operate without sufficient regard to health, safety and the environment, so that accidents recur, caused by the same underlying problems.

This paper analyzes an incident involving the atmospheric release of a large mass of nitrogen tetroxide and nitric acid vapors, that occurred in Bogalusa, Louisiana in 1995. The focus is on what went wrong and how the incident could have been prevented, if controls and procedures had been effective, if emergency preparedness and response was adequate, and if regulatory requirements and industry standards were implemented. Similarities in the causation of the accident at Bogalusa with that of the accident at Union Carbide, Bhopal, are outlined. Such common causes included poor understanding of the hazards presented in the facility, large quantities of a toxic chemical in storage, lack of instrumentation, inadequate mechanical systems, inadequate safety and operating procedures, and lack of implementation of process safety recommendations. By bringing the underlying causes of various accidents to light, and by comparing them, recurring causes are identified. It is hoped that by identifying recurring root and contributing causes, future accidents can be prevented.

2. Description of the incident

On 23 October 1995 in a chemical facility in Louisiana, a railcar tank exploded and ruptured, releasing a large mass of nitrogen tetroxide (N_2O_4), nitrogen dioxide (NO_2), and nitric acid (HNO_3) vapors in the atmosphere (NTSB, 1997).

The N_2O_4 in the railcar tank had become contaminated with water, and the resulting reactions formed corrosive HNO_3. The acid corroded and shortened the offloading dip tubes and also may have thinned the walls of the tank. Following emergency procedures, on-site personnel tried to unload the contaminated liquid into cargo

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tanks. Not being aware of the damage to the dip tubes, they thought that they unloaded most of the contaminated liquid when, in reality, they had just unloaded vapors; most of the mass remained in the rail car tank. In the following two days, company employees purged the tank with water, causing more HNO_3 to form and increasing the pressure in the tank. At some point, a relief valve burst open and N_2O_4/ HNO_3 vapors were emitted directly into the atmosphere for about 45 min. Then, the tank ruptured at one end, creating a large dark-brown cloud almost instantly. The cloud slowly dispersed towards the direction the wind was blowing; its remains could be seen for up to 36 h after the tank had ruptured. Exposure to the cloud of material expelled by the blast caused chemical burns to some facility personnel and firefighters who were responding to the leak. Several local, state, and federal agencies responded to this emergency. Approximately 3000 people were treated at local hospitals, and 981 were admitted.

In the following section, I discuss what mistakes caused this release, the risk the release presented to employees and the public, and how the release could have been prevented.

3. Organizational failures

In my view, this incident can be attributed to organizational shortcomings from the companies owning, supplying, using, and transporting the railcar with the nitrogen tetroxide load. These companies failed in: providing safety systems, adequately training their employees, enforcing safe operating and maintenance procedures, and conducting inspections to detect abnormal conditions.

3.1. Lack of understanding of the characteristics and hazards of N_2O_4

The owner of the facility and the owner of the railcar tank lacked awareness on the hazards posed by N_2O_4, as evidenced by at least three facts:

- Company personnel were routinely spraying water on the railcar tank leaking valves, not realizing that water could eventually get into the tank and react with N_2O_4.
- Company personnel unloaded N_2O_4 to cargo-tanks with Hypalon™ gaskets, which were inadequate and, therefore, were quickly destroyed by the corrosive chemical.
- The owner of the tank car had retrofitted it for N_2O_4 use, after its previous use in chlorine transportation, without performing a hazard analysis. Also, inadequate materials were used for retrofitting.

3.2. Lack of procedures/not enforcement of procedures

The following are examples of the unavailability of procedures or not sticking with safe operating procedures:

- Having a single employee unload a hazardous material from the railcar, although the company's standard loading procedures specified a buddy operation.
- Lacking a checklist for unloading and transferring N_2O_4.
- Failing to keep logs of unloading/transfer operations
- Spraying water on the tank to absorb/disperse leaks of N_2O_4.
- Not taking samples for chemical analysis from the railcar tank at supplier's facility as required, but from the bulk storage tank.

3.3. Lack of training

- All employees interviewed had no formal courses on unloading tank cars; they only had "on-the-job" training.
- There were no records of emergency drills.
- Nobody considered activating the emergency alarm.

3.4. Lack of basic process/storage safety systems

- A 30-year-old tank in poor condition was used for transfer of N_2O_4.
- The railcar tank had neither liquid-level gauges nor pressure gauges.
- There was no capability for chemical analysis of N_2O_4 on site.

3.5. Lack of emergency preparedness

- There was no emergency de-inventory vessel, although the need for one was identified in 1989.
- There was no pollution control equipment for treating releases from pressure relief valves. There was a scrubber with a capacity of ~50 cfm, used for normal operation venting from the storage tank, but this could not handle emergency releases.
- There was no water-deluge mitigation system; only one fire-monitor was available at the scene.
- The safety committee's recommendations to improve emergency communications, emergency response and training, plant procedures and equipment, were not implemented. The specific recommendations were: (i) purchase emergency response equipment; (ii) provide emergency storage for rapid de-inventory; (iii) install

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a water-deluge system for N_2O_4; (iv) test storage tank every three years; and (v) replace the N_2O_4 tank with a stainless-steel one.
- A Hazard and Operability study (HAZOP) carried out in 1994, identified the risk of water intake into the N_2O_4 tank but nothing was done to prevent it.
- A consultant's recommendation to develop a Fault Tree Analysis (FTA) for toxic releases from the tank car, storage tank and pipe lines, was ignored.

3.6. Inadequate emergency response

The company did not have an Emergency Response Program (ERP) to mitigate the consequences of major leaks in the facility. They elected to rely on outside responders for emergency response and have only an Emergency Action Plan (EAP). However, as shown from the following, operators were not trained to follow an EAP.

- Company personnel responded to the incident without donning Personnel Protective Equipment (PPE).
- Workers who had been evacuated initially were allowed to return and respond to the leak without wearing proper PPE.
- Employees were allowed to remain near the area of the leak without donning special PPE.
- There were no assigned duties during evacuation.
- There was no clear command for emergency action (according to the chief of the local Fire Department).
- The company had not issued incident-command vests or other identifiers for people in charge of the emergency operation.
- According to Fire Department reports: "Company guys seemed unorganized and ill prepared". "Company guys seemed shocked and helpless; obviously not adequately trained in emergency procedures".
- The local Fire Department was not given prompt information as to what was spilled and how dangerous it was.

3.7. Previous incidents

The 23 October 1995 major release did not happen without previous warnings. In that year alone, 20 incidents that produced small leaks were reported.

Most incidents happened during N_2O_4 transfer-operations and produced relatively minor releases of N_2O_4 and a visible plume from the scrubber. Contract personnel expressed concern about working around N_2O_4 areas where daily puffs were occurring. Workers for the construction contractor on site were exposed to N_2O_4 fumes on 16 October 1995. One employee was hospitalized and was diagnosed as having chemical burns to his lungs and throat.

3.8. Ignored internal recommendations

This is a list of safety improvements, recommended by the facility's safety personnel and an outside consultant, that were not implemented.

- Change valves and rotameter.
- Undertake a preventive maintenance inspection of the pressure relief valve.
- Conduct vapor cloud dispersion analysis to estimate the potential impact of several different leaks.

Also, a HAZOP team recommended the following items on 8/14/94, which were not implemented:

- Take extreme care at all times to avoid putting water into the storage tank or rail car.
- Remove the water connections from the N_2O_4 tank or the railcar. Getting water in them is the leading potential cause for a major failure of one of these vessels.
- Review unloading procedures. They do not meet OSHA Standard 29 CFR 1910.119 requirements for operating procedures.
- Provide a vessel to unload N_2O_4 from the storage tank in an emergency.
- Install a new emergency-handling scrubber in case the storage tank needs to be purged; the current scrubber is undersized.
- Review emergency equipment, procedures, and training.
- Conduct annual emergency drills.
- Purchase a stainless-steel tank for storage of N_2O_4.

3.9. Ignored warnings

The addition of water in the railcar tank constituted the accident-initiating event because it triggered the formation of corrosive nitric acid that ultimately caused the tank's failure. As discussed later in Section 5, the release still could have been prevented if subsequent warnings were understood. There were symptoms indicating a problem with the dip legs when transferring the chemical from the rail tank to the cargo tanks, but they were ignored.

A worker failed to reduce pressure enough to the N_2O_4 storage tank to replace the dip legs. An internal memo stated: "Dip tube may be corroded, seems at half level getting vapors instead of water".

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4. Similarities of causes of the Bogalusa and the Union Carbide/Bhopal accidents

In this section, the similarities of the causes of the Louisiana incident and the Union Carbide/Bhopal tragedy are outlined, to illustrate two points: (i) Unfortunately, safety awareness in some American chemical facilities is at that low level observed in developing countries eleven years ago; and (ii) the release at the Louisiana facility had the potential to cause dire consequences. Fortunately, these were avoided mainly because there were no people out in the streets around the plant when the release happened.

4.1. The Bhopal accident

The worst accident in recent records involving a chemical release happened on 3 December 1984, when methyl isocyanate (MIC)-vapor leaked from a Union Carbide Corporation plant in Bhopal, India. The vapor spread over an area of five square-miles, killed at least 2500 people, and injured 200,000. The accident-initiating event was the entry of water in a MIC storage tank which triggered a violent chemical reaction. As the reaction of MIC with water greatly increased the temperature in the tank, chloroform which was present at abnormally high levels released chloride ion, which rapidly corroded the tank. The iron from the corrosion (or from earlier cross-contamination) catalyzed the trimerization of MIC, thereby producing CO_2, and increased both the temperature and pressure in the tank. The CO_2 evolved from the reaction caused further mixing of the chemicals which, with the rise in temperature, accelerated both reactions; finally, the build-up of pressure burst the rupture disk in the line to the relief valve. The valve was open for about 2 h, during which most of the material in the tank, about 90,000 lb, was released to the environment as vapor (Fthenakis, 1993).

4.2. Similarities of the Bhopal and Bogalusa accidents

- The quantity of MIC involved in the Union Carbide accident (i.e. 90,000 lb) was similar to the quantity of N_2O_4/HNO_3 (estimated to be 99,933 lb) in the Bogalusa release. Both materials are toxic and are potentially harmful in very low concentrations. MIC has an immediately Dangerous to Life or Health (IDLH) concentration of 3 ppm, NO_2 of 20 ppm, and HNO_3 of 25 ppm.
- The source of water in Bhopal is still controversial. However the most likely scenario is associated with inadequate procedures for cleaning pipes. Inadequate procedures for dispersing small leaks of NO_2 (e.g. spraying water directly on the tank), also is the likely cause for water entering the N_2O_4 tank and initiating the event. The company's standard loading procedures prescribed a water-hose to wash away any liquid spills. However, the hose was occasionally used on the tank valves to disperse vapor leaks.
- The Bhopal plant's staff did not monitor the tank for chloroform for six weeks before the accident, although daily monitoring was required. Personnel at the Louisiana facility did not adequately monitor the transfer of N_2O_4, nor did they monitor the tank's contents for water contamination.
- In both cases there were previous warnings. From December 1981 to October 1982, there were at least five incidents, some resulting in injuries, at the Union Carbide plant. In May 1982, a team of American experts from Union Carbide inspected the plant and was extremely critical of its operation. It seems that the team's recommendations were not implemented.
- There were 20 reportable releases in the Louisiana facility plant in 1995 before the major leak. Several recommendations by the company's safety officials and an outside consultant to improve the safety of the facility were not implemented.
- There were five safety systems at the Bhopal plant, but they were not operational or did not function as expected. A flare tower was disconnected, a scrubber was grossly underdesigned, and a water deluge system was inadequately designed.
- No adequate safety systems were available in the Louisiana facility. There was a scrubber connected with the permanent storage tank but the railcar tank (also used for storage) was not connected with the scrubber. In any case, the scrubber was underdesigned for pressure relief discharges from either the storage or the railcar tanks. Regarding water deluge, there was only one spray-monitor in the Bogalusa facility, instead of a complete system with monitors encircling the tank.
- The lack of adequate planning for emergency preparedness and response raised the death and injury toll in Bhopal, because people ran in panic, often in the direction of the release, did not use simple protective measures against short-time exposure (e.g. a wet towel on the face), and there were not sufficient means of evacuation.
- Fortunately, in Louisiana, there were no people out in the streets around the plant when the release happened, and this prevented fatalities. The lack of adequate emergency planning, however, caused injuries to fire-fighters and toxic exposures to plant personnel and the public.

5. How the accident could have been prevented or controlled

Several engineering and administrative options could have prevented or controlled the N_2O_4 release at the

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Louisiana facility. These are shown in Fig. 1, and outlined below:

1. Inherently safer processes, materials, and procedures.
2. Options to prevent accidental initiating events.
3. Safety systems to prevent or minimize releases.
4. Options for control/mitigation.
5. Emergency preparedness and response plans, and procedures to prevent or reduce human exposures.

5.1. Inherently safer materials and processes

The potential consequences of N_2O_4 releases can be reduced by using smaller transfer containers. Another option was to use a stainless-steel tank, manifold and valves and adequate packing as the US Air Force[1] does.

5.2. Prevent accident initiating events

Administrative and engineering options to prevent an accident initiating event (e.g. entry of water in the tank) include operating procedures, worker training, maintenance, inspections, testing, quality-control, and safeguards against process/product contamination. HAZOP and FTA are pivotal in identifying potential accident-initiating events.

5.3. Prevent/minimize releases

The next step is to implement safety options to suppress a hazard when an accident-initiating event occurs. For the Bogalusa facility, such options include quality control, warning systems, adequately designed and maintained relief-valves, and quick de-inventory. Better quality control at the nitrogen tetroxide supplier's facility and inspections by the railroad company transferring the contaminated cargo, could have given early warnings.

5.4. Control/minimize external release

If an accident occurs and safety systems fail to contain a hazardous gas release, then engineering control systems will be relied on to reduce or minimize environmental releases. Such systems include an adequately designed scrubber connected to the relief valve line, and a water curtain or deluge system.

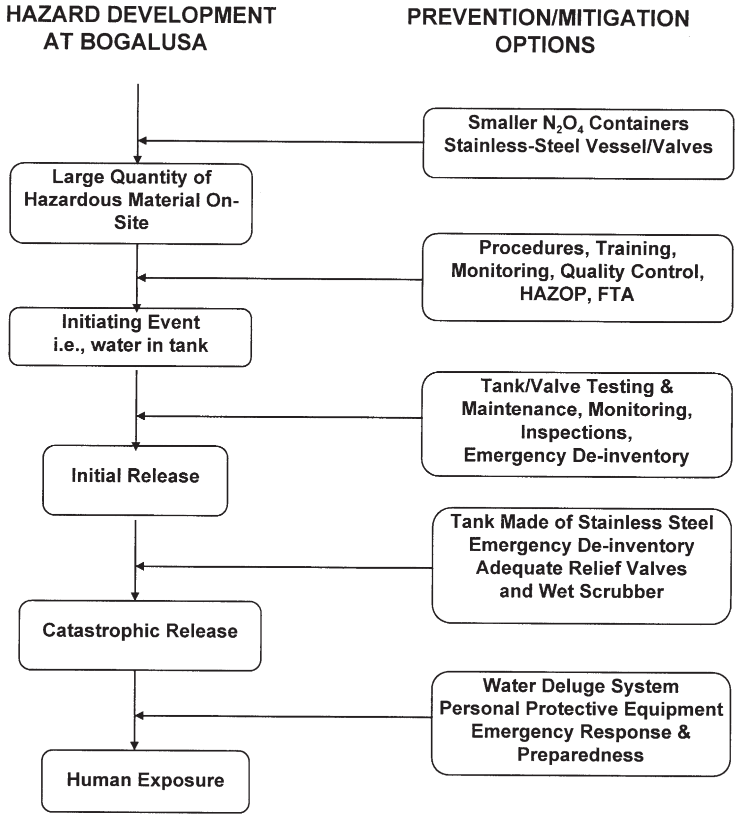

Fig. 1. Hazard development at Bogalusa and options for prevention and mitigation.

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[1] N_2O_4 is used by the US Air Force as a propellant

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5.5. *Prevention/minimization of human exposures*

As a final defensive barrier, human exposures must be prevented if a hazardous gas is released, despite the previous strategies. This barrier includes storing N_2O_4 at a remote location, establishing exclusion zones adjacent to plant boundaries, installing early warning systems, and having emergency-preparedness, response, and evacuation plans to prevent exposures of the public. Evacuation planning requires formulating plans and liaison with outside authorities, including emergency-service personnel, appointment of key personnel and defining their duties, setting up emergency-control centers, and developing site emergency action plans.

6. Conclusion

The major toxic release on 10/23/95 at the Bogalusa facility did not happen without earlier warnings. In that year alone, 20 incidents gave ample warnings about a dangerous situation. Failure to consider the hazards posed by a chemical used in the plant for 30 years, coupled with poor judgment, created the major leak on 23 October 1995.

This release could have been avoided through the preparation and enforcement of unambiguous standard operating procedures, and improved employee training programs. The overall safety in this facility, however, required an upgrade of mechanical systems (e.g. storage and transport vessels, vessels' instrumentation, vessel purging/venting system).

The N_2O_4 release in Bogalusa resembled, in its size and causation, the catastrophic release of MIC in Bhopal in 1984 that killed at least 2500 people and injured 200,000. In both cases, approximately the same quantity of material was released, caused by a series of management mistakes in a similar sequence. Fortunately, there were differences at Bogalusa which prevented fatalities: (1) Low population density around the plant; (2) material that was less toxic; and (3) good response by the Fire Departments and the Police.

While other chemical companies in the United States and abroad are taking extra steps beyond what is required by regulations to assure the safety of their operations, some companies operated in a manner that resembled that in developing countries before the Bhopal tragedy.

Implementation of standard engineering and administrative options could have prevented or controlled the N_2O_4 release in Bogalusa

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