Model on-site emergency plan. Case study: toxic gas release from an ammonia storage terminal

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Received 7 January 1996

Worldwide discussion of disaster management plans to cope with catastrophic injury to people and environmental destruction due to accidents in the chemical process industry was initiated after major chemically caused disasters at Seveso, Flixborough and Bhopal. An emergency plan is a formal written plan based on identified potential accidents together with their consequences. This plan describes how such accidents and their consequences should be handled both on- and off-site. The main aim of the plan is to limit the negative effects of an accident by being prepared with a plan and facilities ready to react without delay. The primary responsibility of the management of a hazardous chemical site is the prevention of accidents resulting in harm to human health, the environment or property. Thus, the plan for handling emergencies should describe all available help from the local professionals as well as governmental officials in order to supplement the company’s own manpower. If a real emergency occurs and the personnel available do not have a well prepared written plan, the results could be far more serious than they would have been if a plan had been available. This paper provides an overview of release scenarios and affects area, response, organization, communications system, key personnel with specified responsibilities, work emergency procedures, emergency control centre, education and training, testing the plan/mock drill, performance review/observation and finalization.

Keywords: on-site; emergency plan; ammonia

Chemical production is on the increase. In addition to finished chemicals, intermediate products pass through many stations from the producer countries to the consumer. Hence most chemical plants need storage facilities for raw materials, intermediate and final products. Intermediates include liquified gases such as ammonia, ethylene, propylene, vinyl chloride, etc. These hazardous liquid products require careful handling by experienced qualified personnel and a high level of competence to ensure safe storage and handling.

No one wants to work in hazardous conditions; however, despite a company’s best efforts, accidents may occur unexpectedly. One must always be prepared for the unexpected emergency. However, even good managers under normal conditions are stressed when faced with the problems of an accident. Hence, there is a real need to have a formal organization and communication system led by individuals of robust nature to deal with accidents. To achieve this state of readiness, specialised training must be given to the personnel involved in the emergency response process. An emergency plan, therefore, has to be exercised by conducting periodic simulated full scale emergency (mock) exercises in order to identify the deficiencies in emergency management systems and to ensure response procedures are kept up to date. The goal of such tests is to provide for immediate and effective action should a severe accident occur.

In this paper we describe the elements of an emergency plan for an ammonia storage terminal and present a case study on the emergency exercise.

Ammonia terminal

The ammonia terminal storage system is comprised of one double integrity atmospheric pressure storage tank of 12,500 metric tonnes capacity, and a set of refrigeration compressors. The inner tank is 33 m inside diameter with height of 22 m. The outer tank has a diameter of 34.6 m. Both the inside and outside shell are constructed with low temperature steels. The tank is provided with necessary inlet, outlet, safety valves and instrument connections. Various safety provisions are incorporated in the design. Compressor accessories consist of coolers, condensers, receivers, expansion valves, etc. The compressors are operated on auto-mode depending upon tank pressure. The tank is fully refrigerated to hold ammonia at its boiling point at atmospheric

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pressure. The technical specifications of the storage tank are given in Table 1.

**Release scenarios and affected area**

Ammonia is a low explosive material within certain limits (16–25% by volume), and conditions for it to explode are unlikely in installations. Furthermore, heat radiation effects will be small as the maximum thermal radiation at the centre of an ammonia fire will be about 14 kW/m². Ammonia itself can burn but it is unlikely to be the cause of a major fire. However, ammonia is a toxic material and can have an adverse effect even at large distances from the source of release. Ammonia gas in concentrations of 0.6–1% by volume is lethal within a few minutes, a concentration of 0.05–0.1% causes irritation to the eyes and the respiratory tract.

A major emergency will exist whenever an ammonia spill or an uncontrollable release of ammonia vapour occurs. The condition must exist for at least 5 min; otherwise, any emergency procedure could not be implemented in time to do any good.

Normally, ammonia chemical releases usually result from equipment failure, such as a ruptured vessel or pipeline, or a blown pump seal, improper positioning of values. The affected distances of release scenarios are given in Table 2.

The worst accident would be an instantaneous release of liquid ammonia due to catastrophic rupture of the tank. The dispersion of ammonia depends on its storage temperature, as well as ambient temperature, humidity, surface roughness and atmospheric stability. The released ammonia vapour cloud will contain aerosol droplets which on evaporation reduces the cloud temperature. There could also be ingress of atmospheric moisture into the cloud. All these make the cloud heavier than air. The dispersion model takes into account the above factors.

The DEGADIS model indicates that the release of ammonia due to rupture of the tank is likely to result in an IDLH (500 ppm) value at a downwind distance of 2.6 km (see Table 2). Nevertheless, the actual concentration is expected to be less than one arrived at by the dispersion model; it is expected that the concentration should fall sharply due to the enhanced turbulence provided by the obstacles in the path of the cloud.

Establishment of two separate plant emergency control centres are suggested. One of the stations act as the main emergency control station when the second one falls under the plume. Identified emergency control stations are shown in Figure 1.
Organization for handling an emergency

Inhouse planning, local authority education, and surrounding neighbour communication is a must for the successful handling of a plant emergency situation. No company can afford to have a group of personnel exclusively to handle emergency situation. Hence, the lines of command remain the same, but the members of the emergency organization must be trained to handle situations in which someone in the line of command may be disabled in the accident.

The emergency team will be drawn from the following departments:

- Fire, safety and environmental
- Personnel
- Security
- Medical.

Communications

The terminal manager will act as the on-site works main controller (WMC). The shift manager in charge of the ammonia terminal will act as the on-site works incident controller (WIC). The WIC should be thoroughly familiar with the plant and be readily recognizable at the scene of the incident.

On being alerted by the WIC, the WMC takes charge of the situation, operating from the emergency control room (ECR). The WMC should be familiar with the plant and should have the authority needed to take decisions affecting the plant, and the neighbourhood.

After activating the on-site emergency alarm (an efficient and widely practiced policy is to allow any employee to activate the alarm), the incident identifier shall notify the WIC of the location, of the incident, probable quantity of chemical involved, probable extent of damage, wind direction and action taken at site, if any. A communication networks for the proposed on-site emergency plan is given in Figure 2. For both controllers deputies should be equally trained and prepared in case of the absence of the designated WMC and WIC.

Roles and responsibilities

Role of incident identifier

If a release of ammonia is noticed anywhere in the terminal one should immediately:

- Call for help
- Inform the shift manager in charge (works incident controller) of ammonia terminal either in person or by telephone
Await instruction from WIC.

Information to be conveyed:
- Location and brief description of incident
- Identification of the magnitude of release
- Wind direction
- Action immediately taken, if any.

Works incident controller
On obtaining information regarding emergency from anyone noticing a release, the WIC:
- Visits site and quickly assesses the scale of emergency
- Alerts works main controller (WMC) through telephone/radio
- Stays within the site at the control room unless relieved
- Concentrates only on containing the source of emissions
- Obtains extra help through WMC if required
- Obtains necessary safety gear for his personnel involved in the plan
- Directs his team to control/contain the source of emissions such as
  - Stopping loading and unloading operations
  - Stopping all transfer operations in the plant
  - Relieving the tank pressure through the flare stack if the compressor is not in operation
- Ensures the safety of electrical machinery
- Shuts down the terminal loading equipment if necessary to avoid a major crisis
- Activates fire-fighting system/water curtains, etc.
- Co-ordinates with any external agency such as the local fire dept.
- Informs WMC by radio, if evacuation/first aid for injured is required
- Documents site events

Informs WMC, specifically pointing out whether it is an on- or off-site emergency

A more detailed instruction list will be available along with the operations manual and highlights will be prominently displayed in the WIC’s office.

Works main controller
On being alerted by WIC, the WMC takes charge of the situation operating from the Emergency Control Centre (ECC).
- Assigns another person to assess independently the nature of emergency (on- or off-site)
- Informs district/local emergency authorities/local fire, police and medical services
- Arranges additional help for WIC from other plants, if required (under a mutual aid scheme)
- Stays in the emergency control centre unless relieved
- Communicates with WIC and emergency management team (EMT)
- Checks the wind direction and looks for secondary effects
- Assesses weather conditions using logic diagram
- Assesses dispersion distances using nomograms/PC installed softwares
- Informs security supervisor at the main gate about the nature and location of the incident
- Informs local pollution control board
- Briefs media, if needed.

A more detailed description of duties will be available in the operation manual and the highlights will be displayed in the emergency control centre.

Fire, safety and environmental department
On receiving information from WMC, the fire safety and environmental manager (FSEM)
Visits the site of incident
Communicates to WMC by radio
Co-ordinates on-site fire and safety activities which includes
Activating mutual aid plans
Organizing first aid
Arranging evacuation
Assesses environmental destruction.

**Personnel department**

On receiving information from WMC, the Personnel Manager (PM):
- Moves to his command post
- Communicates to WMC by radio
- Lists the people in the affected site
- Informs relatives of affected people
- Arranges catering facilities
- Arranges for transport and keeps them in readiness for any urgent need to be co-ordinated by WMC
- Keeps ambulance in readiness
- Ensure that casualties are receiving adequate attention

**Security department**

On receiving information from WMC, the Security Office (SO):
- Moves to his command post
- Communicates with WMC through radio
- Takes control of movement of vehicles and persons into the terminal
- Helps cordon off the affected zone
- Assists FSEM in evacuation and protection of evidence.

**Medical department**

On receiving information from WMC, the Medical Officer (MO):
- Moves to the medical centre
- Communicates with WMC through radio
- Moves injured upwind of spill and renders first aid
- Arranges for hospitalization of affected people if required
- Speed in removing ammonia from contact with the patient and in moving the patient to an un-contaminated atmosphere is of primary importance
- Organizes information card which will contain nature of injury and type of treatment required for the affected persons
- Informs hospitals concerned giving detailed requirements.

**Emergency control centre**

The emergency control centre should be located in a position of minimum risk and with good access both to the site and the outside road system. It should also be accessible to the controllers who have to reach it to control the emergency. Identified ECC for the given plan are shown in Figure 1.

The ECC should contain the following:
- Table, chairs and stationary
- Three telephones, one internal, one external and one for outgoing calls (not listed)
- Radio for contact with all sections/ammonia terminal/WIC, WMC, fire and safety, personnel, security and medical departments
- Log book
- Important telephone numbers displayed on the wall
- Data pertaining to decision making
- Weather station
- Dispersion models/PC installed softwares
- Emergency lights
- Canned food materials and beverages
- Computer with accessories.

The following charts are to be displayed in the ECC:
- Charts on communication network
- Probable events with release quantity expected
- Diagram to assess weather category
- Charts on dispersion distances
- Layout map showing the following
  - escape routes
  - assembly points
  - location of personnel protective equipment
  - site entrances and road systems
  - medical centre location
  - location of works related to surrounding community, etc.
  - location of fire extinguishers/materials.

**Case study**

A detailed on-site emergency plan, as described above, was prepared and circulated to all site personnel concerned. Prior to conducting the mock exercise the following preliminaries were conducted.

**Education and training**

All personnel involved in the emergency response process are trained to ensure a state of readiness for various contingencies. Training of key people should be carried out and assessed regularly.3

**Response team co-ordinators**

Response team co-ordinators, viz. security, fire, safety and environmental, medical and personnel officers and other staff were trained in their respective specialized fields for an emergency response and the following specialized training programmes carried out at the ammonia terminal with the help of experts in the field. Specific training programmes were devised to suit the requirements of different groups of personnel as described below.

**Fire, safety and environmental personnel**

- Handling of chemical fires
- Description of the hazard involved in fighting chemical fires
- Use of personnel protective equipment, first aid equipment and procedures and safety equipment and procedures
- Precautions to be taken in rescuing people trapped in chemically dangerous area
- Reading of site and road maps.
Personnel department
- Identification of affected people and how to inform relatives
- Set up of assembly point
- Reading of site and road maps
- Welfare of the affected people
- Release written statements to the press with approval of WMC.

Security personnel
- Discussing inherent hazards of chemicals on-site
- Use of personnel protective equipment, first aid equipment and procedures
- Methods of handling people and traffic in emergency situations
- Reading of site and road maps.

Medical personnel
- Discussing inherent hazards of chemicals on-site
- Identification of antidotes, life saving equipment, panel of experts available in the community
- First aid
- Identification of hospitals for urgent treatment of casualties
- Setting up of temporary medical camps
- Reading of site and road maps.

Testing the plan
One copy of the emergency plan is kept with WMC, WIC, fire, safety and environmental, security, medical and personnel departments, on-site emergency control stations I & II. The plan was tested with the help of table top models and modified wherever necessary. This exercise was followed by an actual mock drill. The shortcomings and inadequacies in the plan were identified and the plan revised to address them. The main focus of the exercise was to test the basic provisions of the on-site emergency plan; communication procedures, co-ordination between various departments and roles of different authorities involved.

- The data and time of mock drill was known only to the WMC. All observers participating in the trial were briefed, prior to the trial and provided with a checklist for recording the events during the trial
- At 9.00 am the mock drill was initiated by informing the WIC that an emergency had occurred and the nature thereof
- Start of the emergency: 09.00 am
- End of the emergency: 09.30 am
- Employees in the vulnerable areas: 40.

On-site scenario
As already mentioned, the worst case accident scenario was developed and the damaged area worked out. This was used in the testing of the plan. The scenario featured a ruptured tank of ammonia, which produced a toxic cloud. This information was, however, kept confidential until the time of emergency.

Emergency notification
At the appointed time, the mock drill was initiated by informing the ammonia terminal that an emergency has occurred. The terminal manager was asked to initiate action in accordance with the plan requirements. It has been clearly noted in the plan that the WMC can call off the trial at any time if deemed necessary.

De-briefing/lessons learned
Immediately after the drill was over, all the departments and observers involved were assembled in the room at the WMC office for debriefing.

The following observations were noted during the mock drill:
- Wind socks should be installed at the assembly points.
- At least one wind sock should be visible from any point in the ammonia terminal complex
- Irregular parking of vehicles on roads/at unloading terminals is a serious impediment; security departments should be given adequate training for traffic control
- All visitors should be accompanied by security personnel and educated in the use of personnel protective equipment
- An ambulance was placed under the plume; all vehicle drivers should be trained how to determine the wind direction
- Senior department persons should be trained in handling people in emergency situations
- All staff should be trained in raising the alarm
- Some people ran under the plume. All employees should be shown how to determine the wind direction
- All the staff to be trained in reading of site and road maps.

Mock drill review
Based on the observation made during the debriefing, a detailed review of the drill proceedings was carried out and a document prepared. It was circulated to the departments concerned.

The contents of the document were as follows:
- Chronological progress of the mock drill
- Analysis of observations
- Identification of the shortcomings in the plan
- Recommendation for plan modification/implementation.

Plan finalization
Based on the outcome of the suggestions received from various departments/observers, the on-site emergency plan was updated. Copies of the updated versions were issued to the original recipients of the document.

Summary
Emergency planning is an essential part of the loss prevention strategy. A good communication system, training and understanding of emergency procedures, regular interaction between various departments, education and safety training of the employees, review of past accidents/reports/published safety reviews, daily site inspection and ready availability of emergency equip-
ment are the key areas of effective on-site emergency preparedness. Regular emergency exercises (at least one in a 6 month period) will enable management and various departments/agencies involved in the on-site emergency plan to be confident that their task force will form an effective operational team for emergency planning and analysis.

Acknowledgements

The authors would like to thank Dr K.V. Raghavan (Director, CLRI), Dr P.G. Rao, Dr P.C. Panda, Mr G. Swaminathan for their support and Mrs Bhagyalakshmi and Mr P. Venkatesan for word processing.

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