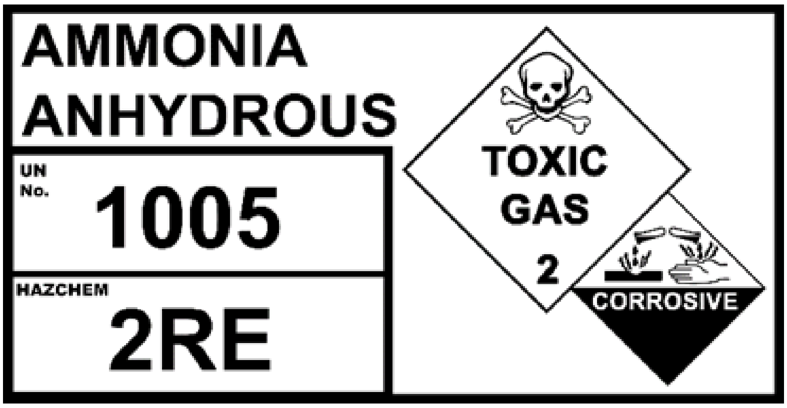
Office of Industrial Relations
Workplace Health and Safety Queensland

Emergency planning for ammonia-based refrigeration systems guide



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Introduction

Under the *Work Health and Safety Act 2011* (WHS Act), all workplaces must prepare an effective emergency plan for the workplace.

The emergency plan must take into account the:

- nature of the work being carried out
- nature of the hazards at the workplace
- size and location of the workplace
- number and composition of the workers and other persons at the workplace.

Workplaces with ammonia-based industrial refrigeration systems must plan for emergencies involving this type of system. Such emergencies involve the release of a toxic ammonia gas that can place workers' and others' health and safety at risk.

An emergency plan is a written document detailing how a workplace and its occupants deal with and manage an emergency such as an ammonia gas release. The level of detail in the emergency plan will depend on the complexity of the facility, the extent of its operations and workforce, and how much and what type of material is being stored and handled.

This guide provides information to assist a person conducting a business or undertaking (PCBU) to prepare an effective emergency plan for workplaces with anhydrous ammonia-based refrigeration systems. The guide includes information on the unique hazards presented by ammonia gas and its use in refrigeration, and relevant duties that apply under the work health and safety (WHS) legislation. It should be read in conjunction with *Emergency Planning: Guidelines for Hazardous Industry*[1], which addresses emergency planning for hazardous materials in general.

Definitions

Emergency

A sudden unexpected event that requires action to correct and protect lives, or property, and the environment. It may include fire, explosion or toxic material release, an electrical failure, security breach or a natural event.

Emergency planning

Preparing to manage an emergency that aims to prepare for and mitigate the effects of the emergency.

Emergency plan

A written document detailing how a workplace and its occupants manage emergency events that may occur. The plan consists of:

- preparedness, response and recovery activities
- agreed emergency management roles, responsibilities, strategies and system arrangements for the workplace.

Ammonia

References to ammonia in this document may cover the various phases of anhydrous ammonia including gas, vapour, liquid and aerosol. If a particular phase is relevant, it will be specifically identified.

[1] Emergency Planning- Guidelines for Hazardous Industry, a joint publication by the Australian and New Zealand Hazardous Industry Planning Taskforce and Chemical Hazards and Emergency Management Unit, 1998 available at www.worksafe.qld.gov.au.

What is anhydrous ammonia and why is it so dangerous?

Anhydrous ammonia, at room temperature, is a pungent, colourless and highly water-soluble gas that can be liquefied under pressure or by cooling to below its boiling point (-33.4°C) at atmospheric pressure. Anhydrous ammonia (where anhydrous means 'without water') has a high affinity for water and is highly water soluble. When anhydrous ammonia is dissolved in water, it forms an alkaline solution of ammonium hydroxide leading to higher pH levels in the solution. Alkaline pH levels create the corrosive conditions that can cause extensive damage to moist areas, including the skin, and the mucous membranes of the eyes, nose, mouth and throat.

What are the health effects?

Exposure to anhydrous ammonia can have the following health effects[2]:

- **up to 100 parts per million (ppm)** – no adverse effect for the average worker with no deliberate exposure for long periods permitted
- **400 ppm –** immediate nose and throat irritation with no serious effect after 30 minutes to one hour
- **700 ppm** – immediate eye irritation with no serious effect after 30 minutes to one hour
- **1,700 ppm –** convulsive coughing; severe eye, nose and throat irritation; could be fatal after 30 minutes
- **2,000-5,000 ppm** – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 15 minutes
- **over 5,000 ppm** – respiratory spasm, rapid asphyxia and fatal within minutes.

Anhydrous ammonia destroys delicate respiratory tissue in the lungs causing pulmonary and respiratory distress. The effect on the eye depends on whether a spray or gas is involved, and may range from mild irritation to eye destruction. Severe ammonia inhalation injury can be followed by a persistent asthma-like syndrome and airway hyper-responsiveness[3]. Moist and sweaty skin is prone to ammonia chemical burns. As an alkali, ammonia causes tissues to liquefy where anhydrous ammonia burns keep spreading until the chemical is diluted. As well as liquefaction, supercooled anhydrous ammonia spray causes a freeze-dry effect like frostbite when it hits skin and is also capable of freezing clothing to skin.

The extent of damage to human tissue will depend on the concentration and length of time of exposure to anhydrous ammonia.

What are the hazards from ammonia released into the air?

Liquefied ammonia released during an incident presents other hazards. For example, liquefied ammonia has an expansion ratio of approximately 850 to 1, which means that on release to ambient air, a given volume of liquefied ammonia will expand 850 times and could potentially cover an extensive area. Such a release will also involve an aerosol phase (i.e. small liquid droplets) along with ammonia gas. When released, it will be very cold and consequently behave as a dense gas (even though it is normally lighter than air) until it is warmed. One of the main characteristics of this cold dense gas behaviour is that the vertical mixing is suppressed. This is due to a stable density layering effect, which generates a slowly diluting vapour cloud that hugs the ground. A release that travels along the ground rather than immediately rising into the air increases the risk of exposure to workers and others. Released ammonia will rapidly absorb moisture from air and will form a dense, visible white cloud at high concentrations. This effect is graphically displayed in a series of images included in Figure 1.

These images were from CCTV footage of an anhydrous ammonia gas release caused by a ruptured hose during a transfer of the product between a storage tank and a tanker vehicle. The release occurred in Seward, Illinois in 2007 and was reported as being up to 18,000 kilograms[4].

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[2] AS2022 (2003) The storage and handling of anhydrous ammonia, Standards Australia, www.standards.org.au.
[3] Clinical Environmental Health and Toxic Exposures, Editors J B Sullivan Jr, G R Krieger, 2nd Edition, 1999.
[4] Images collected from Youtube clip available at https://www.youtube.com/watch?v=qIi4_Poo2HY.

Figure 1: Series of photos showing an ammonia gas cloud travelling from the release point keeping low and travelling along the ground.

If there is no visible cloud, an ammonia release can be detected by its pungent odour at low concentrations. The odour threshold for ammonia is reported in the range 0.02-50 ppm.

Ammonia may be a fire and explosion hazard at concentrations between 15 and 25 per cent in air. If the airborne concentration of ammonia is within the flammable range (typically under confinement), it can be ignited by something as common as an electric spark from a switch. Ammonia has a minimum ignition energy of 680 millijoules (mJ[5]) and an auto-ignition temperature of 669^{o}C[6].

Safety duties

Who has safety duties?

A PCBU (i.e. the person who has overall responsibility for the workplace with an ammonia-based refrigeration system) has duties under the WHS Act for implementing safe systems of work including conducting a comprehensive hazard identification and risk assessment of the workplace to identify situations that will require planning for an emergency.

The process must look at the hazards presented by:

- anhydrous ammonia and the various phases, including liquid and aerosol phases
- associated plant and equipment, including storage and handling systems
- related activities such as operation, maintenance, repair and decommissioning.

It is important to ensure that a comprehensive hazard identification process is undertaken as a foundation to effective safety management and emergency management systems for the workplace. If hazards are not identified, emergency plans will be deficient. Coverage of all hazards associated with an ammonia-based refrigeration system is beyond the scope of this guide. It is expected that a comprehensive hazard identification and risk assessment process for all hazards (not just the ammonia-based refrigeration system) has been conducted as required under the WHS Act. This provides the foundation to use this guidance and develop an effective emergency plan for the workplace.

Further information is available at www.worksafe.qld.gov.au including:

- How to manage work health and safety risks Code of practice 2011
- Managing risks of hazardous chemicals in the workplace Code of Practice 2013.

Specific emergency planning requirements exist under the Work Health and Safety Regulation 2011 (WHS Regulation). Section 43 applies to all workplaces requiring the PCBU to prepare an emergency plan that provides:

- emergency procedures:
  - for an effective response to an emergency
  - evacuation procedures
  - notifying emergency services
  - medical treatment and assistance

[5] Dutch Institute for the Working Environment and the Dutch Chemical Industry Association Chemical Safety Data Sheets: Working Safely with Hazardous Chemicals Kluwer Academic Publishers, 1991.
[6] Safety Data Sheet information.

– effective emergency communications within the workplace.
- testing of the emergency procedures and frequency of testing
- information, training and instruction to relevant workers in relation to implementing the procedures.

Additionally, under section 43, the PCBU must maintain the plan so it remains effective. In developing the plan, the PCBU must have regard to the:
- nature of the work: examples include cold store room work, refrigeration system operation and maintenance, production processes in refrigerated environments
- nature of the hazards: examples include chemical and physical hazards presented by toxic ammonia gas and liquid under pressure
- size of the workplace, number and composition of the workers: for example, an abattoir operation; large food processing workforce within a refrigerated environment; a small crew operating an ice-works; a lone maintenance contractor working on a refrigeration system; a cleaning crew working after hours
- location: for example in a refrigeration plant in close proximity to a residential neighbourhood or in a relatively remote rural area some distance from support services such as contractors and emergency services.

Anhydrous ammonia is classified as a hazardous chemical under the WHS Regulation. This can be confirmed by referring to the manufacturer's safety data sheet (SDS). As a result, the requirements of Part 7.1- Hazardous chemicals apply to the storage, handling and use of anhydrous ammonia. Particular sections that support emergency planning considerations include:
- first aid (s.42)
- personal protective equipment (s.44-47)
- remote or isolated work (s.48)
- managing risks from airborne contaminants (s.49-50)
- managing risks associated with a hazardous atmosphere (s.51-52)
- hazardous chemicals register (s.346)
- manifest for emergency services (s.347)
- notification to Workplace Health and Safety Queensland (WHSQ) of manifest quantities (s.348)
- placarding of storage and handling areas (s.349-350)
- elimination of ignition sources from a hazardous area (s.355)
- containing and managing spills (s.357)
- fire protection and firefighting equipment (s.359)
- emergency equipment (s.360)
- providing a copy of the emergency plan to Queensland Fire and Emergency Services (QFES) when manifest quantity exceeded (s.361)
- safety equipment (s.362)
- control of risks from the ammonia storage and handling systems in regard to operation, testing, and maintenance (s.363).

Workplaces that store, use and handle hazardous chemicals in excess of the prescribed manifest quantity have requirements that apply in addition to the general emergency planning requirements applying to all workplaces under section 43. The prescribed manifest quantity for anhydrous ammonia is 500 litres[7] (water capacity). Most industrial refrigeration plants have a system capacity that exceeds this quantity and may be referred to as manifest quantity workplaces (MQW).

Additional requirements of an MQW are to:
- prepare a manifest including a site plan for use by emergency services
- provide a copy of the workplace's emergency plan to the Queensland Fire and Emergency Service[8] (QFES) for review
- notify Workplace Health and Safety Queensland (WHSQ) as being a MQW and providing a copy of the manifest with the notification.

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[7] Refer to WHS Regulation Schedule 11-Placard and manifest quantities, Item 2-Gas under pressure with acute toxicity as classified under the GHS (Globally Harmonised System of classification and labelling of chemicals). Refer to the manufacturer's safety data sheet for the product's hazardous chemical classification and health and safety information.
[8] For further information refer to www.qfes.qld.gov.au/planning.

The PCBU will also have duties associated with work agreements with other PCBUs such as maintenance contractors that may be engaged to operate and/or maintain a refrigeration system.

Use of contractors at a workplace

Safety duties at a workplace are not transferrable nor able to be ‘outsourced’ to a contractor.

If a refrigeration contractor is engaged to undertake activities relating to the ammonia refrigeration system such as the operation, maintenance, testing and inspection, the PCBU must develop the emergency plans in consultation with the contractor.

The level of consultation will depend on the tasks to be undertaken at the workplace and agreements must be made on the:
- use of resources and equipment
- extent of the emergency response actions undertaken
- provision of training.

If a contractor is engaged to develop emergency plans relating to ammonia systems, they must be developed in consultation with the PCBU responsible for the system and include:
- hazards identified for that particular workplace
- subsequent risk assessments.

Emergency plans

Why do we need emergency plans?

Although the aim is always to prevent incidents, the potential can never be eliminated completely. The way an incident is initially responded to can make a significant difference to the final outcome. If a dangerous event is detected early, assessed correctly and responded to in an effective manner, the consequences can usually be minimised. If this process fails, an incident can escalate quickly. Effective emergency management systems and procedures help reduce the likelihood of an incident escalating thereby reducing the risk of harm to persons, environmental contamination and business losses that may be financial and reputational.

How to develop an emergency plan

The key to effective emergency planning is to develop a strategic plan for emergency response and to practise and test the plan. Following are key points to developing an effective emergency plan:
- consulting with workers, contractors, product and plant specialists, emergency services
- looking at types of emergencies, including common industry incident data and historical data from the facility
- documenting the process of hazard identification and analysis
- checking gap analysis against established standards
- describing the area to be covered by the emergency plan, including people, locations, environment, boundaries, systems, plant and equipment
- describing the emergency management system
- writing the plan using an established format, listing areas to be addressed and schematics/maps required
- describing how the emergency plan is activated and terminated
- describing how the emergency plan is managed including documentation, record keeping and exercises
- documenting training and exercises
- monitoring and reviewing using checklists and exercise debriefs.

What to include in the emergency plan

An emergency plan must include certain minimum information. More details on each point are provided later in the document.

The plan must include:

- potential HAZMAT[9] (hazardous material) emergencies
- organisational structure including roles and responsibilities
- resources and equipment available to deal with a HAZMAT emergency
- emergency procedures that must be followed
- facility layout showing locations of the hazardous chemicals, resources and equipment
- contact details for those who can help in a HAZMAT emergency.

Smaller, more isolated workplaces would require a less extensive plan than a larger more complex workplace situated close to sensitive locations such as dwellings, hospitals, schools, aged-care facilities etc. These larger workplaces will require additional emergency mitigation measures. Any ammonia spill or leak regardless of quantity would require a response effort because of the:

- immediate ammonia volatilisation
- hazardous nature of ammonia dispersing into the environment
- human health risks.

How to document the emergency plan

The emergency planning process must be documented in the workplace's emergency plan. Suggested sections could be:

- objectives and scope
- contacts
- activation and deactivation
- organisational structure
- emergency functions
- roles and responsibilities of various personnel
- emergency response approaches and procedures
- protective actions
- facility resources or resource acquisition arrangements – quantity/location and contacts
- community engagement and media
- facility map
- plan testing and review
- emergency assistance arrangements.

> Tip
>
> It does not need to be as big as a phone book: avoid wordy overly complex presentation, use photos, diagrams and schematics instead of an over-reliance on text and include useful instructions on what to do rather than general information. Importantly, test the effectiveness of procedures in an exercise before they have to be used in a heightened or crisis situation.
>
> *Ref: Brazier A, Emergency Procedures, Loss Prevention Bulletin 254, Institute of Chemical Engineers April 2017*

Emergency planning for anhydrous ammonia

Potential emergencies

The types and causes of ammonia incidents that have occurred within the refrigeration industry should be considered when developing emergency plans to ensure the consequences of uncontrolled releases of anhydrous ammonia are minimised.

[9] HAZMAT is an acronym for the term 'hazardous material', which is an all-encompassing term typically used by emergency services to cover materials that can cause harm including hazardous chemicals, explosives, biological materials and radioactive substances.

Previous incidents involving ammonia in refrigeration plants include the following:

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- Gasket failure
- Faulty solenoid valve
- Condenser tube corrosion failure
- Pressure relief valve incorrectly rated lifting at lower than expected pressure
- mechanical damage to plates and hose connections due to impacts on plate freezer systems
- Component fatigue in plate freezer systems
- Impact by mobile plant on chiller pipework
- Piping failures due to loss of mechanical integrity from corrosion.

Overseas

A review of ammonia incidents across all industries in the United Kingdom[10] revealed that the majority of ammonia-related incidents were associated with refrigeration systems, many involving large releases (up to 3 tonnes). The consequences required the:

- activation of emergency plans
- evacuation of facilities and nearby sites
- involvement of the emergency services.

Many of the refrigeration incidents occurred during maintenance and commissioning activities, the main cause being failure to isolate effectively. Other incidents were caused by plant failure, possibly linked to a lack of preventive maintenance. Other causes were:

- corroded pipework
- failure of seals
- failure of valves
- blockages.

Also, the USEPA Chemical Emergency Preparedness and Prevention Office[11] in the United States, identified causes of releases that included:

- plant upsets leading to the lifting of relief valves
- leaks in rotating seals
- pipeline fractures
- vehicle impacts on pipework
- failures during ammonia delivery such as hose leaks.

Queensland's more significant ammonia-related incidents have involved damage to plate freezer systems resulting in many tonnes of liquefied ammonia being released.

Levels of emergency

Once the type of incident has been identified, the level (or scale) must be assessed. The level of escalation needed to manage an incident is best determined by the impact (consequence) it is expected to have:

- on the local work area
- workplace-wide
- both within and beyond the boundary of the workplace.

Tip Don't focus on just the worst case scenario. Many incidents start small. Provide a tiered set of responses. Procedures need to guide workers to make the correct assessment and to be looking out for potential escalation and the need to scale up the response. *Ref: Brazier A, Emergency Procedures, Loss Prevention Bulletin 254, Institute of Chemical Engineers April 2017.*

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[10] HSE publication: Review of Ammonia Incidents 1992-1998, published 2 October 2000 (no longer available).

[11] USEPA Chemical Emergency Preparedness and Prevention Office, Hazards of Ammonia Releases at Ammonia Refrigeration Facilities (Update), August 2001, available at http://www.epa.gov/oem/docs/chem/ammonia.pdf.

It is important to clearly define the different levels of an emergency at a workplace. For example:

- A major leak, which could be dangerous to people outside the immediate work area such as the plant room, or occur in an occupied process area, would require the emergency management team to be assembled and attended by external emergency services.
- A minor leak, which is unlikely to affect anyone outside the immediate work area, may be dealt with by on-site personnel following the established safe work procedures.

Small workplaces with a relatively small system and few workers (e.g. small ice works or cold stores), may have only one level of emergency requiring isolation, evacuation and emergency services involvement. Workplaces with large systems must focus on major incidents and may require a disaster management approach.

An ammonia release can readily have an impact beyond the boundary of the workplace. Regardless of the size of the workplace, the largest potential release of an ammonia spill or leak must be assessed. It has been reported[12] that almost as many small-scale releases lead to evacuation and injury as large-scale releases; so it is important that emergency planning covers both small and large-scale releases.

Knowing the behaviour of the released ammonia will help identify potentially exposed populations including:

- on-site workers
- neighbours
- downwind communities.

Those affected some distance away may complain about odours (usually to the authorities first), while others may experience severe respiratory distress within the local area. This information will help identify the mitigative measures needed during a significant incident. Dispersion modelling software tools can be used to help assess the consequences.

Organisational structure including roles and responsibilities

AS3745: Emergency control organisation and procedures for buildings, structures and workplaces provides guidance on how to develop procedures, including building evacuation, assembly areas and warden systems for the controlled evacuation of buildings and workplaces during emergencies. However, this will only form part of the requirements to deal with an incident involving anhydrous ammonia.

Personnel involved in dealing with an ammonia incident require specialist emergency response training for activities such as:

- the use of self-contained breathing apparatus (SCBA)
- chemical protective clothing
- water fogging
- rescue
- accessing critical valves in adverse conditions for an emergency isolation and/or shutdown.

> Tip
> Be realistic about who will be available at the time, how long it will be for others to become available (e.g. emergency services, contractors), and consider that some will not become available for the incident (e.g. on leave). Balance the allocation of roles to specific people with the likelihood of them being present (e.g. night-shift, after-hours) and for critical roles, ensure the appropriate level of authority is provided for decision-making.
> *Ref: Brazier A, Emergency Procedures, Loss Prevention Bulletin 254, Institute of Chemical Engineers April 2017*

[12] Weisskopf, M G, Drew J M, Hanrahan L P, Anderson H A, Hazardous Ammonia Releases in Wisconsin: Trends and Risk Factors for Evacuation and Injury. Wisconsin Medical Journal, November 2000.

The roles and responsibilities for those involved in managing an ammonia incident must be identified for the types and levels of emergencies applicable to a particular workplace.

For larger workplaces with potential for more significant consequences, established emergency management structures used by emergency service organisations, such as the nationally recognised Australasian Interservice Incident Management System (AIIMS)[13], may be adopted.

The workplace's incident management system (IMS) must be:
- compatible with the routine organisational structure
- locally used emergency response agency IMS systems
- resourced and sustainable.

All IMS structures must be developed according to staffing levels available on site. After hours responses will also need to be considered accounting for the staff numbers and expertise available.

The roles and responsibilities of the personnel should:
- reflect the agreed structures and emergency response approaches
- be nominated after considering the required training and equipment involved
- be explained clearly and practised.

Setting up a training matrix is a useful way to track and manage training requirements for workers.

Resources and equipment

The organisational structure covers human resources (roles and responsibilities) needed in a particular emergency, but not the 'hardware'. The resources and equipment include items needed to respond to an emergency and assist in the recovery phase.

There are a number of tools that can be used to assist in a more orderly response during an ammonia incident, including:
- electronic resources (system information and schematics, SDS)
- technical expertise (on-site staff and external specialists)
- gas detection equipment
- mitigation equipment:
  - windsocks such as the example shown in Figure 2
  - water fogging equipment
  - neutralising agents such as citric acid for liquid run-off or carbon dioxide for injection to reduce airborne ammonia concentrations
  - pipe repair equipment
  - product transfer equipment
  - suitable high expansion foam to cover liquid spills
  - portable ventilation fans to assist clearing residual gas
  - sand/soil to isolate and/or control the flow of contaminated water run-off
- waste management equipment or arrangements
- respiratory and skin protection
- communication equipment.

Figure 2: Windsock showing wind direction and likely direction of travel for a vapour cloud.

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[13] The Queensland Fire and Emergency Service (QFES) adopt the highly recognised AIIMS. For further information, contact the QFES Training and Emergency Management section at www.qfes.qld.gov.au .

A practical way to ensure such equipment is readily available is to establish an emergency response container as shown in Figure 3.

Figure 3: An example of a dedicated ammonia emergency response kit that includes response equipment including SCBA. The unit is portable using a forklift and serves to protect the gear and ensure it is readily available.

Pre-planning is vital to ensure the required resources are readily available, practised and tested for effectiveness. Without pre-planning, finding the right equipment will likely prolong the response to an incident.

A robust maintenance program should be established to ensure the allocated resources are serviceable (e.g. personal protective equipment, fixed and portable gas detectors, fire extinguishers). The resources must match the plan and be available at all times including the arrangements for additional resources and trained personnel.

Personal protective equipment including SCBA[14]

Personal protective equipment (PPE), including SCBA, must be used to safely manage an ammonia incident. A risk assessment must be conducted to determine the level of personal protective equipment likely to be needed for various activities, including access and rescue in contaminated areas.

Emergency planning must include the need to rescue anyone who may have been affected to the extent that their mobility has been impaired (e.g. loss of consciousness). A minimum of two sets of SCBA and the appropriate number of trained personnel should be available to respond. If small workplaces with few staff do not adopt this approach, a documented risk assessment must be undertaken to determine the extent of response actions with the available resources.

If the workplace relies on external emergency services for equipment such as SCBA, the response time of the local emergency services, to perform the rescue operations, must be considered. For example, where emergency services are located close to the facility, response time must be allowed for:

- reaction to the emergency call
- travel
- conducting a facility assessment on arrival
- setting up a SCBA station and donning equipment
- the entry to perform the search and rescue.

PCBUs should:

- consult with the local QFRS when developing their plans
- know the capability of the local QFRS station/s and the region.

All QFRS stations have a HAZMAT response capability, while collectively the region’s capability is much greater.

[14] SCBA: Self Contained Breathing Apparatus as described in Australian and New Zealand Standard AS/NZS 1715 Selection, use and maintenance of respiratory protective equipment, Standards Australia, www.standards.org.au.

Emergency procedures

Emergency procedures must detail specific duties of all staff and the arrangements for:

- evacuation
- rescue
- first aid
- resuscitation
- plant isolation.

During an emergency, people must have clear, simple, practical instructions to follow.

Emergency procedures need to be in place to deal with:

- detecting a gas escape, using both fixed-type and portable or hand-held type detectors
- responding to an alarm, including acknowledgement and actioning
- raising the alarm to alert others including when to call emergency services
- assessing the situation to provide initial information on type and scale of leak
- checking wind speed and direction
- containing releases
- operating fire protection equipment
- evacuation taking into account the location of released gas
- monitoring gas concentrations over time at various locations
- emergency venting of plant (ventilation)
- emergency shutdown processes
  - closing valves to isolate the system into smaller sections and to prevent further escape
  - equipment shutdown
  - dealing with power outages
- system start-up after an emergency shutdown
- isolating electrical appliances where required
- dealing with leaks of liquefied ammonia that may pool and/or flow
- tables of the safe operating conditions for critical valves and components
- diagram/s of the current as-fitted operating system showing integral parts and critical valves and their locations at the facility
- safe work procedures to conduct anticipated emergency response actions
- coordination with local emergency responders.

Written safe work procedures for several basic facility operations, including removing oil from the refrigeration system and start-up procedures, must be developed. Post-incident investigations revealed these routine operations appear to have caused a significant number of the emergencies. Where procedures require closing specific valves, these should be marked and identified on the drawings and readily identifiable in the plant.

Death of maintenance worker in USA, 2006:

- Incident occurred at a food processing plant.
- Incident involved installing a temporary vacuum hose on a drain pipe to remove the ammonia from a refrigeration unit so they could replace a leaking cooling coil.
- A pipe fitting split suddenly while workers were trying to drain anhydrous ammonia from refrigeration equipment, spraying anhydrous ammonia on the face.

Source: US Department of Labor, Occupational Safety and Health Administration, Data and Statistics available at http://www.osha.gov/oshstats/index.html and US Chemical Safety Board news report www.csb.gov accessed on 10 March 2009.

Identifying the source of a leak

Emergency procedures must include instructions on how to identify the source of the leak and determine the extent. Portable hand-held gas detectors are a valuable tool for helping to determine the location and extent of the leak.

Those entering an area where ammonia is likely to be present for fault-finding or rescue must wear an appropriate level of personal protective equipment. Because of ammonia's heavier-than-air behaviour when cold, a person entering an area where ammonia is present may experience a wall-effect where a relatively low concentration is followed by a rapid increase in concentration.

Wearing appropriate personal protective equipment will protect against this wall-effect. A high level of personal protection (e.g. SCBA and encapsulated gas-tight suit) can be reduced once the situation is known and controlled. Under no circumstances should anyone enter areas where a flammable concentration of gas is likely to exist. Note: Smell must not be relied on to locate the source of the leak.

Triggers for action

Emergency plans must include trigger levels that recognise abnormal atmospheres and initiate specific actions. Trigger levels can be based on the concentration of ammonia gas present and the selected trigger level will be determined by the required outcome. For example, a low trigger level would be set to initiate an evacuation of a process area, but a relatively high trigger level would be set to initiate electrical isolation of a plant room.

Specified trigger levels can be used to guide specific actions such as:

- wearing specifically identified personal protective equipment
- initiating mechanical ventilation systems
- initiating electrical isolation of an enclosed area
- initiating evacuation procedures
- calling external emergency services
- initiating community protection actions.

A combination of both fixed-type and portable hand-held ammonia gas detectors can and should be used to check airborne ammonia gas concentrations and to guide response actions.

Trigger levels for wearing PPE

Trigger levels can be based on various published values contained in the Australian Occupational Exposure Standards[15] provided to protect workers. These standards recommend airborne concentrations which, according to current knowledge, should neither impair the health of, nor cause undue discomfort to nearly all workers.

The Australian Occupational Exposure Standards for ammonia gas are:

- TWA16 25 ppm
- STEL[17] 35 ppm.

Also, Immediately Dangerous to Life and Health (IDLH)[18] values are published to guide the selection of breathing apparatus that are made available to workers or firefighters in specific situations. The IDLH value for ammonia gas is **300 ppm**.

Personal protective equipment could be worn during emergency operations on the basis of a specified trigger level such as:

- **less than 25 ppm**, don full-face respirator
- **25 to 300 ppm**, don splash suit and SCBA (or suitable respirator)
- **over 300 ppm**, don encapsulated (impervious) suit (example shown in Figure 4) and SCBA to prevent chemical burns (e.g. may occur from ammonia dissolving in sweat).

[15] Published by SafeWork Australia, available at http://hcis.safeworkaustralia.gov.au/.

[16] TWA, Time Weighted Average, means the average airborne concentration of a particular substance when calculated over a normal eight-hour working day, for a five-day working week.

[17] STEL refers to the Short Term Exposure Limit means a 15 minute TWA exposure which should not be exceeded at any time during a working day even if the eight-hour TWA average is within the TWA exposure standard. Exposures at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL.

[18] IDLH is defined by the US National Institute for Occupational Safety and Health (NIOSH) as exposure to airborne contaminants that is "likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment".

Figure 4: Personal protective equipment (PPE), including SCBA, must be used to safely manage an ammonia incident.

Community protection

Trigger levels are also available from a number of internationally recognised sources. The American Industrial Hygiene Association provides trigger levels for initiating emergency actions in the **E**mergency **R**esponse **P**lanning **G**uidelines (ERPG).

The ERPG levels are defined as follows:

ERPG-3 1500 ppm	The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour **without experiencing or developing life-threatening health effects**.
ERPG-2 150 ppm	The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which **could impair an individuals' ability to take protective action**.
ERPG-1 25 ppm	The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without **experiencing other than mild transient adverse health effects** or perceiving a clearly defined objectionable odour.

The USEPA has also developed the Acute Exposure Guideline Levels (AEGL) to provide guidance in situations where there can be a rare, typically accidental exposure to a particular chemical that could involve the general public. The AEGL are based primarily on acute toxicology data and not subchronic or chronic data and do not reflect the effects from frequent exposure. These levels can be used for emergency planning, prevention and response activities related to the accidental release of hazardous materials.

They are also designed to protect the general population, including the elderly and children, groups that are generally not considered in the development of workplace exposure levels.

The AEGL are defined as follows:

AEGL-1	The airborne concentration, (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
AEGL-2	The airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL-3	The airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Using the descriptions above, the AEGL for ammonia are identified in the Table 1 below.

Table 1 Acute Exposure Guideline Levels (AEGL) for ammonia.

Ammonia (values in ppm)					
	10 min	30 min	60 min	4 hours	8 hours
AEGL 1	30	30	30	30	30
AEGL 2	220	220	160	110	110
AEGL 3	2 700	1 600	1 100	550	390

PCBUs can use these values to run consequence modelling for different situations when planning for ammonia emergencies. Dispersion modelling software programs[19] can help predict how a toxic ammonia gas cloud will disperse after a release and who might be affected. Figure 5 shows a large ammonia gas cloud being dispersed as it travels away from the release point.

Figure 5: A visible ammonia gas cloud travelling downwind and dispersing.

These models help to estimate ammonia concentrations downwind from the source of a leak taking into account the toxicological and physical characteristics of ammonia. This information could influence the location of evacuation assembly points, or identify any neighbours that may be affected. The modelling must allow for changing wind directions.

The plan should cover the likely impact on the local community and include:

- the neighbours at risk and their location
- how they can be contacted
- the crisis communication arrangements.

Depending on the maximum release situation, and the location and nature of the surrounding community, the local disaster management group may need to be engaged for public protection. This may require using evacuation or in-house sheltering and crisis communication arrangements.

Environmental considerations

Emergency plans will need to cover potential environmental impacts (i.e. pollution control). For example, large quantities of contaminated water will be generated during a significant incident where water fogging or spray is used to reduce the airborne ammonia levels. Ammonia dissolved in water is toxic to aquatic ecosystems.

The ammonia-contaminated run-off water can be directed into existing catchment ponds, bunded areas, or traps to prevent environmental harm. The contaminated water must be prevented from entering stormwater drains and local water courses.

When large airborne concentrations of ammonia are exhausted from a plant room through the emergency ventilation system, and the workplace is in close proximity to built-up areas, wet-scrubbing of the exhausted air should be considered.

[19] Dispersion modelling proprietary software is available. For example, the ALOHA software package developed by the United States Environmental Protection Agency is available as a free download. When dispersion modelling software is used, ensure appropriately experienced personnel are employed to operate it. Also ensure that the modelling parameters chosen, the modelling limitations, and any assumptions are accounted for.

The quantity of ammonia released may affect communities several kilometres downwind and be influenced by the:

- quantity released
- mitigation measures in place
- time of day
- ambient temperature
- topography
- wind speed and direction.

Layout of workplace

A site plan must be available as part of the emergency services manifest. Specific information to be included in the manifest and site plan are specified in WHS Regulation Schedule 12. A manifest is essentially a summary of information and should specify key items of the refrigeration system such as location of the plant room, areas where ammonia is located and key isolation points. More detailed information such as the t refrigeration system design drawings clearly showing the pipework and fittings (e.g. isolation valves) may not be part of the manifest document but will need to be available.

As part of emergency management, all pipework and instrument diagrams (P&IDs), showing the location of isolation valves, must be:

- up-to-date
- accurately reflect the ‘as-installed’ system
- readily available.

The critical valves on the P&IDs must be clearly marked and identifiable in the plant to assist emergency operations.

Emergency contact details

24-hour emergency contact details should be provided for:

- external assistance such as emergency services
- refrigeration system contractors
- resource or recovery providers
- company contacts as detailed in the emergency organisational structure.

For potential off-site consequences, at-risk commercial and industrial premises should be identified and their contact details recorded.

Training

PCBUs must ensure that those with a role in responding to an emergency are trained and appropriately resourced.

Competency-based training is a key part of the emergency management process and should:

- relate to the role and responsibilities of those involved
- use recognised standards
- be practised on a regular basis.

The content may range from:

- incident management training
- media training
- first aid or specialist HAZMAT emergency response training
- evacuations and drills.

All staff should be trained in the hazards of ammonia and how to respond to foreseeable emergencies which is tailored to their role and responsibility.

By their nature, emergency plans should be seldom needed, hence long periods of time may pass before an incident occurs and emergency actions are triggered. This places increased emphasis on the need to frequently train workers and conduct exercises to test the plan and build resilience in the workforce so that when a real incident occurs, the plan is carried out as intended.

Below are examples of how specific training relates to specific roles:

- **New staff, contractors and visitors –** site safety induction including evacuation procedures.
- **Machinery operators/engine drivers** – refrigeration system hazards, safe work procedures, use of PPE, emergency procedures including use of portable gas detectors, emergency shutdown and start-up procedures.
- **Process workers** – recognition of alarms and evacuation procedures.
- **Selected operational staff –** first aid, and use of fire extinguishers.
- **Emergency response team –** incident management training, SCBA and chemical protective clothing, use of gas detectors, emergency shutdown.
- **Senior management –** incident management training, media training
- oral testing.

Training documentation should reflect how the level of understanding was measured and/or verified.

Death of Maintenance Engineer in UK, 2005

- Occurred at a company operating cold storage for foodstuffs.
- Involved a 2.5 tonne ammonia release.
- Worker died while draining oil.
- There was only one air cylinder for the breathing apparatus.
- Ex-employee Stuart, the firm's business development director at the time, said he had argued for two sets of breathing apparatus, a spare bottle and chemical suits.
- Quote from court proceedings: "*Working on the ammonia system requires specialist knowledge but Alan had had no specialist training*".

Source: UK Crown Office Chambers' Health and Safety and Regulatory Law Update, HSE Vs Cold Move Ltd, Issue 5 January 2009.

Appropriate training records (who, when and what) must be kept. It is important to check that the level of staff training is adequate and this can be done by:

- observing performance
- written testing
- oral testing.

Training documentation should reflect how the level of understanding was measured and verified.

Testing and reviewing the emergency plan

The emergency plan should be tested and reviewed at suitable intervals to identify and correct deficiencies. Two usual methods of testing are:

- desktop simulations
- practical exercises or drills such as realistic emergency response exercises.

Robust management of change is required to ensure procedures stay relevant and reflect current operations such as the size and make-up of the workforce, site attributes and layout and inventories. Ensure that opportunities for improvement are captured (e.g. via observations, feedback and de-brief), required improvements are made and re-tested at an appropriate time.