M8: Fates and Effects of Ammonia Spills

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Ammonia is one of the most common hazardous materials being transported in the U.S., especially in agricultural areas where it is used as an important fertilizer. It is also a common industrial and commercial refrigerant. Ammonia is usually produced from natural gas, so it is also found in large quantities near petroleum producing areas. It is shipped throughout the country in ships and barges, rail tank cars, and tanker trucks.

Anhydrous ammonia (CAS No. 7664-41-7) is normally shipped in liquefied form (refrigerated on barges, pressurized on smaller carriers) and immediately vaporizes when lost (boiling point is -28°F).

Ammonia vapor forms a buoyant cloud. It has a high health hazard rating (3), but acute inhalation toxicity is much greater than uncomfortable odor level. It is highly irritating to throat at 400 ppm and eye irritation is noticeable at 70 ppm. The acceptable exposure limits are usually 25 to 50 ppm. It has a slight fire hazard rating (1) due to its narrow explosive limits (16 to 25%). If it enters a receiving water, it is highly soluble and is toxic to fish (20 to 300 mg/L).

Transportation Accidents

Alabama has about 200 transportation accidents every year involving hazardous materials. This is a typical amount for many states. Ammonia and ammonia compounds are some of the most commonly lost hazardous materials from transportation accidents (highway, rail, barge, and pipeline transfer accidents).

Birmingham News (Alabama)

Over a ten year period, the following amounts of ammonia and ammonia compounds have been lost during transportation accidents in Alabama:

- Transfer stations:
  - Hydroxyl ammonium sulfate (1 accident of 3,500 gal)
  - Anhydrous ammonia (4 accidents of 200 lbs)
  - Ammonium nitrate (1 accident of 5 gal)
- Highway accidents:
  - Ammonium nitrate and mixtures (6 accidents of 30,000 lbs plus)
  - Anhydrous ammonia (3 accidents of 1,000 gal)

Ammonia Accidents in Alabama (1990s), cont.

- Marine Operations
  - Anhydrous ammonia (1 accident, <1 gal)
- Railroad Operations
  - Anhydrous ammonia (8 accidents of 2,125 lbs)
  - Ammonium nitrate (1 accident of 65 gal)

Total Ammonia Losses:

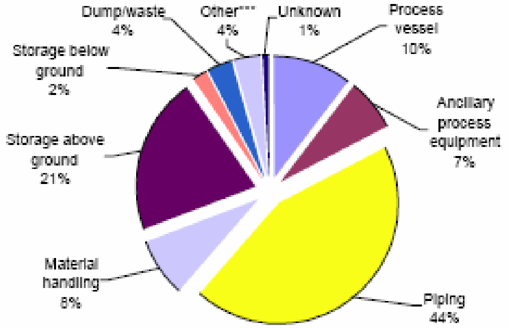
- Anhydrous ammonia: 16 accidents, >2,000 lbs
- Ammonium nitrate and mixtures: 8 accidents, >30,000 lbs

New York State Ammonia Spills (1993 – 1998)

- Of 2,415 reported releases of hazardous substances, 107 (4.4%) involved ammonia.
- Of the 814 people injured during releases of hazardous substances, 61 (7.5% were injured following ammonia releases.
- Equipment failure caused 58% of the ammonia releases and injured 38 people.
- Most of the ammonia releases involved piping (44%)
- 44% of the injured people were employees, 41% were general public and 15% were responders.
- More than 1,899 people were evacuated following the 107 ammonia releases.
- Most of the ammonia releases occurred in food/beverage processing (29%) or chemical/metal/equipment manufacturing (27%).

New York State Dept of Health (2000)

Figure 1. Location* of 101 Reported Ammonia Events at Fixed Facilities**



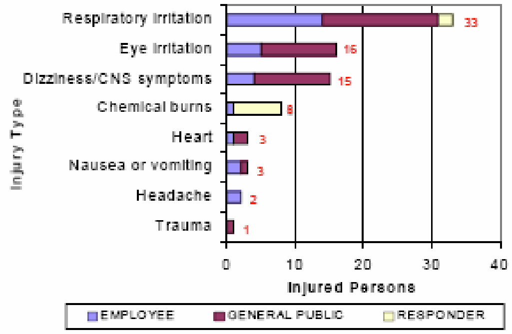
*Study design allows a maximum of two locations per event. Total number of locations is 114.

**6 ammonia events were transportation-related and are not included.

***Other: entire facility (2), hotel restroom (1), construction site (1).

New York State Dept of Health (2000)

Figure 2. Injuries Following Reported Ammonia Events

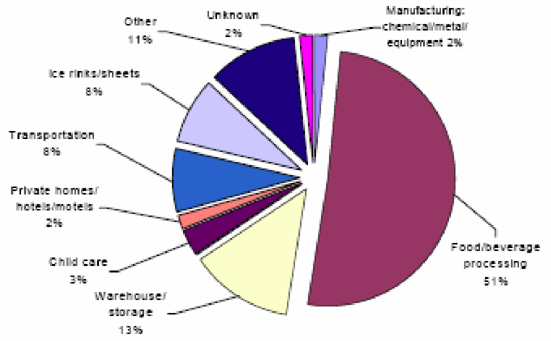


* The injured persons (61) belong to the following categories: employees (27), general public (25) and responders (9).

**The total number of injury types (81) exceeds the total number of injured persons (61) because some people had more than one injury.

New York State Dept of Health (2000)

Figure 3. Injured People Following Accidental Ammonia Releases by Facility Type



*Other: paper/printing (4), other metal products (1), sanitary services (3), research and development (2), public order/safety (1), agricultural services/production and livestock (2), and construction (1).

New York State Dept of Health (2000)

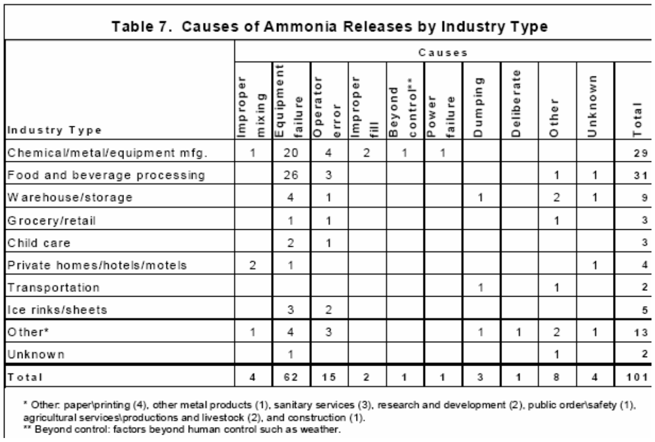


Table 7. Causes of Ammonia Releases by Industry Type

	Causes										
Industry Type	Improper mixing	Equipment failure	Operator error	Improper fill	Beyond control**	Power failure	Dumping	Deliberate	Other	Unknown	Total
Chemical/metal/equipment mfg.	1	20	4	2	1	1					29
Food and beverage processing		26	3						1	1	31
Warehouse/storage		4	1				1		2	1	9
Grocery/retail		1	1						1		3
Child care		2	1								3
Private homes/hotels/motels	2	1								1	4
Transportation							1		1		2
Ice rinks/sheets		3	2								5
Other*	1	4	3				1	1	2	1	13
Unknown		1							1		2
Total	4	62	15	2	1	1	3	1	8	4	101

* Other: paper\printing (4), other metal products (1), sanitary services (3), research and development (2), public order\safety (1), agricultural services\productions and livestock (2), and construction (1).
** Beyond control: factors beyond human control such as weather.

New York State Dept of Health (2000)

Late one Wednesday evening, a lone workman wearing no personal protective equipment was repairing a compressor at a college ice rink. After adding oil to the system, he accidentally punctured a line carrying anhydrous ammonia and 1,000 cubic feet of the liquid refrigerant was rapidly released. Hot oil contaminated with ammonia sprayed his face and caused eye injuries which required hospitalization. Firefighters who responded to the incident were concerned about the potential for an explosion and used large exhaust fans to vent the sports facility.

New York State Dept of Health (2000)

Two young male employees were overcome by chemical fumes and the entire floor of an office building was evacuated (approximately 20 people for one hour) after a half gallon of ammonium hydroxide spilled in an engineering consultant's office. The chemical was used to operate the company's blueprint machine and spilled when a shelf broke. The injured men were treated at the hospital for respiratory irritation. Although the amount seems small, the chemical soaked the carpet and powerful fumes circulated throughout the floor. The fire and police departments evacuated all second floor occupants including an oral surgery clinic. Firefighters cut the portion of the carpet where the chemical spilled and removed it in a metal container for disposal as hazardous waste.

New York State Dept of Health (2000)

Twenty-five pounds of ammonia were released at a commercial blue print shop when the protective domed cover on a 100-lb tank sheared the valve as it was being opened. During the evacuation, one woman fell down the stairs and broke her leg. As a result, she was exposed to the ammonia vapors, suffered dizziness and respiratory irritation, and required hospitalization. One hundred and fifteen people were evacuated for four hours.

New York State Dept of Health (2000)

A relief valve on a refrigeration unit at a bottling plant malfunctioned in the open position and released 200 gallons of ammonia. Employees were exposed when they were evacuated into an area downwind of the plume. Eleven employees sustained injuries including eye and respiratory irritation, headache, chest tightness, sore throat and dizziness. Nine employees received on-scene first aid and two were transported to the hospital for treatment. Thirty-five people were evacuated for about four hours from other facilities located downwind.

New York State Dept of Health (2000)

An inmate at a correctional facility generated a noxious gas by mixing bleach and ammonia. The inmate and two facility employees sustained respiratory irritation. The employees were treated and released at a local hospital and the inmate was treated at the facility health clinic. Ten people were evacuated for about 1.5 hours.

New York State Dept of Health (2000)

Case Study: Train Derailment and Spill of Anhydrous Ammonia, near Minot, North Dakota

A train derailment early Friday, January 18, 2002, sent a cloud of anhydrous ammonia over Minot, North Dakota, killed one man, sent part of a rail car slamming into a house and forced dozens of people to the hospital with breathing problems. The derailment, which happened about 1:40 a.m., knocked out power to about 1,000 people in parts of Minot and Burlington, a small town just to the west. About 30 cars derailed, and 17 or 18 of the cars were carrying anhydrous ammonia, at least five were punctured. The train was headed from Medicine Hat, Alberta to Minneapolis, MN. The air temperature was about 5°F below zero. The cold temperatures and a lack of wind made the gas linger in the area. Previously, the town of Newburg, near Minot, was evacuated because of an ammonia leak in 1997.

More than 60 people went to the hospital and 13 were admitted, seven in intensive care. The Minot Fire Department sent a bus to evacuate the residents of Tierrecita Vallejo at about 7 a.m. Some were taken to the hospital, others to a triage center at Edison Elementary School, about five miles away. More than 80 people went to the elementary school.

“The entire house shook,’ Jennifer Johnson said, still sobbing. ‘I ran downstairs and looked out the window. I saw a giant white cloud coming right for me. Before I could look away it crashed through the window and burned my face. I couldn’t see anything. I covered my face with a washcloth and went looking for my kids. We went down to the basement. The phone line was out, so I couldn’t call 911. The only thing on the radio was music -- no one was telling us what happened or what to do. The kids were crying. We were burning up, our eyes were on fire. We were trapped.”

Minot Daily News

“Johnson’s other son Michael, 17, was trying to drive his Jeep out of the small community they lived in, just southwest of Minot proper. He heard an explosion. He saw a train car fly through a stand of trees and crash through Lee and Carmel Wieland’s bedroom, a tail of fire following. The car missed the Wielands’ bed -- and them -- by about a foot. It ripped through the side of the house, exposing the entire bedroom. The Wielands weren't touched.”

“Down the street, a garage door hung sideways from the garage. The occupants of the house hadn’t bothered to raise it in their haste to leave, and backed right through it.”

Minot Daily News

Minot Daily News

Minot Daily News

Minot Daily News

Minot Daily News


Minot Daily News

The following comments were written in the aftermath of the accident:

"Many, many North Dakota communities are bisected by railroad tracks, carrying cars of anhydrous ammonia or worse. It's also common to meet farm vehicles pulling tanks of the deadly liquid fertilizer on the state's roads and highways."

"On trucks and rail, 'The biggest quantity coming through is mixed stuff, consumer commodities in cases,' said Battalion Chief Kurt Leben of Bismarck Fire and Inspections. After that is propane, then anhydrous, followed by diesel fuel, fuel oil and various solvents."

Mint Daily News

"'It could happen here' -- that's what went through peoples' minds as they learned about the Minot disaster. Not a groundless revelation at all. The Tribune, in response to the crash, asked local emergency officials if this community was prepared for an emergency like that in Minot. They said they were."

Mint Daily News

Properties of Ammonia

Ammonia is a colorless gas at atmospheric pressure and normal temperature. It is alkaline and possesses a characteristic penetrating odor. On compression and cooling, ammonia gas condenses to a liquid about 60 percent as heavy as water. The liquid has a high vapor pressure at ordinary temperature, and commercial shipment requires pressure containers unless the liquid is refrigerated. Ammonia is readily absorbed in water to make ammonium hydroxide (NH_4OH). Considerable heat evolves during the solution of ammonia gas in water (1 lb NH_3 gas produces 937 Btu when dissolved in water).

Physiological Response	Approximate Ammonia Concentration in Air (ppm)
Least detectable odor	50
Maximum concentration allowable for prolonged exposure	100
Maximum concentration allowable for short exposure (1/2-1 hr)	300-500
Least amount causing immediate irritation to throat	400
Least amount causing immediate irritation to eyes	700
Compulsive coughing and possible death	1700
Dangerous for even short exposure (1/2 hr)	2500-4500

Potential Sources of Accidental Releases

Vessels

1. A catastrophic accident, such as a collision involving a vessel could release a potential maximum of about 12,000 tons of liquid ammonia.
2. The refrigeration system on a vessel could develop a leak from a broken pipe or fitting. During a transfer operation, the loss during a 5-minute shutdown period could amount to about 125 lb, while without a transfer, the loss could be about 42 lb.
3. Spills could occur at a terminal during off-loading of a vessel. Because of automatic emergency equipment, the losses would be limited to line drainage between the automatic valves and the break. This loss could be about 7 tons.

Trucks and Rail Cars

1.Trucks and rail cars could be involved in accidents with sub-sequent leaks or spills. If there is a tank rupture, the entire ammonia cargo of up to about 20 tons/truck and 80 tons/rail car could be spilled almost instantaneously. A lesser amount could be lost through a tank crack or a broken fitting.

2.During the normal loading of a tank truck at a storage terminal, approximately 1 ounce of ammonia vapor may be released to the atmosphere through a vent stack usually 20 ft high.

Venting

1. The relief valves on ammonia carrying vessels can begin to vent after several days without refrigeration. These losses can amount to 200 to 500 lb/hr.

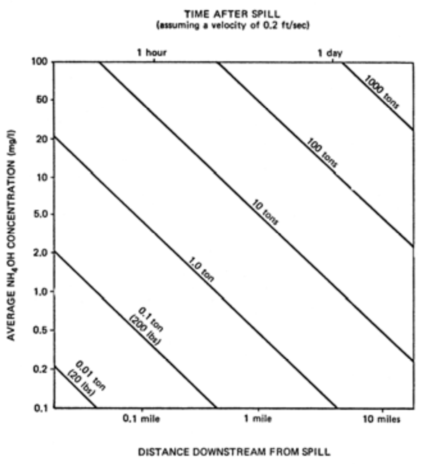
2. Large refrigerated storage tanks can vent after about 4 hours without refrigeration. The maximum vent rate can be about 750 lb/hr per tank. This would require an extremely long time to completely vent a tank. Backup electrical generators are typically used to supply electricity to the refrigeration equipment in case of prolonged power outages (the most probable cause of refrigeration failures).

3. The tanks on trucks and rail cars likely will vent only if involved in a fire. In a fire, a full truck tank would empty in about 4.5 hours, and a full rail car would empty in about 18 hours.

Water Quality Effects

Anhydrous ammonia is a cryogenic liquid (boiling point is -28°F) at normal atmospheric pressure. It floats on the water surface, rapidly dissolving within the water body into ammonium hydroxide (NH_4OH), while at the same time boiling into the atmosphere as gaseous ammonia (NH_3). The partition ratio (the quantity of ammonia that dissolves into the receiving water divided by the total quantity spilled) is normally between 0.5 and 0.8 for surface spills and somewhat higher for underwater spills. For simplicity, the partition ratio for these analyses is assumed to be 0.6 for all spills. Furthermore, all spills are considered to be instantaneous.

If the water body near the site is of a generally one-dimensional nature and lacks advective currents, the spill would be distributed evenly over the cross section of the channel. Furthermore, it is expected that the length of channel affected by the spill would be roughly proportional to the length of time elapsed after the spill. If one further assumes that the concentration is constant longitudinally behind the ad-vancing pollution front, then a single concentration value can be calculated to represent the entire contaminated prism as a function of increasing channel length for a given spill quantity.



This figure assumes a constant cross sectional area of 10,000 ft^2 within a ship channel and a speed of the pollution-front advance of approximately 0.2 ft/sec.

Mean ammonium hydroxide concentrations in estuarine prisms for various ammonia spill quantities.

Air Quality Effects

The physical processes governing atmospheric dispersion when large quantities (over 1,000 tons) of liquid ammonia (LNH_3) are spilled instantaneously on, or under, water are not well understood. However, laboratory, swimming pool, and lake tests provide some insight into the dispersion behavior. These results offer tentative models for estimating potential atmospheric concentrations from spills. The important parameters needed for analysis of instantaneous ammonia spills are the following:

1. The amount of LNH_3 released;
2. The actual ratio of LNH_3 that evaporates into the atmosphere when the accident happens on or under the water (one minus the partition ratio); and
3. The estimated rate of rise of the NH_3 vapor cloud.

Tank Ruptures on Vessels

Expected ambient concentrations were calculated for distances of 0.2 to 10 miles downwind from a hypothetical vessel accident in which an entire cargo of liquid ammonia (12,000 tons) was spilled into the water instantaneously. It was assumed that (1) the entire spill would spread over a circular area with a radius of about 800 ft and (2) 40 percent of the LNH_3 would evaporate in several minutes.

Downwind distances to points at which selected concentrations were calculated. It should be noted that 0.2 miles is just outside the assumed spill area. It was assumed that concentrations within the spill area would be at least 5000 ppm (and quickly lethal).

Atmospheric Stability Class	**Wind Speed (mph)**	**Downwind Distances (miles) for:**			
		50 ppm	**300 ppm**	**1700 ppm**	**5000 ppm**
A	5	2.0	0.7	<0.2	<0.2
B	11	4.4	1.9	0.8	0.4
C	15	1.2	0.9	0.6	0.4
	25	9.0	3.5	1.6	1.0
D	≤15	<0.2	<0.2	<0.2	<0.2
	25	0.6	0.5	0.4	0.3
	35	1.1	0.9	0.7	0.5
	45	2.0	1.5	1.1	0.8

The maximum durations of exposure for the various concentrations will be along the dispersion centerline in the horizontal plane at the ground and in the direct downwind direction. Away from this centerline, durations of similar concentrations will be shorter.

Atmospheric Stability Class	**Wind Speed (mph)**	**Estimated Duration (minutes) for:**			
		≥50 ppm	**≥300 ppm**	**≥1700 ppm**	**≥5000 ppm**
		At a distance of 0.5 mile			
A	5	19	8	0	0
B	11	9	7	4	0
C	15	4	3	1	0
	25	3	3	2	1
D	≤15	0	0	0	0
	25	<1	0	0	0
	35	1	1	<1	<0.5
	45	1	1	<1	<0.5

The calculated exposure values indicate that:

For atmospheric stability classes A and B, which involve only low wind speeds, ambient concentrations at a given distance are relatively low, but exposure durations are longer.

For stability classes C and D, which generally involve higher wind speeds, ambient concentrations at a given distance are relatively high, but exposure durations are relatively short.

The ammonia cloud is not expected to touch the ground surface within 10 miles for stability classes E and F, because of the small dispersion coefficients and rapid rise of the NH_3 cloud. For all atmospheric stability classes, under certain terrain conditions, ambient concentrations higher than those calculated may occur, depending upon relative altitude and distance from the spill. As an example, a rising plume may strike the ground in an area of extreme topography or if high buildings are nearby.

In fog or low cloud conditions, some spilled NH_3 would react with the water vapor, becoming NH_4OH. This reaction would cause lower ambient concentrations and longer durations than shown. In fog or a low stratus cloud layer, the lateral spread is expected to be small. In cumulus clouds, there would be greater lateral and vertical spreading. Since an NH_4OH molecule is about twice as heavy as a water molecule, it is expected that fallout would occur, primarily near the scene of the accident.

Transfer Sills

Transfer spills could occur during the loading or off-loading of a vessel, truck or rail car. When modeling a potential spill in this category, it is assumed that the LNH_3 from a transfer spill would spread evenly on the land and completely evaporate in one hour or, for a spill duration of greater than one hour, for the duration of the spill. It also would be assumed that none of the ammonia would run off into the water. The spill would then act as a continuous source, allowing use of the Gaussian dispersion model for a continuous point ground level source to predict concentrations downwind. Other malfunctions, such as venting from relief valves on vessels, storage tanks, trucks, and rail cars, can be described by the same model, with the only variation being the rate of venting or evaporation.

The highest concentrations would be estimated for stability class D, as discussed previously. For planning purposes, the calculations should be based on a wind speed of 10 mph because this value represents the most turbulent conditions expected to occur in class D.

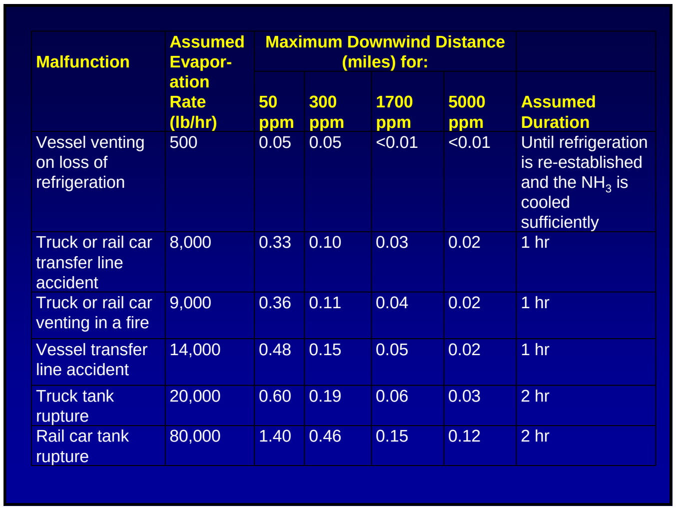
Venting Leaks

With loss of refrigeration, LNH_3 will begin to boil (vaporize). As heat is absorbed from the surroundings, the temperature and pressure inside the tank will rise. Because of the heavy insulation of large LNH_3 storage tanks, about 4 hours without refrigeration can elapse before the relief valves begin to vent. Even higher pressure settings on relief valves on vessels means that several days without refrigeration would be required before the internal pressure would build to the point where venting begins. Maximum venting rates are expected to be about 200 to 500 lb/hr for vessel tanks.

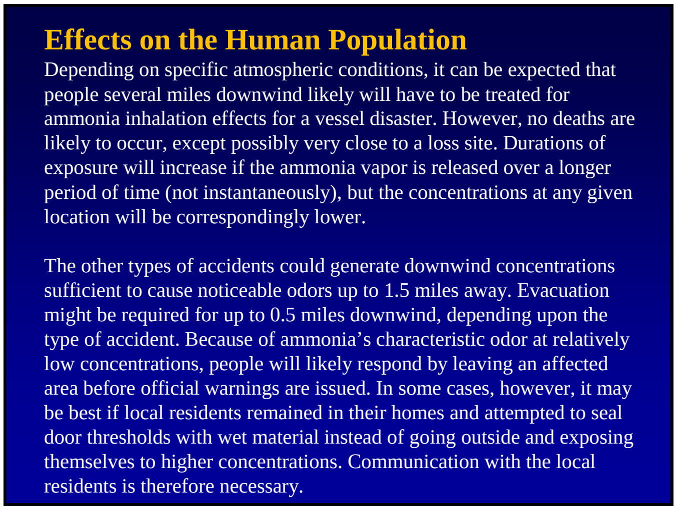
Trucks and trains are designed to transport liquid ammonia under pressure at ambient temperatures. A fire in or near a truck or rail car could cause relief valves to open. The rate capacity of the relief valves is about 4.5 tons/hr of NH_3. The heat from a fire, in addition to causing the ammonia to boil, would create a strong updraft which likely would cause the ammonia vapors to quickly rise. A fire could also incinerate some of the ammonia vapors. Both of these conditions would combine to reduce ground level concentrations to below those predicted.

Tank Ruptures

Trucks and trains are susceptible to accidents which could create more serious hazard conditions than venting. The worst accident situation would be one in which the tank ruptured and instantaneously spilled 20 tons of LNH_3 (truck) or 80 tons of LNH_3 (rail car) onto the ground without a fire. Without the additional heat from a fire, no special supporting updraft would be created, and the ammonia cloud, though rising, would stay closer to the ground for a greater distance downwind, especially if foggy or rainy, or under strong inversion conditions. It typically is assumed that the entire cargo would spread out to a uniform depth of about 3 inches (EPA 1999 assumes a pool depth of 1 cm and the corresponding pool would therefore be about 7.5 times larger. The total evaporation rate would be similarly larger, but for a shorter duration). Ammonia pools of 3 inches in depth are expected to evaporate in approximately 2 hours. The evaporation rate would be 40 ton/hr (rail car) and 10 tons/hr (truck). If the LNH_3 is contained in a smaller area, if a smaller total amount spills, or if the atmosphere is in a condition other than class D and/or has higher wind speeds, ammonia concentrations downwind are expected to be less. Similarly, if the pool was 1 cm deep (as assumed by the EPA 1999 method), the ammonia would evaporate in about 15 minutes. The evaporation rate would be about 300 ton/hr (rail car) and 75 tons/hr (truck), and the corresponding downwind concentrations would be about 7.5 times larger than if a 3 inch pool was formed.



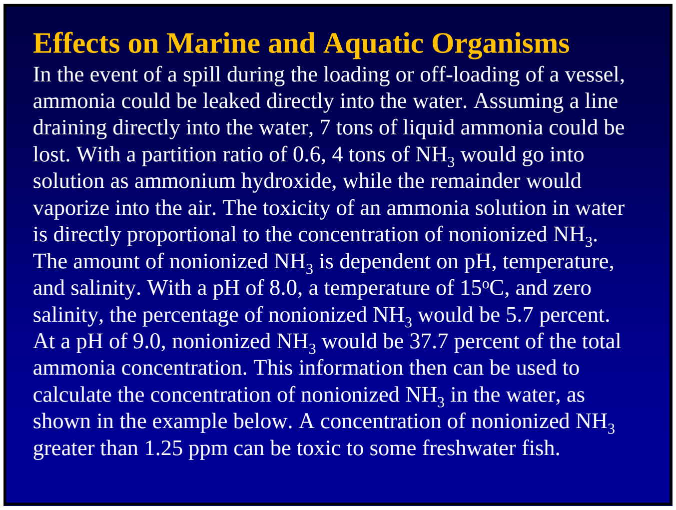
Malfunction	Assumed Evapor-ation Rate (lb/hr)	Maximum Downwind Distance (miles) for:				
		50 ppm	300 ppm	1700 ppm	5000 ppm	Assumed Duration
Vessel venting on loss of refrigeration	500	0.05	0.05	<0.01	<0.01	Until refrigeration is re-established and the NH_3 is cooled sufficiently
Truck or rail car transfer line accident	8,000	0.33	0.10	0.03	0.02	1 hr
Truck or rail car venting in a fire	9,000	0.36	0.11	0.04	0.02	1 hr
Vessel transfer line accident	14,000	0.48	0.15	0.05	0.02	1 hr
Truck tank rupture	20,000	0.60	0.19	0.06	0.03	2 hr
Rail car tank rupture	80,000	1.40	0.46	0.15	0.12	2 hr



Effects on the Human Population

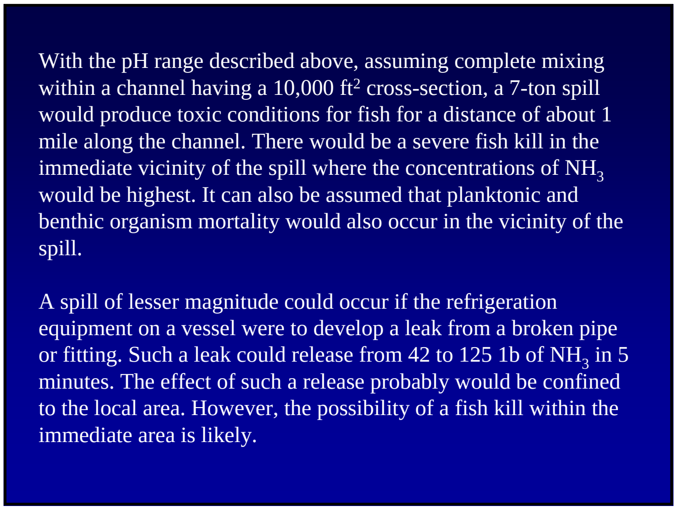
Depending on specific atmospheric conditions, it can be expected that people several miles downwind likely will have to be treated for ammonia inhalation effects for a vessel disaster. However, no deaths are likely to occur, except possibly very close to a loss site. Durations of exposure will increase if the ammonia vapor is released over a longer period of time (not instantaneously), but the concentrations at any given location will be correspondingly lower.

The other types of accidents could generate downwind concentrations sufficient to cause noticeable odors up to 1.5 miles away. Evacuation might be required for up to 0.5 miles downwind, depending upon the type of accident. Because of ammonia's characteristic odor at relatively low concentrations, people will likely respond by leaving an affected area before official warnings are issued. In some cases, however, it may be best if local residents remained in their homes and attempted to seal door thresholds with wet material instead of going outside and exposing themselves to higher concentrations. Communication with the local residents is therefore necessary.



Effects on Marine and Aquatic Organisms

In the event of a spill during the loading or off-loading of a vessel, ammonia could be leaked directly into the water. Assuming a line draining directly into the water, 7 tons of liquid ammonia could be lost. With a partition ratio of 0.6, 4 tons of NH_3 would go into solution as ammonium hydroxide, while the remainder would vaporize into the air. The toxicity of an ammonia solution in water is directly proportional to the concentration of nonionized NH_3. The amount of nonionized NH_3 is dependent on pH, temperature, and salinity. With a pH of 8.0, a temperature of $15^{o}C$, and zero salinity, the percentage of nonionized NH_3 would be 5.7 percent. At a pH of 9.0, nonionized NH_3 would be 37.7 percent of the total ammonia concentration. This information then can be used to calculate the concentration of nonionized NH_3 in the water, as shown in the example below. A concentration of nonionized NH_3 greater than 1.25 ppm can be toxic to some freshwater fish.



With the pH range described above, assuming complete mixing within a channel having a 10,000 ft^2 cross-section, a 7-ton spill would produce toxic conditions for fish for a distance of about 1 mile along the channel. There would be a severe fish kill in the immediate vicinity of the spill where the concentrations of NH_3 would be highest. It can also be assumed that planktonic and benthic organism mortality would also occur in the vicinity of the spill.

A spill of lesser magnitude could occur if the refrigeration equipment on a vessel were to develop a leak from a broken pipe or fitting. Such a leak could release from 42 to 125 1b of NH_3 in 5 minutes. The effect of such a release probably would be confined to the local area. However, the possibility of a fish kill within the immediate area is likely.

In the unlikely event that a catastrophic accident were to occur causing the release of an entire vessel's contents, approximately 12,000 tons of NH_3 could be released into the water. Such a spill could ultimately cause toxic concentrations of NH_3 throughout a large area. The size of the affected area would change as the contaminated water moves downstream. There would be massive mortalities of fish, plankton, shellfish, and other benthic organisms.

A long-term result of any ammonia spill would be increased eutrophication of the receiving waters, depending on the presence of other needed nutrients. The additional nutrient levels could stimulate noxious blooms of algae, which would cause continuous water quality degradation.

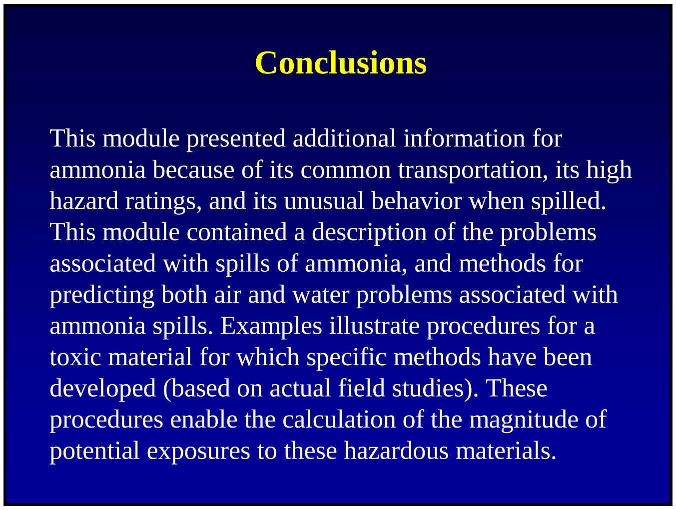
Effects on Terrestrial Biology

Regardless of where a total vessel spill occurred along an inland route, high concentrations of ammonium hydroxide would likely reach shore. If this chemical floated into any of the wetlands bordering the shipping route, much of the vegetation would be killed, potentially causing destruction of important habitat for waterfowl, shorebirds, and other shore species.

Waterfowl and shorebirds present in the wetlands at the time the ammonium hydroxide came into shore could be directly affected. A large number of birds could be killed by ingestion of the chemical. The ammonium hydroxide could also strip protective oils from the feathers of waterfowl, causing the loss of the birds' natural water repellency. In this case, birds would die either from drowning or from infections contracted as a result of getting wet.

The ammonia which would escape into the atmosphere would form a plume with a concentration of several thousand ppm at its center. Concentrations of 1700 ppm or more of ammonia would occur for several minutes at sea level for a distance of several miles downwind from the location of a vessel accident or for longer periods but over a smaller area if the ship leaked slowly. It is likely that any bird or animal exposed to these high concentrations of ammonia would be injured or rapidly killed. Birds in the vicinity of the accident could possibly become disoriented in their attempts to escape the odor and might fly into the lethal part of the plume. If the vessel broke up near shore, animal and birds could be killed for several miles inland.

Severe damage to vegetation would also be expected to occur. The extent of this damage would depend upon the resistance of individual plant species to ammonia and the time of year the spill occurred. Plant species differ in their sensitivity to ammonia. It is possible that some species may be able to withstand high concentrations of the gas for several minutes. In the spring or summer, a concentrated ammonia plume would probably severely damage most vegetation that it contacts. Perennial species in the natural flora would be most affected by ammonia in the summer and early fall when they are under the greatest physiological stress because of low soil moisture. Since seeds are most resistant to ammonia, annual species in the natural flora would not be greatly affected during summer months. These species would be hardest hit in the spring or fall.



Conclusions

This module presented additional information for ammonia because of its common transportation, its high hazard ratings, and its unusual behavior when spilled. This module contained a description of the problems associated with spills of ammonia, and methods for predicting both air and water problems associated with ammonia spills. Examples illustrate procedures for a toxic material for which specific methods have been developed (based on actual field studies). These procedures enable the calculation of the magnitude of potential exposures to these hazardous materials.