Ammonia
September 2003

Introduction

Ammonia is a naturally occurring compound found in the soil as a product of bacterial action on decaying organic matter. As a key intermediate in the nitrogen cycle, ammonia is essential in many biological processes, such as the formation of nitrates and nitrites, as well as being a nutrient for many bacteria and plants. It is also essential for the creation of proteins and other nitrogen compounds such as the base compounds of DNA

Ammonia: Overview

Most adults have encountered ammonia before and recognize the distinctive, sharply irritating odor of this colorless gas. It quickly evaporates and readily dissolves in water, forming ammonium hydroxide in solution. A lesser known property of the gas is that it is somewhat flammable at concentrations of 15% to 25% by volume in air. Ammonia's odor threshold is quite low, 5 parts per million, which is well below the concentration at which the first symptoms of eye irritation occur. This low threshold is also good in that it alerts the individual to move from the area of exposure. Unfortunately olfactory fatigue is known to occur fairly rapidly, creating a risk for prolonged exposure.

Ammonia is commercially manufactured for use in fertilizer, textiles, plastics, explosives, pulp and paper production, food and beverages, household cleaning products, refrigerants (as anhydrous ammonia), and other products. It is commonly available in liquid form, either pressurized in tanks or dissolved in water as ammonium hydroxide, an alkaline solution that can be highly corrosive.

Its use as a terrorist weapon is anticipated because of its easy availability. Although rarely lethal in the concentrations that a terrorist attack could generate, an attack with ammonia could potentially disable many people and burden our healthcare system with acute and long-term patients.

Ammonia: Toxicity

Since ammonia is a naturally occurring substance whose concentrations vary based on a number of factors such as pH and temperature, it is difficult to assess uniform safe levels in water or air. Any environmental release greater than 100 pounds of ammonia or 1,000 pounds of ammonium salts must be reported to the EPA. For air exposure, OSHA has set a limit of 50 parts per million over an 8-hour workday, 40-hour workweek. In disagreement, however, NIOSH, the National Institute of Occupational Safety and Health, advises that workplace air should not exceed 25 ppm ammonia averaged over a 10-hour workday or 40-hour workweek. That is half the level advised by OSHA. For short-term exposures up to 15 minutes, a maximum concentration of 35 ppm is recommended.

From a clinical perspective, ammonia typically produces physiologic symptoms at around 20 parts per million, and significant injury can be seen at levels greater than 100 parts per million. Prolonged exposure to 300 parts per million is known to cause serious injury or death.

As a gas, ammonia's main route of toxicity is inhalation. While anhydrous ammonia is lighter than air, vapors from liquefied gas are initially heavier than air and may spread along the ground causing asphyxiation in poorly ventilated or enclosed areas. Because of this, children may be more vulnerable to the effects of ammonia gas since a child's short stature places him at the point of greatest exposure. Also, inexperience limits the child's ability to recognize the danger and move from the area. Very young children may not be able to move from the area on their own. From a physiologic perspective, children also have smaller airway diameters, a higher minute volume per kilogram of weight, and a greater lung surface area to body weight ratio – all of which increases the level of exposure and potential for injury.

Protective Equipment

There are a variety of rubber and plastic materials capable of resisting ammonia, and very effective protective gear is available. Emergency personnel should wear protective clothing and masks that are appropriate to the type of exposure they expect to encounter. In areas of high ammonia gas concentrations, positive-pressure, self-contained breathing apparatus (SCBA) is recommended. It is also important that emergency vehicles carry ammonia-resistant plastic sheeting and bags to contain and isolate contaminated clothing and other materials. This prevents further spread and secondary exposure to the chemical.

Detection

Ammonia's distinctively irritating odor makes it relatively easy to identify, especially for anyone who has encountered it before. In addition, there are a wide

variety of commercially available monitors and gas sensors that can be used to detect ammonia's presence in an area before serious exposures can occur. Water detectors sense ammonia in a range of 1 – 500 mg/L. Air detectors take ammonia from the air, dissolve it water and use an ion chromatograph to analyze the ammonia level in the water sample. These are sensitive down to 0.02 $\mu gm/m^3$.

Decontamination

The first rule of decontamination is to remove victims from the area of exposure and into fresh air. Following that, the victim's clothing should be removed to limit continued exposure to ammonia trapped within the fibers of the clothes. If the eyes have been exposed, they should be flushed immediately with copious amounts of lukewarm water for a minimum of 15 minutes or until the conjunctival fluid pH has normalized to around 7.35. If contact lenses are present, they should be removed carefully so as to avoid additional corneal damage. Likewise, exposed skin and hair should be flushed well with water for at least 5 minutes, followed by a thorough washing with soap and water and an additional rinse.

Although uncommon, gastrointestinal exposures can occur if a solution of ammonium hydroxide is ingested. In such situations, administer 4 to 8 ounces of water or milk to these who can safely swallow. Do not induce emesis, perform gastric lavage, attempt neutralization, or administer activated charcoal in these cases.

Signs and Symptoms

The diagnosis of ammonia exposure is a clinical one that is confirmed by detection of the chemical at the site of exposure. Whether the exposure is to ammonia as a gas or liquid, as well as the duration of the exposure, will also be factors in the signs and symptoms displayed by the victim.

Ophthalmic exposure will occur in most likely scenarios. As noted, eye symptoms usually begin at a concentration of 20 parts per million. Such levels can be achieved in common household exposures where 5% ammonia solutions are found in cleaning products. At these low levels, there will be irritation of the eyes, and possibly the skin, but little damage. At levels above 25% for solutions or above 100 parts per million for the gas, there will be pain, inflammation, and more extensive eye injury involving the cornea. As levels increase, blisters, necrosis, and deep penetrating burns can occur. The damage will be more extensive in moist areas where the ammonia can dissolve in water and form a corrosive, alkaline solution of ammonium hydroxide. Healthcare providers should also be alert to frostbite injuries in victims exposed to liquefied ammonia.

In the rare event of ammonium hydroxide ingestion, there will be nausea, vomiting, and abdominal pain. If the solution involved has a concentration of

10% or higher, serious burns of the mouth, pharynx, esophagus, and stomach, are likely and care must be taken in placing nasogastric tubes or performing endoscopy.

Signs and Symptoms

As a gas, ammonia causes serious injury by inhalation. Breathing very small amounts of ammonia for even short periods can have adverse effects on the respiratory system. At low concentrations of gas, from 20 to 100 parts per million, there will be eye and nasal irritation, sore throat, lacrimation, rhinorrhea, and coughing. At concentrations greater than 100 parts per million, nasopharyngeal and tracheal burns, bronchiolar and alveolar edema, and airway destruction can occur. If the injury is severe, respiratory distress or failure will develop. As pulmonary symptoms worsen, there will be tachypnea, dyspnea, cyanosis, wheezing, rales, a feeling of suffocation, and, in more serious injuries, hemoptysis. In addition, bronchiolar edema can narrow the airways to an extent that causes significant airway obstruction. Pulmonary injury may progress over 24 hours and ultimately result in lung collapse. Since there can be a delay in the presentation of symptoms, anyone complaining of shortness of breath, severe cough, or chest tightness following ammonia exposure should be hospitalized and, at a minimum, observed until he or she is symptom-free.

The cardiovascular system is also affected by ammonia toxicity with hypertension being reported most frequently. Be aware that such a blood pressure rise can reach malignant levels and be very difficult to control. Myocardial infarct and cardiac deaths have also been reported following serious ammonia exposure.

Treatment

The treatment of ammonia exposure starts with decontamination and basic first aid, including advanced life support as indicated for those patients who are comatose, hypotensive, seizing, or displaying dysrhythmias. There is no specific antidote or treatment for ammonia toxicity and care is primarily supportive.

Following decontamination, the eyes should be thoroughly examined and visual acuities determined. Chemical conjunctivitis should be treated appropriately, and corneal burns require urgent ophthalmologic consultation. It is also advised that all ophthalmic injury be re-evaluated by an ophthalmologist within 24 hours, with the understanding that the full extent of eye injuries may not be evident for up to a week.

Serious chemical burns to the skin, should be treated as thermal burns. Full-thickness burns require evaluation of a surgeon or tertiary burn center as indicated. All mild to moderate skin burns should be re-assessed within 24 hours. For frostbite injuries, the involved area should be gradually rewarmed using a water bath at a temperature of 102 to 108 degrees Fahrenheit, or 40 to 42 degrees

Celsius. This should continue until a pink to red flush returns to the skin, often within 20 to 30 minutes.

Treatment

The treatment of cardiopulmonary injury will be dependent upon the level of exposure, and mild injuries may only require observation and supportive care. Victims of mild to moderate pulmonary exposures will benefit from the administration of humidified 100% oxygen and typically may be released once their symptoms have resolved. However, pulmonary injury may evolve over 18 to 24 hours, so at the first sign of laryngeal edema or airway compromise it is critical to secure the airway and maintain ventilation using endotracheal intubation under direct visualization or cricothyroidotomy. Because of possible damage to the nasopharynx and airways, blind nasotracheal intubation or the use of an esophageal obturator must be avoided. The damaged airways increase the victim's risk for pneumonia, and if there are mental status changes, the risk for aspiration pneumonia is great, further indicating the need for a secure airway. So, be aware of this risk and consider prophylactic antibiotic treatment in severe pulmonary injuries. The organisms most likely to produce problems are those typically found in nosocomial infections: enteric gram negative rods, streptococcus pneumoniae, haemophillus influenza, and methicillin-sensitive staphylococcus aureus, as well as anaerobes, legionella, acinetobacter, and pseudomonas aeruginosa. Methicillin-resistant staph (MRSA) must also be considered if encountered in your hospital. Empiric treatment would follow the ATS 3 guidelines for severe pneumonia with risk factors. This includes ciprofloxacin or an aminoglycoside, plus either piperacillin, piperacillin/tazobactam, a third generation cephalosporin, aztreonam, or imipenem. Vancomycin should be considered if MRSA is suspect.

For patients in bronchospasm, the use of aerosolized bronchodilators is warranted in an ammonia exposure if not contraindicated. For stridor in children, racemic epinephrine at a dose of 0.25 to 0.75 milliliters of 2.5% solution in 2.5 milliliters of sterile water, repeating this dose every 20 minutes as needed, may be helpful.

The blood pressure of hypertensive patients should be lowered medically and patients should be monitored closely for evidence of cardiac injury.

Long Term Medical Sequelae

Unlike some of the agents that might be likely terrorist weapons, ammonia is known for the potential of long-term complications. Residual bronchoconstriction, bronchiectasis, small airway disease, and chronic lung disease can develop following severe inhalation injury. All inhalation victims who were initially symptomatic should be observed carefully and reexamined periodically, including annual pulmonary function testing. With ammonia-related eye injuries, ulceration and perforation of the cornea can develop weeks or even

months after exposure, with the potential for permanent blindness. Cataracts and glaucoma have also been reported following acute exposures. Ingestion injuries may result in permanent damage to the mucous membranes of the alimentary canal, with bleeding, perforation, scarring, or stricture formation as potential sequelae. The reproductive, carcinogenic, and teratogenic effects of ammonia are not known.

Environmental Sequelae

Since ammonia occurs naturally and is readily taken up from soil and water by plants and bacteria to be reused through the nitrogen cycle, there is less potential for environmental disaster compared to other chemicals which might be used in a terrorist attack. However, major spills can cause environmental damage by producing overgrowth of aquatic plants and the depletion of oxygen in the water, and through the corrosive effects of ammonium hydroxide.

Summary

In summary, ammonia is expected to have potential for terrorist use because it is inexpensive and readily available, either commercially or by direct production. As a weapon it is less likely to exact a high mortality rate, but it can be very disabling and tax our healthcare system. Exposures to low concentrations, in the range of 20 to 100 parts per million, may result in little more than skin and eye irritation; while exposures to higher concentrations may result in dermal burns, nasopharyngeal and tracheal burns, bronchiolar and alveolar edema, and airway destruction resulting in respiratory distress or failure. Prolonged exposure to concentrations greater than 300 parts per million can cause permanent injury or death. In terms of therapy, decontamination and basic first aid are critical. Basic first aid should be administered with primarily supportive care. Advanced life support guidelines should be followed where appropriate.

References:

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