Scientists often categorize hazardous chemicals by the type of chemical or by the effects a chemical would have on people exposed to it. The categories/types used by CDC are as shown below. For select agents, the CDC provides medical management guidelines for acute chemical exposures. Click a link (blue) below to view the guidelines for a specific agent or use the scroll bar to browse the pages of the PDF file.

**Biotoxins**
*Poisons that come from plants or animals*
- Abrin
- Brevetoxin
- Colchicine
- Digitalis
- Nicotine
- Ricin
- Saxitoxin
- Strychnine
- Tetrodotoxin
- Trichothecene

**Blood Agents**
*Poisons that affect the body by being absorbed into the blood*
- Arsine (SA)
- Carbon Monoxide
- Cyanide
  - Cyanogen chloride (CK)
  - Hydrogen cyanide (AC)
  - Potassium cyanide (KCN)
  - Sodium cyanide (NaCN)
- Sodium monofluoroacetate (compound 1080)

**Blister Agents/Vesicants**
*Chemicals that severely blister the eyes, respiratory tract, and skin on contact*
- Mustards
  - Distilled mustard (HD)
  - Mustard gas (H) (sulfur mustard)
  - Mustard/lewisite (HL)
  - Mustard/T
  - Nitrogen mustard (HN-1, HN-2, HN-3)
  - Sesqui mustard
  - Sulfur mustard (H) (mustard gas)
- Lewisites/chloroarsine agents
  - Lewisite (L, L-1, L-2, L-3)
  - Mustard/lewisite (HL)
- Phosgene oxime (CX)

**Caustics (Acids)**
*Chemicals that burn or corrode people’s skin, eyes, and mucus membranes (lining of the nose, mouth, throat, and lungs) on contact*
- Hydrofluoric acid (hydrogen fluoride)

**Choking/Lung/Pulmonary Agents**
*Chemicals that cause severe irritation or swelling of the respiratory tract (lining of the nose, throat, and lungs)*
- Ammonia
- Bromine (CA)
- Chlorine (CL)
- Hydrogen chloride
- Methyl bromide
- Methyl isocyanate
- Osmium tetroxide
- Phosgene
  - Diphosgene (DP)
  - Phosgene (CG)
- Phosphine
- Phosphorus, elemental, white or yellow
- Sulfuryl fluoride

**Incapacitating Agents**
*Drugs that make people unable to think clearly or that cause an altered state of consciousness (possibly unconsciousness)*
- BZ
- Fentanyls & other opioids

**Long-Acting Anticoagulants**
*Poisons that prevent blood from clotting properly, which can lead to uncontrolled bleeding*
- Super warfarin

**Metals**
*Agents that consist of metallic poisons*
- Arsenic
- Barium
- Mercury
- Thallium

**Nerve Agents**
*Highly poisonous chemicals that work by preventing the nervous system from working properly*
- G agents
  - Sarin (GB)
  - Soman (GD)
  - Tabun (GA)
- V agents
  - VX

**Organic Solvents**
*Agents that damage the tissues of living things by dissolving fats and oils*
- Benzene

**Riot Control Agents/Tear Gas**
*Highly irritating agents normally used by law enforcement for crowd control or by individuals for protection (for example, mace)*
- Bromobenzylcyanide (CA)
- Chloroacetophenone (CN)
- Chlorobenzylidenemalononitrile (CS)
- Chloropicrin (PS)
- Dibenzoxazepine (CR)

**Toxic Alcohols**
*Poisonous alcohols that can damage the heart, kidneys, and nervous system*
- Ethylene glycol

**Vomiting Agents**
*Chemicals that cause nausea and vomiting*
- Adamsite (DM)

All Medical Management Guidelines provided in this document were developed by the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. The MMGs comprise Volume III of the three volume ATSDR Managing Hazardous Material Incidents (MHMI) series. You may obtain more information about the complete MHMI series, at the MHMI home page:
Blister Agents
Lewisite (L) \((\text{C}_2\text{H}_2\text{AsCl}_3)\) CAS 541-25-3, UN 1556; and Mustard-Lewisite Mixture (HL) CAS Number not available, UN 2810

Synonyms for Lewisite include L, arsine (2-chlorovinyl) dichloro-, arsenous dichloride (2-chloroethenyl)-, chlorovinylarsine dichloride, 2-chlorovinylidichloroarsine, beta-chlorovinylidichloroarsine, dichloro-(2-chlorovinyl)arsine, EA1034.

Synonyms for Mustard-Lewisite include HL and Sulfur Mustard/Lewisite.

Persons whose skin or clothing is contaminated with liquid Lewisite or Mustard-Lewisite Mixture can contaminate rescuers by direct contact or through off-gassing vapor.

- **Lewisite** is an oily, colorless liquid with an odor like geraniums. Mustard-Lewisite Mixture is a liquid with a garlic-like odor. Volatility of both agents is significant at high ambient temperatures.

- Lewisite and Mustard-Lewisite Mixture are rapidly absorbed by the skin causing immediate pain and burning followed by erythema and blistering. Ocular exposure to Lewisite or the mixture may cause immediate incapacitating burning and inflammation of the cornea and conjunctiva. Inhalation damages the respiratory tract epithelium and may cause death.

**Description**

Lewisite is an organic arsenical known for its vesicant properties. Pure Lewisite is an oily, colorless liquid, while impure Lewisite is amber to black. It remains a liquid at low temperatures and is persistent in colder climates. It has the odor of geraniums.

Mustard-Lewisite Mixture is a liquid mixture of distilled Mustard (HD) and Lewisite. Due to its low freezing point, the mixture remains a liquid in cold weather and at high altitudes. The mixture with the lowest freezing point consists of 63% Lewisite and 37% Mustard. It has a garlic-like odor.

**Routes of Exposure**

**Inhalation**

Exposure to Lewisite vapor at a concentration of 8 \text{mg-min/m}^3\text{3} causes immediate burning pain of the respiratory tract. Its odor is noted at about 20 \text{mg-min/m}^3\text{3}. The L\text{C}_\text{50} (the product of concentration times time that is lethal to 50\% of the exposed population by inhalation) is approximately 1,500 \text{mg-min/m}^3\text{3}. Exposure to Mustard-Lewisite Mixture vapor induces immediate respiratory tract irritation and severe inflammation after a few
hours latency period. Both agents are readily absorbed from the lungs.

**Skin/Eye Contact**

Absorption may occur after skin or eye contact with liquid or vapor Lewisite. Absorption across the skin begins within minutes. Vesication is caused by about 14 µg of liquid, and the LD₅₀ of liquid on the skin is about 30-50 mg/kg. Liquid Lewisite causes severe eye damage within minutes of contact. The vapor also acts quickly, with pain on contact, followed by edema of the conjunctiva and eyelids, and iritis and corneal damage with high doses.

Systemic absorption may occur following skin or eye exposure to liquid or vapor Mustard-Lewisite Mixture. The mixture causes immediate stinging pain of the skin, with blistering delayed for hours. Graying of the skin will follow within a very short time if exposure is from liquid (because of Lewisite). Erythema and blisters will appear earlier than from mustard alone. Exposure of the eyes to Mustard-Lewisite Mixture produces lacrimation and inflammation of the conjunctiva and cornea. After exposure to low amounts of Lewisite or to the mixture, temporary loss of eyesight may occur because of blepharospasm or eyelid edema. After exposure to high amounts, permanent loss of sight may occur because of corneal damage; however, this is unusual.

**Ingestion**

Ingestion of either Lewisite or Mustard-Lewisite Mixture is an uncommon route for exposure but can lead to local effects and systemic absorption.

**Sources/Uses**

Lewisite is an arsenical vesicant that was first synthesized in 1918. Large amounts were produced by the United States to be used in Europe; however, World War I ended while the shipment was at sea and the vessel was sunk. There have been allegations that it was used by Japan against Chinese forces in the late 1930s; however, there are no confirmed reports that it has been used in warfare, although it may be stockpiled by some countries. Destruction of U.S. stockpiles of chemical agents, including Lewisite, was mandated by the Chemical Weapons Convention to take place before April 2007.

Mustard-Lewisite Mixture is a mixture of distilled Mustard and Lewisite developed to achieve a lower freezing point for ground dispersal and aerial spraying.
Guidelines

Lewisite and Mustard-Lewisite Mixture: Airborne Exposure Limit (as recommended by the Surgeon General’s Working Group, U.S. Department of Health and Human Services) = 0.003 mg/m³ as a time-weighted average (TWA) for the workplace and a 72-hour TWA for the general population.

Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Lewisite</th>
<th>Mustard-Lewisite Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Oily, colorless liquid</td>
<td>Dark, oily liquid</td>
</tr>
<tr>
<td>Warning properties</td>
<td>Odor like geraniums</td>
<td>Garlic-like odor</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>207.32</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>(760 mm Hg) = 374 °F (190 °C)</td>
<td>(760 mm Hg) = Indefinite, but below 374 °F (190 °C)</td>
</tr>
<tr>
<td>Freezing point</td>
<td>0.4 °F (-18 °C)</td>
<td>13 °F (-25.4 °C) (purified mix), -43.6 °F (-42 °C) (typical production batch)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.888 at 68 °F (20 °C) (water = 1.0)</td>
<td>1.60 at 68 °F (20 °C) (water = 1.0)</td>
</tr>
<tr>
<td>Vapor pressure</td>
<td>0.394 mm Hg at 68 °F (20 °C)</td>
<td>0.248 at 68 °F (20 °C)</td>
</tr>
<tr>
<td>Vapor density</td>
<td>7.1 (air = 1.0)</td>
<td>6.5 (air = 1.0)</td>
</tr>
<tr>
<td>Liquid density</td>
<td>1.89 g/cm³ at 77 °F (25 °C)</td>
<td>1.66 g/cm³ at 68 °F (20 °C)</td>
</tr>
<tr>
<td>Flash point</td>
<td>Does not burn easily. When heated, emits toxic fumes of hydrogen chloride and arsenic.</td>
<td>Data not available on flammability. Toxic fumes of hydrogen chloride, sulfur oxides, and arsenic may be produced in a fire.</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>Negligible</td>
<td>Practically insoluble</td>
</tr>
<tr>
<td>Volatility</td>
<td>4,480 mg/m³ (20 °C)</td>
<td>No data</td>
</tr>
<tr>
<td>NAERG#</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

Incompatibilities

Heating causes Lewisite to yield arsenic trichloride, tris-(2-chlorovinyl)arsine, and bis-(2-chlorovinyl)chloroarsine.

Mustard-Lewisite Mixture is rapidly corrosive to brass at 65 °C and will corrode steel at a rate of 0.0001 inches of steel per month at 65 °C. It will hydrolyze into hydrochloric acid, thiodiglycol, and non-vesicant arsenic compounds.
Health Effects

Lewisite and Mustard-Lewisite Mixture are blister agents that are highly and immediately irritating to the skin, eyes, and airways. Contact with liquid or vapor forms may result in skin erythema and blistering, corneal damage and iritis, damage to the airway mucosa, and pulmonary edema.

- Lewisite is a systemic poison binding with thiol groups in many enzymes and may cause pulmonary edema, diarrhea, capillary leakage, and subsequent hypotension.
- Systemic absorption of Mustard-Lewisite Mixture may cause bone marrow suppression due to the alkylating properties of the Mustard component.

### Acute Exposure

Lewisite damages skin, eyes, and airways by direct contact. It inhibits many enzymes, in particular those with thiol groups, such as pyruvic oxidase, alcohol dehydrogenase, succinic oxidase, hexokinase, and succinic dehydrogenase. The exact mechanism by which Lewisite damages cells is not known. Mustard-Lewisite Mixture shares the vesicant properties of Lewisite and the DNA alkylation and cross-linking properties of mustard.

**Dermal**

Lewisite liquid or vapor produces pain and skin irritation within seconds to minutes after contact. For liquid Lewisite, erythema occurs within 15 to 30 minutes after exposure and blisters start within several hours, developing fully by 12-18 hours. For the vapor, response times are a little longer. The Lewisite blister starts as a small blister in the center of the erythematous area and expands to include the entire inflamed area. Mustard-Lewisite Mixture also produces pain and irritation immediately, and erythema within 30 minutes. Blistering is delayed for hours and tends to cover the entire area of reddened skin.

**Ocular**

Lewisite vapor causes pain and blepharospasm on contact. Edema of the conjunctiva and eyelids follows, and the eyes may be swollen shut within an hour. With high doses, corneal damage and iritis may follow. Liquid Lewisite causes severe eye damage on contact. Mustard-Lewisite Mixture also causes ocular effects extremely rapidly. Lacrimation, photophobia, and inflammation of the conjunctiva and cornea may occur.

**Respiratory**

Lewisite and Mustard-Lewisite Mixture are extremely irritating to the respiratory tract mucosa. Burning nasal pain, epistaxis, sinus pain, laryngitis, cough and dyspnea may occur. Necrosis can cause pseudomembrane formation and local airway
obstruction. Pulmonary edema may occur following exposure to high concentrations.

**Gastrointestinal**

Ingestion or inhalation of Lewisite may cause nausea and vomiting. Ingestion of Mustard-Lewisite Mixture produces severe stomach pains, vomiting, and bloody stools after a 15-20 minute latency period.

**Cardiovascular**

High-dose exposure to Lewisite may cause “Lewisite shock,” a condition resulting from increased capillary permeability and subsequent intravascular fluid loss, hypovolemia, and organ congestion.

**Hepatic**

Hepatic necrosis may occur due to shock and hypoperfusion following exposure to high levels of Lewisite.

**Renal**

Exposure to high levels of Lewisite may cause decreased renal function secondary to hypotension.

**Hematopoietic**

Systemic absorption of Mustard-Lewisite Mixture may induce bone marrow suppression and an increased risk for fatal complicating infections.

**Potential Sequelae**

Chronic respiratory and eye conditions may persist following exposure to large amounts of Lewisite or Mustard-Lewisite Mixture.

**Chronic Exposure**

Chronic exposure to Lewisite may lead to arsenical poisoning (see Arsenic MMG). Chronic exposure to Mustard-Lewisite Mixture can cause immune sensitization and chronic lung impairment consisting of cough, shortness of breath, and chest pain.

**Carcinogenicity**

There is only anecdotal evidence for the potential carcinogenicity of Lewisite. However, the data are not definitive and do not support classifying Lewisite as a suspected carcinogen. Repeated exposures to Mustard-Lewisite Mixture over a long period of time may produce respiratory and skin cancer due to the mustard content. There are no specific data regarding the carcinogenicity of Mustard-Lewisite Mixture.

**Reproductive and Developmental Effects**

Human data regarding reproductive/developmental effects of Lewisite are inconclusive because of limited human exposures. Animal studies show no clear evidence of developmental effects.
Prehospital Management

Victims whose skin or clothing is contaminated with liquid Lewisite or Mustard-Lewisite Mixture can contaminate rescuers by direct contact or through off-gassing vapor.

Lewisite and Mustard-Lewisite Mixture cause immediate pain and irritation to the eyes, skin, and respiratory tract. Systemic effects include capillary leakage and subsequent shock.

Decontamination immediately after exposure decreases tissue damage.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201 ), ask for the Staff Duty Officer.

Rescuer Protection

Lewisite and Mustard-Lewisite Mixture are readily absorbed by inhalation and by ocular and dermal contact. Both Lewisite and Mustard-Lewisite Mixture are extremely irritating to the respiratory tract, skin, and eyes.

Respiratory protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any level of Lewisite and Mustard-Lewisite Mixture vapor.

Skin/ocular protection: Personal protective equipment (PPE) and butyl rubber chemical protective gloves are recommended at all times when these chemicals are suspected to be involved.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories:
immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4). Clinical signs and effects of lewisite agents associated with each of these categories are presented in Table 2 (below).

**Before transport, all casualties must be decontaminated.** If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

Patients who have sustained injury to the skin, eyes, or airways and patients who have ingested Lewisite or Mustard-Lewisite Mixture should be transported to a medical facility for evaluation and treatment.

Consult with the base station physician, closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.

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**General principles of triage for chemical exposures are as follows:**

- Check triage tag/card for any previous treatment or triage.
- Survey for evidence of associated traumatic/blast injuries.
- Observe for sweating, labored breathing, coughing/vomiting, secretions.
- Severe casualty triaged as immediate if assisted breathing is required.
- Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
- Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
- If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms. *For Lewisite and Mustard-Lewisite mixture which do not have delayed effects overtriage would not be appropriate.*
- Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.
1. Immediate: casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. Delayed: casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. Minimal: casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. Expectant: casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be triaged to a higher category.

### Table 2. Triage for Lewisite Casualties

<table>
<thead>
<tr>
<th>Category (Priority)</th>
<th>Clinical Signs and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate (1)</td>
<td>Lower respiratory signs (dyspnea, productive cough)</td>
</tr>
<tr>
<td>Delayed (2)</td>
<td>Eye lesions with impaired vision; moderate sized skin lesions for liquid exposure or any body surface burn for vapor exposure; lower respiratory symptoms (cough with sputum production)</td>
</tr>
<tr>
<td>Minimal (3)</td>
<td>Minor eye lesion with no vision impairment; small skin lesions in noncritical areas; minor upper respiratory symptoms (cough, sore throat).</td>
</tr>
<tr>
<td>Expectant (4)</td>
<td>Lower respiratory signs (dyspnea, necrosis); skin lesion covering more than half of body surface area from liquid exposure</td>
</tr>
</tbody>
</table>

**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be
removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

**Decontamination Zone**

All victims require decontamination (see *Basic Decontamination*, below). Rapid decontamination is critical to prevent further absorption by the patient and to prevent exposure to others. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

**Rescuer Protection**

Personnel should wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control bleeding, if present.

**Basic Decontamination**

To significantly reduce tissue damage, the eyes and skin must be decontaminated **within 1 or 2 minutes** after exposure. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller’s earth. If exposure to vapor only is certain, remove outer clothing and wash exposed areas with soap and water or 0.5% solution.
of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis.

Transfer to Support Zone
As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone
Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders
Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.

Additional Decontamination
In cases of ingestion, do not induce emesis.

Advanced Treatment
Intubate the trachea in cases of respiratory compromise. When the patient’s condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility
Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.
Emergency Department Management

Patients whose skin or clothing is contaminated with liquid Lewisite and Mustard-Lewisite Mixture can contaminate rescuers by direct contact or through off-gassing vapor.

Lewisite and Mustard-Lewisite Mixture cause immediate pain and irritation to the eyes, skin, and respiratory tract. Systemic effects include capillary leakage and subsequent shock. The Mustard-Lewisite Mixture may cause bone marrow suppression due to the mustard component.

British Anti-Lewisite (BAL) can be given by intramuscular injection as an antidote for systemic effects but has no effect on the local lesions of the skin, eyes, or airways. Treatment consists primarily of supportive care.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Personal Protection

If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can only take place inside the hospital if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

Basic Decontamination

Flush the eyes with water for about 5-10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.
Blister Agent (HL, L)

If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered. There are no data regarding the efficacy of activated charcoal after exposure to Lewisite or Mustard-Lewisite Mixture.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see Decontamination Area, above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in ABC Reminders, above). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Triage

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will have pain or irritation if they were exposed. If they have no pain or irritation, they may be sent home and told to return with the onset of symptoms. Following decontamination, patients with signs of airway involvement should be admitted directly to the Critical Care Unit. Whether in the hospital or not, patients with no symptoms should be observed for 18 to 24 hours. Patients arriving later should be evaluated as described below. The sooner after exposure that symptoms occur, the more likely they are to progress and become severe.

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity), treatment with a soothing eye solution such as Visine or Murine, and be advised to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate a need for inpatient care and observation.
Lesions more severe than conjunctivitis should be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Consult an ophthalmologist for patients with severe corneal injuries. Topical analgesics should be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain should be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia. Some authorities feel that topical steroids (used within the first 24 hours only) may reduce inflammation.

**Skin Exposure**

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion and a systemic analgesic, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a significant area of erythema with or without blistering should be admitted for further evaluation.

Most burns are second degree although third degree burns may occur after liquid exposure. In general, small blisters (i.e., <1 cm) should remain roofed and larger ones (i.e., >1 cm) should be unroofed. This is a controversial issue, but many feel that the roof will eventually come off anyway. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Fluids are not lost as they are in thermal burns, and fluid replacement should be according to the general needs of the patient and not according to “burn therapy” formulas. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism. Patients with a large area of second or third degree burns should be transferred to a Burn Unit for further care and reverse isolation.

**Airway Exposure**

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be advised to use a cool steam vaporizer and lozenges or cough drops, and sent home with instructions to return if the symptoms worsen. Intubation should be done at the first sign of more severe effects. A patient with more severe effects (laryngitis, shortness of breath, a productive cough, pulmonary edema, pseudomembrane formation) should be provided with oxygen-assisted ventilation as necessary and
admitted directly to the Critical Care Unit once decontamination has been assured. Signs of damage to the larynx or lower airway indicate oxygen-assisted ventilation with PEEP. Patients with less severe effects should be admitted to a routine care ward.

Lewisite causes systemic capillary leakage, and hypovolemic shock may occur in severely exposed patients. Closely monitor blood pressure, blood volume, and hepatic and renal function.

**Ingestion Exposure**

**Do not induce emesis.** Treat nausea and vomiting with antiemetics.

**Antidotes**

British Anti-Lewisite (BAL), also called Dimercaprol, is a chelating agent shown to reduce systemic effects from Lewisite exposure. Due to toxic side effects, **BAL should be administered only to patients who have signs of shock or significant pulmonary injury.**

Chelation therapy should be performed only by trained personnel. Consultation with the regional poison control center is recommended. The standard dosage regimen is 3 to 5 mg/kg IM every 4 hours for four doses. This regimen can be adjusted depending on the severity of the exposure and the symptoms. Contraindications to BAL include pre-existing renal disease, pregnancy (except in life threatening circumstances) and concurrent use of medicinal iron.

Alkalization of the urine stabilizes the Dimercaprol-metal complex and has been proposed to protect the kidneys during chelation therapy. If acute renal insufficiency develops, hemodialysis should be considered to remove the Dimercaprol-arsenic complex. Side effects of BAL administered at 3 mg/kg are mostly pain at the injection site. At 5 mg/kg, the effects may include nausea; vomiting; headache; burning sensation of the lips, mouth, throat, and eyes; lacrimation; rhinorrhea; salivation; muscle aches; burning and tingling in the extremities; tooth pain; diaphoresis; chest pain; anxiety; and agitation.

**Laboratory Tests**

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, serum electrolytes, and liver and kidney function tests. Consider monitoring hourly fluid intake and output. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for all patients with inhalation exposures. Since Lewisite contains arsenic, urinary arsenic excretion may be helpful if the diagnosis is in doubt. A test for urine thiodiglycol, a metabolite of mustard,
can be performed at specialized laboratories, but is not a routine laboratory measure.

**Disposition and Follow-up**

Patients who have skin, eye, or airway signs and symptoms will require hospitalization, as discussed above.

**Delayed Effects**

Skin burns take up to 18 hours to fully develop. Chemical pneumonitis may begin within 24 hours or up to 3 days after inhalation exposure. Significant systemic absorption of Mustard-Lewisite Mixture may produce a fall in the leukocyte count beginning on days 3 through 5. Erythrocytes and thrombocytes may subsequently fall if bone marrow damage is severe and in this case the risk of life-threatening infection rises.

**Patient Release**

A patient who initially had mild symptoms should be observed for at least 18 to 24 hours after exposure. If no further symptoms develop and there is no significant progression, the patient may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop (see below, Follow-up Instructions, included with the Lewisite and Mustard-Lewisite Mixture Patient Information Sheet).

**Follow-up**

Follow-up laboratory evaluation of bone marrow, hepatic, and renal function should be arranged for severely exposed patients until they are completely recovered. Patients who have mild skin burns or corneal lesions should be reexamined within 24 hours.

**Reporting**

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.
Lewisite and Mustard-Lewisite Mixture
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to Lewisite or Mustard-Lewisite Mixture.

What are Lewisite and Mustard-Lewisite Mixture?
Lewisite is a chemical warfare agent that was first produced in 1918. It has not been used in warfare, although it may be stockpiled by some countries. Mustard-Lewisite Mixture is a mixture of Lewisite and Mustard. It was developed to achieve a lower freezing point for ground dispersal and aerial spraying.

What immediate health effects can be caused by exposure to Lewisite and Mustard-Lewisite Mixture?
Lewisite and Mustard-Lewisite Mixture produce pain and skin irritation immediately after exposure. Both compounds cause skin blisters and damage to the airways and eyes. They are also extremely irritating to the eyes, skin, nose, and throat. Exposure to very high levels may result in kidney and liver damage. Mustard-Lewisite Mixture can also damage the immune system.

Can Lewisite and Mustard-Lewisite poisoning be treated?
Immediate decontamination reduces symptoms. Intramuscular injection of British Anti-Lewisite (BAL) may be used to treat severe conditions but will not prevent lesions on the skin, eye, or airways. Persons who have been exposed to large amounts of Lewisite and Mustard-Lewisite Mixture will need to be hospitalized.

Are any future health effects likely to occur?
Adverse health effects, such as chronic respiratory diseases, may occur from exposure to high levels of these agents. Severe damage to the eye may be present for a long time after the exposure.

What tests can be done if a person has been exposed to Lewisite or Mustard-Lewisite?
There is no specific test to confirm exposure to Lewisite or Mustard-Lewisite Mixture; however, measurement of arsenic in the urine may help to identify exposure.

Where can more information about Lewisite or Mustard-Lewisite be found?
More information about Lewisite and Mustard-Lewisite Mixture can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.
Lewisite and Mustard-Lewisite Mixture
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, shortness of breath, or discolored sputum
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin; fever; or chills

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. __________________ in the practice of __________________.
When you call for your appointment, please say that you were treated in the Emergency Department at ____________________________ Hospital by ____________________________ and were advised to be seen again in ______ days.

[ ] Return to the Emergency Department/ ____________________________ Clinic on (date) ____________ at __ ____________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for ______ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: ____________________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

[ ] Other instructions: _____________________________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ____________________________

________________ or ____________________________, or by checking out the following Internet Web sites: ____________________________; ____________________________.

Signature of patient ____________________________ Date ________________

Signature of physician ____________________________ Date ________________
Blister Agents
Nitrogen Mustard (HN-1) (C₆H₁₃Cl₂N) CAS 538-07-8, UN 2810; Nitrogen Mustard (HN-2) (C₅H₁₁Cl₂N) CAS 51-75-2, UN 2927; and Nitrogen Mustard (HN-3) (C₆H₁₂Cl₃N) CAS 555-77-1, UN 2810

Synonyms:
HN-1: Bis(2-chloroethyl)ethylamine; 2-chloro-N-(2-chloroethyl)-N-ethylethanamine; 2,2'-dichlorotriethylamine; ethylbis(2-chloroethyl)amine; ethyl-S
HN-2: MBA; mechloretamine; mustine; 2,2'-dichloro-N-methyldiethylamine; dichloren; caryolysin; mechlorethanamine; chlormethine; bis(2-chloroethyl)methylamine
HN-3: Tris(2-chloroethyl)amine; 2-chloro-N,N-bis(2-chloroethyl)ethanamine; 2,2',2''-trichlorotriethylamine

People whose skin or clothing is contaminated with nitrogen mustard can contaminate rescuers by direct contact or through off-gassing vapor.

- Nitrogen mustards are colorless to yellow, oily liquids with variable odors.
- Nitrogen mustards are absorbed by the skin causing erythema and blisters. Ocular exposure to these agents may cause incapacitating injury to the cornea and conjunctiva. When inhaled, nitrogen mustard damages the respiratory tract epithelium and may cause death.

Description
Nitrogen mustards are vesicants and alkylating agents. They are colorless to pale yellow, oily liquids that evaporate slowly. HN-1 has a faint, fishy or musty odor. It is sparingly soluble in water but miscible with acetone and other organic solvents. At temperatures greater than 194 °C, it decomposes.

HN-2 has a fruity odor at high concentrations and a soapy odor at low concentrations. Its solubility is similar to HN-1.

HN-3 is odorless when pure but has been reported to have a butter almond odor. It is the most stable of the nitrogen mustards but decomposes at temperatures greater than 256 °C. It has a much lower vapor pressure than HN-1 or HN-2 and is insoluble in water.

Routes of Exposure
Inhalation
Inhalation is an important route of exposure. Nitrogen mustard vapors are heavier than air. The LC₅₀ (the product of concentration times time that is lethal to 50% of the exposed
population by inhalation) is approximately 1,500 mg-min/m$^3$ for HN-1 and HN-3, and 3,000 mg-min/m$^3$ for HN-2.

**Skin/Eye Contact**

Exposure to nitrogen mustard vapor can cause injury to the eyes, skin, and mucous membranes at low concentrations. Direct contact with the liquid can cause skin and eye burns. The median incapacitating dose for the eyes is 100 mg-min/m$^3$ for HN-2 and 200 mg-min/m$^3$ for HN-1 and HN-3. Absorption may occur after skin or eye exposure to liquid or vapor nitrogen mustard and may cause systemic toxicity.

**Ingestion**

Ingestion is an uncommon route for exposure but can lead to local effects such as esophageal or gastrointestinal burns and systemic absorption.

**Sources/Uses**

Nitrogen mustards were first developed in the late 1920s and early 1930s. HN-1 was originally designed to remove warts but was later identified as a potential chemical warfare agent; HN-2 was designed as a military agent but was later used in chemotherapy; HN-3 was developed as a military agent. None of the nitrogen mustards have been used on the battlefield, and none are included in U.S. stockpiles.

**Standards and Guidelines**

HN-1: Airborne Exposure Limit (as recommended by the Surgeon General’s Working Group, U.S. Department of Health and Human Services) = 0.003 mg/m$^3$ as a time-weighted average (TWA) for the workplace. No standards exist for HN-2 or HN-3.
**Physical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>HN-1</th>
<th>HN-2</th>
<th>HN-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Colorless to pale yellow oily liquid</td>
<td>Pale amber to yellow oily liquid</td>
<td>Colorless to pale yellow oily liquid</td>
</tr>
<tr>
<td>Warning properties</td>
<td>Faint fishy or musty odor</td>
<td>Faint soapy odor at low concentrations; fruity odor at high concentrations</td>
<td>Faint butter almond odor</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>170.08 daltons</td>
<td>156.07 daltons</td>
<td>204.54 daltons</td>
</tr>
<tr>
<td>Boiling point</td>
<td>(760 mm Hg) = 381 °F (194 °C)</td>
<td>(760 mm Hg) = 167 °F (75 °C)</td>
<td>(760 mm Hg) = 493 °F (256 °C) (decomposes)</td>
</tr>
<tr>
<td>Freezing point</td>
<td>29.2 °F (-34 °C)</td>
<td>-85 to -76 °F (-65 to -60 °C)</td>
<td>25.3 °F (-3.7 °C)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>No data (water = 1.0)</td>
<td>No data (water = 1.0)</td>
<td>No data (water = 1.0)</td>
</tr>
<tr>
<td>Vapor pressure</td>
<td>0.25 mm Hg at 77 °F (25 °C)</td>
<td>0.427 mm Hg at 77 °F (25 °C)</td>
<td>0.0109 mm Hg at 77 °F (25 °C)</td>
</tr>
<tr>
<td>Vapor density</td>
<td>5.9 (air = 1.0)</td>
<td>5.4 (air = 1.0)</td>
<td>7.1 (air = 1.0)</td>
</tr>
<tr>
<td>Liquid density</td>
<td>1.09 g/mL at 77 °F (25 °C)</td>
<td>1.15 g/mL at 68 °F (20 °C)</td>
<td>1.24 g/mL at 77 °F (25 °C)</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>Sparingly soluble</td>
<td>Sparingly soluble</td>
<td>Practically insoluble</td>
</tr>
<tr>
<td>Volatility</td>
<td>No immediate danger of fire or explosion</td>
<td>No immediate danger of fire or explosion; however, polymerization results in components which present an explosion hazard in open air</td>
<td>No immediate danger of fire or explosion; however, polymerization results in components which present an explosion hazard in open air</td>
</tr>
<tr>
<td>NAERG#</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

**Incompatibilities**

HN-1 is corrosive to ferrous alloys at temperatures of 149 °F (68 °C) and higher. HN-2 and HN-3 do not have any incompatible actions on metals or other materials.
Health Effects

Nitrogen mustards are vesicants causing skin, eye, and respiratory tract injury. Although these agents cause cellular changes within several minutes of contact, the onset of pain and other clinical effects is delayed for hours.

Nitrogen mustards are alkylating agents that may cause bone marrow suppression and neurologic toxicity.

Acute Exposure

Nitrogen mustards are vesicants and alkylating agents; however, the mechanisms of action are not clearly understood. They are highly reactive and combine rapidly with proteins, DNA, or other molecules. Therefore, within minutes following exposure intact mustard or its reactive metabolites are not found in tissue or biological fluids.

CNS

High doses of nitrogen mustards have caused tremors, seizures, incoordination, ataxia, and coma in laboratory animals.

Respiratory

Damage to the mucosa of the airways begins within hours and may progress over several days. Nasal and sinus pain or discomfort, pharyngitis, laryngitis, cough, and dyspnea may occur. Pulmonary edema is uncommon.

Gastrointestinal

Ingestion may cause chemical burns of the GI tract and hemorrhagic diarrhea. Nausea and vomiting may occur following ingestion, dermal, or inhalation exposure.

Ocular

Exposure to nitrogen mustard vapor or liquid may cause intense conjunctival and scleral inflammation, pain, swelling, lacrimation, photophobia, and corneal damage. High concentrations can cause burns and blindness.

Dermal

Direct skin exposure to nitrogen mustards causes erythema and blistering. Generally, a rash will develop within several hours, followed by blistering within 6 to 12 hours. Prolonged contact, or short contact with large amounts, may result in second- and third-degree chemical burns.

Hematopoietic

Systemic absorption of nitrogen mustard may induce bone marrow suppression and an increased risk for fatal complicating infections, hemorrhage, and anemia.

Delayed Effects

Chemotherapeutic doses of HN-2 have been associated with menstrual irregularities, alopecia, hearing loss, tinnitus, jaundice,
Potential Sequelae

Chronic respiratory and eye conditions may persist following exposure to large amounts of nitrogen mustards. Narrowing of the esophagus and severe corrosive damage to the stomach lining can result from ingesting formalin.

Chronic Exposure

In laboratory animal studies, prolonged or repeated exposures to nitrogen mustards have caused cancer, developmental and reproductive effects, and hepatic toxicity. Repeated exposures result in cumulative effects because mustards are not naturally detoxified by the body.

Carcinogenicity

The International Agency for Research on Cancer (IARC) has classified nitrogen mustard as probably carcinogenic to humans (Group 2A). There is some evidence that it causes leukemia in humans, and it has been shown to cause leukemia and cancers of the lung, liver, uterus, and large intestine in animals.

Reproductive and Developmental Effects

Nitrogen mustards may decrease fertility. A few case reports have linked treatment with HN-2 to fetal abnormalities in humans. Nitrogen mustards have produced developmental effects in animals.

impaired spermatogenesis, generalized swelling, and hyperpigmentation.
Prehospital Management

Victims whose skin or clothing is contaminated with liquid nitrogen mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Nitrogen mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for nitrogen mustard toxicity. Decontamination of all potentially exposed areas within minutes after exposure is the only effective means of decreasing tissue damage.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from the U.S. Soldier and Biological Chemical Command–Edgewood Research Development and Engineering Center (from 0700-1630 EST call 410-671-4411, and from 1630-0700 EST call 410-278-5201; ask for the Staff Duty Officer).

Rescuer Protection

Nitrogen mustard vapor and liquid are readily absorbed by inhalation and ocular and dermal contact.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any amount of nitrogen mustard.

Skin/Ocular Protection: Personal protective equipment (PPE) and butyl rubber chemical protective gloves are recommended at all times when these chemicals are suspected to be involved.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4).
Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

Because most signs and symptoms of nitrogen mustard exposure do not occur for several hours postexposure, patients should be observed for at least 6 hours or sent home with instructions to return immediately if symptoms develop. Patients who develop significant dermal, ocular, or airway injury and patients who have ingested nitrogen mustard should be transported to a medical facility for evaluation.

Symptoms may not develop for 24 hours. Patients with mild symptoms who are seen long enough after exposure to minimize the likelihood that the lesions will worsen may be sent home after their names, addresses, and telephone numbers have been recorded. They should be advised to rest and to seek medical care promptly if additional symptoms develop (see Follow-up Instructions included with the Nitrogen Mustard Patient Information Sheet).

Consult with the base station physician or closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.

General principles of triage for chemical exposures are as follows:

1. Check triage tag/card for any previous treatment or triage.
2. Survey for evidence of associated traumatic/blast injuries.
3. Observe for sweating, labored breathing, coughing/vomiting, secretions.
4. Severe casualty triaged as immediate if assisted breathing is required.
5. Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
6. Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
7. If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms. For nitrogen mustards, potentially exposed individuals should be observed for 6 - 8 hours and, if signs or symptoms appear, be sent to the hospital.
8. Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.
1. **Immediate:** casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. **Delayed:** casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. **Minimal:** casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. **Expectant:** casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be retriaged to a higher

### ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

### Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

### Decontamination Zone

Decontamination within 1 or 2 minutes following exposure is the only effective means for decreasing tissue damage. Later decontamination is not likely to improve the victim’s condition but will protect other personnel from exposure. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

### Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see Rescuer Protection under Hot Zone, above).
**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control heavy bleeding, if present.

**Basic Decontamination**

The eyes and skin must be decontaminated within 1 or 2 minutes after exposure to reduce tissue damage. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller’s earth. If exposure to vapor only is certain, remove outer clothing and wash exposed areas with soap and water or 0.5% solution of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis. There is no evidence that administration of activated charcoal is beneficial.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

Be certain that victims have been decontaminated properly (see Decontamination Zone, above). Victims who have undergone decontamination pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

**ABC Reminders**

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.
**Additional Decontamination**

In cases of ingestion, **do not induce** emesis. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink. There is no evidence that administration of activated charcoal is beneficial.

**Advanced Treatment**

Intubate the trachea in cases of respiratory compromise. When the patient’s condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators. Trauma patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

**Transport to Medical Facility**

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.
Patients whose skin or clothing is contaminated with liquid nitrogen mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Nitrogen mustards are extremely toxic and may damage eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed. Thus, patients arriving immediately from the scene of exposure are not likely to have signs and symptoms.

There is no antidote for nitrogen mustard toxicity. Decontamination of all potentially exposed areas within minutes after exposure is the only effective means of decreasing tissue damage. Thus, by the time a patient arrives in the emergency department, decontamination can only prevent secondary exposure to medical staff; it does not limit the patient’s injury. Medical treatment is supportive.

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### Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

#### ABC Reminders

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators. Patients who are comatose or hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma, should be treated in the conventional manner.

#### Personal Protection

If contaminated patients are expected to arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can take place inside the hospital only if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

#### Basic Decontamination

Flush the eyes with water for about 5 to 10 minutes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.

If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be
accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered. There is no evidence that administration of activated charcoal is beneficial.

**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

**ABC Reminders**

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, above). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose, hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

**Triage**

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will rarely have symptoms. Following decontamination, patients with signs of airway involvement should be admitted directly to the Critical Care Unit. The others should be observed for at least 6 hours. Patients arriving later should be evaluated as described below. The sooner after exposure that symptoms occur, the more likely they are to progress and become severe.

**Eye Exposure**

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate a need for inpatient care and observation.

**Skin Exposure**

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a
significant area of erythema with or without blistering should be admitted for further evaluation.

**Airway Exposure**

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops, and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

**Ingestion Exposure**

**Do not induce emesis.** If a large dose has been ingested and the patient’s condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material. However, the risk of potential bleeding and perforation must be considered. There is no evidence that activated charcoal is beneficial.

**Antidotes and Other Treatments**

There is no antidote for nitrogen mustard. Treatment is supportive.

**Laboratory Tests**

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, and serum electrolytes. Chest x-ray and pulse oximetry (or ABG measurements) are recommended for inhalation exposures.

**Disposition**

As discussed above, consider hospitalizing patients who have had significant exposures.

**Delayed Effects**

Significant systemic absorption of nitrogen mustard may produce a fall in the leukocyte count beginning on days 3 to 5. Erythrocytes and thrombocytes may subsequently fall if bone marrow damage is severe and in this case the risk of life-threatening infection rises.

**Patient Release**

Patients who have sustained mild exposure may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop (see page 22, *Follow-up Instructions*, included with the *Nitrogen Mustard Patient Information Sheet*).
Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.
Since there are no immediate effects from mustard, most patients will go home or elsewhere from the incident and present to a medical facility hours later when effects occur. These patients must not be allowed to enter the facility until they have been decontaminated.

Patients whose skin or clothing is contaminated with liquid nitrogen mustard can contaminate medical personnel and others by direct contact or through off-gassing vapor.

Nitrogen mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for nitrogen mustard toxicity. Medical treatment is supportive.

Decontamination Area
A patient who arrives at a general medical facility (non-emergency) probably will not have undergone decontamination. Such a patient must be decontaminated as described below before being allowed to enter the facility.

ABC Reminders
Patients may have other injuries and must be evaluated using the concepts of BLS and ALS.

Personal Protection
Medical personnel or others (e.g., HAZMAT personnel) must meet incoming patients outside the facility or, if available, in the facility’s decontamination area. Decontamination can take place inside the medical facility only if there is a decontamination area with negative air pressure and floor drains to contain contamination. Personnel must wear protection required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

Basic Decontamination
A patient who has arrived directly from the scene must be decontaminated before being admitted to the facility. If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. If the patient was exposed to vapor only, removal of outer clothing and flushing of exposed skin (face, hair, and arms/hands) with soap and water or water alone is adequate. Place contaminated clothes and personal belongings in a sealed double bag.

A patient who has gone home and bathed and changed clothes may be considered decontaminated; however, the home will
require decontamination. Otherwise, patients should undergo the decontamination procedures described above.

**Initial Evaluation**

Patients arriving at the medical facility directly from the scene of potential exposure (within 30–60 minutes) will rarely have signs and symptoms. Patients with signs of airway involvement should be admitted directly to the Critical Care Unit once decontamination has been assured. The others should be observed for at least 6 hours.

Patients arriving later should be evaluated as described below. The sooner after exposure signs and symptoms occur, the more likely they are to progress and become severe.

**Eye Exposure**

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution, such as Visine or Murine, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate admission.

**Skin Exposure**

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a significant area of erythema with or without blistering should be admitted for further evaluation.

**Airway Exposure**

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough, pseudomembrane formation) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

**Ingestion Exposure**

Do not induce emesis. If a large dose has been ingested and the patient’s condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material. However, the risk of potential bleeding and perforation must be
considered. There is no evidence that activated charcoal is beneficial.

**Medical Management**

**General**

There is no antidote for nitrogen mustard. Management is supportive.

A guideline is to keep the wounds (skin, eye, airway) free from infection. A patient with severe skin burns may require care in a burn unit.

**Skin Exposure**

Most burns are second degree although third degree burns may occur after liquid exposure. In general, small blisters (i.e., <1 cm) should remain roofed and larger ones (>1 cm) should be unroofed. This is a controversial issue, but many feel that the roof will eventually come off anyway. Blister fluid does not contain mustard or other toxic substances. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Fluids are not lost as they are in thermal burns, and fluid replacement should be according to the general needs of the patient and not according to “burn therapy” formulas. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism. Patients with a large area of second or third degree burns should be transferred to a Burn Unit for further care and reverse isolation.

**Eye Exposure**

Eye lesions range from conjunctivitis to involvement of the entire eye including cornea and lids. Erosion of or perforation of the cornea may occur with very severe exposure to liquid, but this is rare. Readily available eye solutions may suffice for conjunctivitis. More severe lesions should be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Topical analgesics may be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain should be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia. Some authorities feel that topical steroids (used within the first 24 hours only) may reduce inflammation.
**Inhalation Exposure**

Airway damage may range from irritation of the nose and sinuses, to pharyngitis, to destruction of the airway mucosa from the upper airways to the smallest bronchiole. Airway damage is a common cause of death. Upper airway irritation (nose, sinuses, pharynx) may benefit from cool steam inhalation and cough drops or throat lozenges. A patient with signs of airway damage below the pharynx should be provided with oxygen, assisted ventilation as necessary (with PEEP); at the first sign of damage of the larynx or below, the patient should be intubated and transferred to the Critical Care Unit. Bronchodilators should be used if there are signs of bronchoconstriction; steroids might be used if the usual bronchodilators are not effective, but otherwise steroids are not of proven value. Daily sputum cultures should be done and systemic antibiotics should be begun with signs of infection and an identified organism. A chemical pneumonitis may occur in the first several days with infiltrates on X-ray, an increase in WBC, and a fever, but this is generally sterile. Organisms generally are not the cause until the third or fourth day postexposure, and antibiotics should not be used prophylactically. Patients with airway damage below the pharynx should be managed on the Critical Care Unit by a physician experienced in the management of complicated pulmonary and airway injuries.

**Bone Marrow**

If the bone marrow has been damaged, the white blood cell count in the peripheral blood will start to decrease at about days 3 to 5 after exposure. This decrease may be followed by a decrease in red blood cells and platelets. Often, this decrease is not marked and the marrow recovers. Transfusions may be useful. Treatment with granulocyte colony-stimulating factor (GCSF) has been successful experimentally with nitrogen mustard. Marrow transplants have not been attempted, but might be useful. A patient with a marked decrease in white blood cell count should be transferred to an Oncology or Burn Unit for reverse isolation.

**Laboratory Evaluation**

Routine laboratory studies for admitted patients include glucose, serum electrolytes, and daily CBC. Chest X-ray and pulse oximetry (or ABG measurement) should be done frequently on all patients with inhalation exposure.

**Disposition and Follow-up**

Patients with moderate to severe exposures will require hospitalization, as described above.

**Patient Release**

Patients who have sustained mild exposure may be discharged. Discharged patients should be advised to rest and to seek medical
care promptly if symptoms develop (see below, *Follow-up Instructions*, included with the *Nitrogen Mustard Patient Information Sheet*).

**Follow-up**

Follow-up evaluation of respiratory, neurological, and bone marrow function should be arranged for severely exposed patients.

**Reporting**

Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.
Blister Agents
Nitrogen Mustard (HN-1, HN-2, and HN-3)
Patient Information Sheet

This handout provides information and follow-up instructions for people who have been exposed to nitrogen mustards.

What are nitrogen mustards?
Nitrogen mustards are compounds that were initially developed as chemical warfare agents or pharmaceuticals. They have never been used on the battlefield. HN-2 has been used in chemotherapy.

What immediate health effects can be caused by exposure to nitrogen mustards?
Nitrogen mustards cause injury to the skin, eyes, nose and throat. Eye damage may occur within minutes of exposure. Nausea and vomiting also may occur shortly after exposure. Skin rashes, blisters, and lung damage may develop within a few hours of exposure but may take 6 hours or more. Nitrogen mustards can also suppress the immune system.

Can nitrogen mustard poisoning be treated?
There is no antidote for nitrogen mustard, but its effects can be treated and most exposed people recover. Immediate decontamination reduces symptoms. People who have been exposed to large amounts of nitrogen mustard will need to be treated in a hospital.

Are any future health effects likely to occur?
Adverse health effects, such as chronic respiratory diseases, may occur from exposure to high levels of these agents. Severe damage to the eye may be present for a long time following the exposure.

What tests can be done if a person has been exposed to nitrogen mustard?
There are no routine tests to confirm exposure.

Where can more information about nitrogen mustard be found?
More information about nitrogen mustards can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, shortness of breath, or discolored sputum
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin
- fever or chills

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. ___________________________ in the practice of ___________________________. When you call for your appointment, please say that you were treated in the Emergency Department at ___________________________ Hospital by ___________________________ and were advised to be seen again in ________ days.

[ ] Return to the Emergency Department/ ___________________________ Clinic on (date) ___________ at ________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for ________ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: ___________________________.

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ____________________________________________

[ ] Other instructions: ____________________________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ___________________________ or ___________________________, or by checking out the following Internet Web sites: ___________________________; ___________________________.

Signature of patient ___________________________ Date __________________

Signature of physician ___________________________ Date __________________
Blister Agents
Sulfur Mustard Agent H or HD (C₄H₈Cl₂S)
CAS 505-60-2, UN 2927;
and Sulfur Mustard Agent HT CAS 6392-89-8

Synonyms:
H and HD: Bis(2-chloroethyl) sulfide; bis(beta-chloroethyl) sulfide; di-2-chloroethyl sulfide; 1-chloro-2(beta-chloroethylthio)ethane; 2,2'-dichloroethyl sulfide; sulfur mustard; Iprit; Kampstoff “Lost”; mustard gas; senfgas, S-yperite; yellow cross liquid; yperite
HT: Mixture of bis(2-chloroethyl) sulfide and bis[2-(2-chloroethylthio)-ethyl]ether

People whose skin or clothing is contaminated with sulfur mustard can contaminate rescuers by direct contact or through off-gassing vapor.

- Sulfur mustards are yellow to brown oily liquids with a slight garlic or mustard odor. Although volatility is low, vapors can reach hazardous levels during warm weather.
- Sulfur mustards are absorbed by the skin, causing erythema and blisters. Ocular exposure to these agents may cause incapacitating damage to the cornea and conjunctiva. Inhalation damages the respiratory tract epithelium and may cause death.

Description
Sulfur mustards are vesicants and alkylating agents. They are colorless when pure but are typically a yellow to brown oily substance with a slight garlic or mustard odor. H contains about 20 to 30% impurities (mostly sulfur); distilled mustard is known as HD and is nearly pure; HT is a mixture of 60% HD and 40% agent T (a closely related vesicant with a lower freezing point). Sulfur mustards evaporate slowly. They are very sparingly soluble in water but are soluble in oils, fats, and organic solvents. They are stable at ambient temperatures but decompose at temperatures greater than 149°C.

Routes of Exposure
Inhalation
Sulfur mustards are readily absorbed from the respiratory tract; injury develops slowly and intensifies over several days. The odor of sulfur mustards does not provide adequate warning of detection. The LC₅₀ (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) is approximately 1,500 mg-min/m³. The vapors are heavier than air. When inhaled, these agents may cause systemic effects. The estimated Ct for airway injury is 100 to 200 mg-min/m³.
**Skin/Eye Contact**

Mustard vapor and liquid are absorbed through the eyes, skin, and mucous membranes. Clinical effects do not occur until hours after exposure. The median incapacitating dose for the vapor is 200 mg-min/m³. A Ct of 12 to 70 mg-min/m³ produces eye lesions. Direct contact with the liquid can cause skin and eye burns that develop an hour or more after exposure. A 10 µg droplet is capable of producing blisters. Skin, eye, and airway exposure to vapor sulfur mustard and skin and eye exposure to liquid mustard may cause systemic toxicity. The lethal dose is about 100 mg/kg or 1 to 1.5 teaspoons of liquid.

**Ingestion**

Ingestion may cause local effects and systemic absorption.

**Sources/Uses**

Sulfur mustards were first developed in the early-to-mid-1800s and were introduced as chemical warfare agents in 1917 during World War I. They have been used extensively in chemical warfare and remain a major threat. More than a dozen countries have sulfur mustard in their chemical arsenals. Destruction of U.S. stockpiles of chemical agents, including sulfur mustards, was mandated by the Chemical Weapons Convention to take place before April 2007.

**Standards and Guidelines**

Airborne Exposure Limit (as recommended by the Surgeon General’s Working Group, U.S. Department of Health and Human Services) is 0.003 mg/m³ as a time-weighted average (TWA) for the workplace.

**Physical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Agent H and HD</th>
<th>Agent HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Colorless when pure but usually a pale yellow, dark brown or black oily liquid. The vapor is colorless</td>
<td>Clear yellowish liquid</td>
</tr>
<tr>
<td>Warning properties</td>
<td>Faint garlic or mustard odor (odor threshold 0.6 mg/m³)</td>
<td>Slight garlic or mustard-like odor</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>159.08 daltons</td>
<td>159.08 daltons (HD); 263.2 daltons (T)</td>
</tr>
<tr>
<td>Boiling point</td>
<td>(760 mm Hg) = 419 °F (217.5 °C)</td>
<td>(760 mm Hg) = &gt;442 °F (&gt;228 °C)</td>
</tr>
<tr>
<td>Freezing point</td>
<td>58.1 °F (14.5 °C)</td>
<td>32 to 34.3 °F (0 to 1.3 °C)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.27 g/mL (water = 1.0)</td>
<td>No data</td>
</tr>
</tbody>
</table>
### Blister Agent (H, HD, HT)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor pressure</td>
<td>0.072 mm Hg at 68 °F (20 °C); 0.11 mm Hg at 77 °F (25 °C)</td>
<td>No data</td>
</tr>
<tr>
<td>Vapor density</td>
<td>5.4 to 5.5 (air = 1.0)</td>
<td>6.92 (air = 1.0)</td>
</tr>
<tr>
<td>Liquid density</td>
<td>1.24 to 1.27 g/mL at 68 °F (20 °C)</td>
<td>1.27 g/mL</td>
</tr>
<tr>
<td>Flash point</td>
<td>221 °F (105 °C)</td>
<td>212 °F (100 °C)</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>0.8 g/L at 68 °F (20 °C)</td>
<td>Practically insoluble</td>
</tr>
<tr>
<td>Volatility</td>
<td>600 mg/m³ (20 °C)</td>
<td>No data</td>
</tr>
<tr>
<td>NAERG#</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

**Incompatibilities**  
Sulfur mustards are rapidly corrosive to brass and steel at 149 °F (65 °C); they are destroyed by strong oxidizing agents. These agents hydrolyze to form hydrochloric acid (HCl) and thioglycol.
Health Effects

Sulfur mustards are vesicants causing skin, eye, and respiratory tract injury. Although these agents cause cellular changes within minutes of contact, the onset of pain and other clinical effects are delayed for 1 to 24 hours.

- Sulfur mustards are alkylating agents that may cause bone marrow suppression and neurologic and gastrointestinal toxicity.

Acute Exposure

Sulfur mustards are vesicants and alkylating agents; however, the biochemical mechanisms of action are not clearly understood. They are highly reactive and combine rapidly with proteins, DNA, or other molecules. Therefore, within minutes following exposure intact mustard or its reactive metabolites are not found in tissue or biological fluids. Sulfur mustards also have cholinergic activity, stimulating both muscarinic and nicotinic receptors. The onset of clinical symptoms and their time of onset depend on the severity of exposure (Table 1). The death rate from exposure to sulfur mustard is low (2 to 3% during World War I). Death usually occurs between the 5th and 10th day due to pulmonary insufficiency complicated by infection due to immune system compromise.

Ocular

The eye is the most sensitive tissue to sulfur mustard effects. Sulfur mustard vapor or liquid may cause intense conjunctival and scleral pain, swelling, lacrimation, blepharospasm, and photophobia; however, these effects do not appear for an hour or more. Miosis due to cholinergic effects may occur. High concentrations of vapor or liquid can cause corneal edema, perforation, blindness, and later scarring.

Dermal

Direct skin exposure to sulfur mustards causes erythema and blistering. Generally, a pruritic rash will develop within 4 to 8 hours followed by blistering 2 to 18 hours later. Contact with the vapor may result in first and second degree burns, while contact with the liquid typically produces second and third degree chemical burns. An area of burn covering 25% or more of the body surface area may be fatal.

Respiratory

Dose-dependent inflammatory reactions in the upper and lower airway begin to develop several hours after exposure and progress over several days. Burning nasal pain, epistaxis, sinus pain, laryngitis, loss of taste and smell, cough, wheezing, and dyspnea may occur. Necrosis of respiratory epithelium can cause pseudomembrane formation and local airway obstruction.
Gastrointestinal

Ingestion may cause chemical burns of the GI tract and cholinergic stimulation. Nausea and vomiting may occur following ingestion or inhalation. Early nausea and vomiting is usually transient and not severe. Nausea, vomiting, and diarrhea occurring several days after exposure indicates damage to the GI tract and thus is a poor prognostic sign.

CNS

High doses of sulfur mustards can cause hyperexcitability, convulsions, and insomnia.

Hematopoietic

Systemic absorption of sulfur mustard may induce bone marrow suppression and an increased risk for fatal complicating infections, hemorrhage, and anemia.

Delayed Effects

Years after apparent healing of severe eye lesions, relapsing keratitis or keratopathy may develop.

Potential Sequelae

Persistent eye conditions, loss of taste and smell, and chronic respiratory illness including asthmatic bronchitis, recurrent respiratory infections, and lung fibrosis may persist following exposure to sulfur mustards.

Chronic Exposure

Prolonged or repeated acute exposure to sulfur mustards may cause cutaneous sensitization and chronic respiratory disease. Repeated exposures result in cumulative effects because mustards are not naturally detoxified by the body.

Carcinogenicity

The International Agency for Research on Cancer (IARC) has classified sulfur mustard as carcinogenic to humans (Group 1). Epidemiological evidence indicates that repeated exposures to sulfur mustard may lead to cancers of the upper airways.

Reproductive and Developmental Effects

There is limited evidence that repeated exposures to sulfur mustards may cause defective spermatogenesis years after exposure. Sulfur mustard has been implicated as a potential developmental toxicant because of its similarity to nitrogen mustard; however, data are inconclusive.
Table 1. Clinical Effects and Time of Onset by Severity of Exposure to Sulfur Mustard

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Severity of exposure</th>
<th>Clinical effects</th>
<th>Time to first effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td>Mild</td>
<td>Tearing, itching, burning, gritty feeling</td>
<td>4-12 hours</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Above effects and reddening, lid edema, moderate pain</td>
<td>3-6 hours</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>Marked lid edema, possible corneal damage, severe pain</td>
<td>1-2 hours</td>
</tr>
<tr>
<td>Airways</td>
<td>Mild</td>
<td>Rhinorrhea, sneezing, epistaxis, hoarseness, hacking cough</td>
<td>6-24 hours</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>Above effects and productive cough, mild to severe dyspnea</td>
<td>2-6 hours</td>
</tr>
<tr>
<td>Skin</td>
<td>Mild</td>
<td>Erythema</td>
<td>2-24 hours</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>Erythema and vesication</td>
<td>2-24 hours</td>
</tr>
</tbody>
</table>
Prehospital Management

Victims whose skin or clothing is contaminated with liquid sulfur mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Sulfur mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for sulfur mustard toxicity. Decontamination within 1 or 2 minutes after exposure is the only effective means of decreasing tissue damage. Sodium thiosulfate given IV within minutes after exposure may prevent lethality.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local Hazmat teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Sulfur mustard vapor and liquid are readily absorbed by inhalation and ocular and dermal contact.

Respiratory protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any amount of sulfur mustard.

Skin/ocular protection: Personal protective equipment (PPE) and butyl rubber chemical-protective gloves are recommended at all times when these chemicals are suspected to be involved.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the
box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4). Clinical signs and effects of sulfur mustards associated with each of these categories are presented in Table 2.

**Before transport, all casualties must be decontaminated.** If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

Because signs and symptoms of exposure do not occur for several hours postexposure, patients should be observed for at least 6 hours or sent home with instructions to return immediately if symptoms develop. Patients whose clinical effects and time of onset indicate moderate or severe exposure (see Table 1) and patients who have ingested sulfur mustard should be transported to a medical facility for evaluation.

Symptoms may not develop for 24 hours. Patients who are seen at least 24 hours after exposure and whose symptoms indicate mild exposure (see Table 1) may be sent home after treatment and once their names, addresses, and telephone numbers have been recorded. They should be advised to rest and to seek medical care promptly if additional symptoms develop (see *Follow-up Instructions*, included with the *Sulfur Mustard Patient Information Sheet* below).

Consult with the base station physician, closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.
General principles of triage for chemical exposures are as follows:

1. Check triage tag/card for any previous treatment or triage.
2. Survey for evidence of associated traumatic/blast injuries.
3. Observe for sweating, labored breathing, coughing/vomiting, secretions.
4. Severe casualty triaged as immediate if assisted breathing is required.
5. Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
6. Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
7. If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms.
8. Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. **Immediate**: casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. **Delayed**: casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. **Minimal**: casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. **Expectant**: casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be triaged to a higher category.
### Table 2. Triage for Mustard Agent Casualties

<table>
<thead>
<tr>
<th>Category (Priority)</th>
<th>Time of Onset</th>
<th>Clinical Signs and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate (1)</td>
<td>&lt;4 up to 12 hours post exposure</td>
<td>Lower respiratory signs (dyspnea)</td>
</tr>
<tr>
<td>Delayed (2)</td>
<td>&gt; 4 hours (eye and skin); or &gt;12 hours (respiratory) post exposure</td>
<td>Eye lesions with impaired vision; skin lesion covering 2 to 50% of body surface area for liquid exposure or any body surface burn for vapor exposure; lower respiratory symptoms (cough with sputum production, dyspnea)</td>
</tr>
<tr>
<td>Minimal (3)</td>
<td>&gt; 4 hours post exposure</td>
<td>Minor eye lesion with no vision impairment; skin lesion &lt; 2% of body surface area in noncritical areas; minor upper respiratory symptoms (cough, sore throat).</td>
</tr>
<tr>
<td>Expectant (4)</td>
<td>&lt; 4 hours post exposure</td>
<td>Lower respiratory signs (dyspnea); skin lesion covering 50% or more of body surface area from liquid exposure</td>
</tr>
</tbody>
</table>

**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

**Decontamination Zone**

Decontamination within 1 or 2 minutes following exposure is the only effective means for decreasing tissue damage. Later decontamination is not likely to improve the victim’s condition but will protect other personnel from exposure. Decontaminable gurneys and backboards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and
is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The Chemical Resuscitation Device is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

**Rescuer Protection**
Personnel should continue to wear the same level of protection as required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

**ABC Reminders**
Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control bleeding, if present.

**Basic Decontamination**
Early decontamination, preferably within 1 or 2 minutes after exposure, is the only way to reduce tissue damage. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, victims should remove all clothing and wash skin with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller’s earth. If exposure to vapor only is certain, remove outer clothing and wash with soap and water or 0.5% solution of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis. There is no evidence that administration of activated charcoal is beneficial.

**Transfer to Support Zone**
As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**
Be certain that victims have been decontaminated properly (see Decontamination Zone, above). Victims who have undergone decontamination pose no serious risk of secondary
contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

**ABC Reminders**

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor. Direct pressure should be applied to stop bleeding, if present.

**Additional Decontamination**

In cases of ingestion, do not induce emesis. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink. There is no evidence that administration of activated charcoal is beneficial.

**Advanced Treatment**

Intubate the trachea in cases of respiratory compromise. When the patient’s condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators.

Trauma patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

**Transport to Medical Facility**

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.
Patients whose skin or clothing is contaminated with liquid sulfur mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Sulfur mustards are extremely toxic and may damage eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed. Thus, patients arriving immediately from the scene of exposure are not likely to have signs and symptoms.

There is no antidote for sulfur mustard toxicity. Decontamination of all potentially exposed areas within minutes after exposure is the only effective means of decreasing tissue damage. Thus, by the time a patient arrives in the emergency department, decontamination can only prevent secondary exposure to medical staff; it does not limit the patient’s injury. Medical treatment is supportive.

**Decontamination Area**

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

**ABC Reminders**

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

**Personal Protection**

If contaminated patients are expected to arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can take place inside the hospital only if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

**Basic Decontamination**

Flush the eyes with water for about 5 to 10 minutes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.
If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using warm water and low water pressure to reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered. There is no evidence that administration of activated charcoal is beneficial.

**Treatment Area**

Be certain that appropriate decontamination has been carried out (see Decontamination Area, below).

**ABC Reminders**

Evaluate and support the airway, breathing, and circulation (as in ABC Reminders, above). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose, hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

**Triage**

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will rarely have symptoms. Following decontamination, patients with signs of airway involvement should be admitted directly to the Critical Care Unit. The others should be observed for at least 6 hours. Patients arriving later should be evaluated as described below. The sooner after exposure that symptoms occur, the more likely they are to progress and become severe.

**Eye Exposure**

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution, such as Visine or Murine, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate a need for inpatient care and observation.

**Skin Exposure**

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a
significant area of erythema with or without blistering should be admitted for further evaluation.

**Airway Exposure**

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

**Ingestion Exposure**

**Do not induce emesis.** If a large dose has been ingested and the patient’s condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material. However, the risk of potential bleeding and perforation must be considered. There is no evidence that activated charcoal is beneficial.

**Antidotes and Other Treatments**

There is no antidote for sulfur mustard. Treatment is supportive.

**Laboratory Tests**

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, and serum electrolytes. Chest x-ray and pulse oximetry (or ABG measurements) are recommended for inhalation exposures. A test for urine thiodiglycol, a metabolite of mustard, can be performed at specialized laboratories, but is not a routine laboratory measure.

**Disposition**

As discussed above, consider hospitalizing patients who have had significant exposures.

**Delayed Effects**

Significant systemic absorption of sulfur mustard may produce a fall in the leukocyte count beginning on days 3 to 5. Erythrocytes and thrombocytes may subsequently fall if bone marrow damage is severe and in this case the risk of life-threatening infection rises.

**Patient Release**

Patients who have sustained mild exposure (see Table 1) may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms progress (see, *Follow-up Instructions*, included with the *Sulfur Mustard Patient Information Sheet* below).
Reporting  Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.
Since there are no immediate effects from mustard, most patients will go home or elsewhere from the incident and present to a medical facility hours later when effects occur. These patients must not be allowed to enter the facility until they have been decontaminated.

Patients whose skin or clothing is contaminated with liquid sulfur mustard can contaminate medical personnel and others by direct contact or through off-gassing vapor.

Sulfur mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for sulfur mustard toxicity. Medical treatment is supportive.

### Decontamination Area
A patient who arrives at a general medical facility (non-emergency) probably will not have undergone decontamination. Such a patient must be decontaminated as described below before being allowed to enter the facility.

### ABC Reminders
Patients may have other injuries and must be evaluated using the concepts of BLS and ALS.

### Personal Protection
Medical personnel or others (e.g., HAZMAT personnel) must meet incoming patients outside the facility or, if available, in the facility’s decontamination area. Decontamination can take place inside the medical facility only if there is a decontamination area with negative air pressure and floor drains to contain contamination. Personnel must wear protection required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

### Basic Decontamination
A patient who has arrived directly from the scene must be decontaminated before being admitted to the facility. If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, removal of outer clothing and flushing of exposed skin (face, hair, and arms/hands) with soap and water or water alone is adequate. Place contaminated clothes and personal belongings in a sealed double bag.
A patient who has gone home and bathed and changed clothes may be considered decontaminated; however, the home will require decontamination. Otherwise, patients should undergo the decontamination procedures described above.

**Initial Evaluation**

Patients arriving at the medical facility directly from the scene of potential exposure (within 30–60 minutes) will rarely have signs and symptoms. Patients with signs of airway involvement should be admitted directly to the Critical Care Unit once decontamination has been assured. The others should be observed for at least 6 hours.

Patients arriving later should be evaluated as described below. The sooner after exposure signs and symptoms occur, the more likely they are to progress and become severe (see Table 1).

**Eye Exposure**

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution such as Visine or Murine, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate admission.

**Skin Exposure**

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a significant area of erythema with or without blistering should be admitted for further evaluation.

**Airway Exposure**

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

**Ingestion Exposure**

*Do not induce emesis.* If a large dose has been ingested and the patient’s condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material.
However, the risk of potential bleeding and perforation must be considered. There is no evidence that activated charcoal is beneficial.

Medical Management

**General**

There is no antidote for sulfur mustard. Management is supportive.

A guideline is to keep the wounds (skin, eye, airway) free from infection. A patient with severe skin burns may require care in a burn unit.

**Skin Exposure**

Most burns are second degree although third degree burns may occur after liquid exposure. In general, small blisters (i.e., <1cm) remain roofed and larger ones (i.e., >1cm) should be unroofed. This is a controversial issue, but many feel that the roof will eventually come off anyway. Blister fluid does not contain mustard or other toxic substances. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Fluids are not lost as they are in thermal burns, and fluid replacement should be according to the general needs of the patient and not according to “burn therapy” formulas. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism. Patients with a large area of second or third degree burns should be transferred to a Burn Unit for further care and reverse isolation.

**Eye Exposure**

Eye lesions range from conjunctivitis to involvement of the entire eye including cornea and lids. Erosion of or perforation of the cornea may occur with very severe exposure to liquid, but this is rare. Readily available eye solutions may suffice for conjunctivitis. More severe lesions should be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Topical analgesics should be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain should be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia. Some authorities feel that topical steroids (used within the first 24 hours only) may reduce inflammation.
Inhalation Exposure

Airway damage may range from irritation of the nose and sinuses, to pharyngitis, to destruction of the airway mucosa from the upper airways to the smallest bronchiole. Airway damage is a common cause of death. Upper airway irritation (nose, sinuses, pharynx) may benefit from cool steam inhalation and cough drops or lozenges. A patient with signs of airway damage below the pharynx should be provided with oxygen-assisted ventilation as necessary (with PEEP); at the first sign of damage of the larynx or below, the patient should be intubated and transferred to the Critical Care Unit. Bronchodilators should be used if there are signs of bronchoconstriction; steroids might be used if the usual bronchodilators are not effective, but otherwise steroids are not of proven value. Daily sputum cultures should be done and systemic antibiotics should be begun with signs of infection and an identified organism. A chemical pneumonitis may occur in the first several days with infiltrates on X-ray, an increase in WBC, and a fever, but this is generally sterile. Organisms generally are not the cause until the third or fourth day postexposure, and antibiotics should not be used prophylactically. Patients with airway damage below the pharynx should be managed on the Critical Care Unit by a physician experienced in the management of complicated pulmonary and airway injuries.

Bone Marrow

If the bone marrow has been damaged, the white blood cell count in the peripheral blood will start to decrease at about days 3 to 5 after exposure. This decrease may be followed by a decrease in red blood cells and platelets. Often, this decrease is not marked and the marrow recovers. Transfusions may be useful. Treatment with granulocyte colony-stimulating factor (GCSF) has been successful experimentally with nitrogen mustard. Marrow transplants have not been attempted, but might be useful. A patient with a marked decrease in white blood cell count should be transferred to an Oncology or Burn Unit for reverse isolation.

Laboratory Evaluation

Routine laboratory studies for admitted patients include glucose, serum electrolytes, and daily CBC. Chest X-ray and pulse oximetry (or ABG measurement) should be done frequently on all patients with inhalation effects. A test for urinary thioglycol (a metabolite of mustard) can be performed at specialized laboratories, but is not a routine laboratory measure.
Disposition and Follow-up

Patients with moderate to severe exposures will require hospitalization, as described above.

Patient Release

Patients who have sustained mild exposure (see Table 1), may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms progress (see below, Follow-up Instructions, included with the Sulfur Mustard Patient Information Sheet).

Follow-up

Follow-up evaluation of respiratory, neurological, and bone marrow function should be arranged for severely exposed patients.

Reporting

Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.
Blister Agents
Sulfur Mustard (H, HD, and HT)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to sulfur mustard.

What are sulfur mustards?
Sulfur mustards are yellowish to brown liquids that have been used as chemical warfare agents since 1917.

What immediate health effects can result from exposure to sulfur mustards?
Sulfur mustards produce blistering and cell damage, but symptoms are delayed for hours. They cause damage to the skin, eyes, and respiratory tract. The eyes are the most sensitive. Nausea and vomiting may occur within the first few hours after exposure. Skin rashes, blisters, and lung damage may develop within a few hours of exposure but may take 12 to 24 hours to develop. Sulfur mustard can also suppress the immune system.

Can sulfur mustard poisoning be treated?
There is no antidote for sulfur mustard, but its effects can be treated and most exposed people recover. Immediate decontamination reduces symptoms. People who have been exposed to large amounts of sulfur mustard will need to be treated in a hospital.

Are any future health effects likely to occur?
Adverse health effects, such as chronic respiratory diseases, may occur from exposure to high levels of these agents. Severe damage to the eyes and skin may be present for a long time following the exposure.

What tests can be done if a person has been exposed to sulfur mustards?
There are no routine tests to determine if someone has been exposed to sulfur mustard. Thiodiglycol (a break-down product of mustard) may be detected in the urine up to 2 weeks following exposure; however, this test is available only in several specialized laboratories.

Where can more information about sulfur mustards be found?
More information about sulfur mustard can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, shortness of breath, or discolored sputum
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin
- fever or chills

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. ___________ in the practice of ___________. When you call for your appointment, please say that you were treated in the Emergency Department at ___________. Hospital by ___________ and were advised to be seen again in ________ days.

[ ] Return to the Emergency Department/_________ Clinic on (date) ________ at __________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: ____________________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ____________________________

[ ] Other instructions: ______________________________________________________

  ______________________________________________________

  ______________________________________________________

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: ________________ or ________________, or by checking out the following Internet Web sites: ____________________________

Signature of patient ____________________________ Date ________________

Signature of physician ____________________________ Date ________________
Phosgene Oxime (CHCl₂NO)  
CAS 1794-86-1

Synonyms include dichloroformoxime; CX.

Persons whose clothing or skin is contaminated with liquid or solid phosgene oxime can cause secondary contamination by direct contact or through off-gassing vapor. Persons exposed only to phosgene oxime vapor pose no risk of secondary contamination.

Phosgene oxime is a colorless, crystalline solid or a yellowish-brown liquid with a disagreeable penetrating odor. The solid can vaporize at ambient temperatures.

Phosgene oxime is readily absorbed by the skin causing an immediate corrosive lesion. Ocular and pulmonary exposure may cause incapacitating inflammation.

Description

Phosgene oxime is an urticant or nettle agent. It is one of the least well studied chemical warfare agents; therefore, specific information is limited. Pure phosgene oxime is a colorless, crystalline solid; however, the munitions grade compound is a yellowish-brown liquid. The solid material can release enough vapor to cause symptoms. Post World War II studies indicate that concentrations below 8% cause no or inconsistent effects.

Routes of Exposure

Inhalation

Inhaled phosgene oxime is extremely irritating to the upper airways and causes pulmonary edema. Irritation occurs with exposures to 0.2 mg-min/m³ and becomes unbearable at 3 mg-min/m³. The estimated LCT₅₀ (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) is 1,500 to 2,000 mg-min/m³.

Skin/Eye Contact

Pain and local tissue destruction occur immediately on contact with skin, eyes and mucous membranes. Phosgene oxime is rapidly absorbed from the skin and eyes and may result in systemic toxicity. The LD₅₀ for skin exposure is estimated as 25 mg/kg.

Ingestion

No human data are available. Animal studies suggest phosgene oxime may induce hemorrhagic inflammatory lesions in the gastrointestinal tract.

Sources/Uses

Phosgene oxime was developed as a potential chemical warfare agent but has never been known to be used on the battlefield.
Standards and Guidelines

No standards are available.

Physical Properties

Table 1. Physical Properties of Phosgene Oxime

<table>
<thead>
<tr>
<th>Property</th>
<th>Agent Phosgene Oxime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Colorless solid or yellowish-brown liquid</td>
</tr>
<tr>
<td>Warning properties</td>
<td>No data</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>113.93 daltons</td>
</tr>
<tr>
<td>Boiling point</td>
<td>(760 mm Hg) = 128 °C</td>
</tr>
<tr>
<td>Melting point</td>
<td>95 to 104 °F (35 to 40 °C)</td>
</tr>
<tr>
<td>Freezing point</td>
<td>No data</td>
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<tr>
<td>Vapor pressure</td>
<td>11.2 mm Hg at 25 °C (solid); 13 mm Hg at 40 °C (liquid)</td>
</tr>
<tr>
<td>Vapor density</td>
<td>&lt;3.9</td>
</tr>
<tr>
<td>Liquid density</td>
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</tr>
<tr>
<td>Flash point</td>
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</tr>
<tr>
<td>Solubility in water</td>
<td>70% in water; highly soluble in most organic solvents</td>
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<tr>
<td>Volatility</td>
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</tbody>
</table>

Incompatibilities

It decomposes when in contact with many metals, but it also is corrosive to most metals.
Health Effects

- Direct contact with phosgene oxime results in immediate pain, irritation, and tissue necrosis. Inhalation and systemic absorption may result in pulmonary edema, necrotizing bronchiolitis, and pulmonary thrombosis.

- Phosgene oxime is known to cause more severe tissue damage than vesicants and other urticants but it has not been well studied and the mechanism of action is unknown.

### Acute Exposure

Phosgene oxime is an urticant or nettle agent capable of producing erythema, wheals, and urticaria. It is considered a corrosive agent because it causes extensive tissue damage. The skin effects are similar to those caused by strong acids; however, the mechanism of action is unknown.

- **Ocular** Contact with the eyes may result in severe pain, conjunctivitis, and keratitis.

- **Dermal** Direct skin exposure to any form of phosgene oxime causes immediate pain and blanching with an erythematosus ring. After 30 minutes a wheal occurs followed by necrosis. Extreme pain may persist for days. Absorption through the skin can cause pulmonary edema.

- **Respiratory** Phosgene oxide produces immediate irritation to the upper respiratory tract. Inhalation and systemic absorption may cause pulmonary edema, necrotizing bronchiolitis and pulmonary thrombosis.

- **Gastrointestinal** There are no human data; however, animal studies suggest that hemorrhagic inflammatory lesions may occur throughout the gastrointestinal tract.

### Chronic Exposure

There are no data regarding potential effects of chronic exposure to phosgene oxime.

### Carcinogenicity

No data exist.

### Reproductive and Developmental Effects

No data exist.
Phosgene Oxime

Health Effects

ATSDR
Prehospital Management

- Victims whose skin or clothing is contaminated with liquid phosgene oxime can contaminate rescuers by direct contact or through off-gassing vapor.
- Phosgene oxime is extremely toxic and may cause immediate pain and necrotic lesions of the eyes, skin, and respiratory tract.
- There is no antidote for phosgene oxime toxicity. Treatment consists of supportive measures.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Phosgene oxime is readily absorbed by inhalation and by dermal and ocular contact. It causes immediate irritation and pain.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any level of phosgene oxime vapor.

Skin/Ocular Protection: Personal Protective Equipment (PPE) and butyl rubber gloves must be worn at all times when skin contact with any form of the material is possible because lesions and dermal absorption may occur. Phosgene oxime may attack the butyl rubber in the butyl rubber gloves and boots, which nevertheless, are expected to protect against field concentrations of phosgene oxime until they can be exchanged for fresh gloves and boots.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General
principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4).

**Before transport, all casualties must be decontaminated.** If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

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**General principles of triage for chemical exposures are as follows:**

- Check triage tag/card for any previous treatment or triage.
- Survey for evidence of associated traumatic/blast injuries.
- Observe for sweating, labored breathing, coughing/vomiting, secretions.
- Severe casualty triaged as immediate if assisted breathing is required.
- Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
- Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
- If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms. *For phosgene oxime, effects are immediate. No overtriage would be anticipated.*
- Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

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1. **Immediate:** casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. **Delayed:** casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. **Minimal:** casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. **Expectant:** casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined an possibly be triaged to a higher category.
**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

**Decontamination Zone**

Decontamination or self-aid immediately after skin and ocular exposure is the only means for preventing or decreasing tissue damage since phosgene oxime is absorbed within seconds. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The Chemical Resuscitation Device is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

**Rescuer Protection**

Personnel should continue to wear the same level of protection as required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control bleeding, if present.

**Basic Decontamination**

The eyes and skin must be decontaminated immediately after exposure because the agent is absorbed from the skin within seconds. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.
If exposure to liquid is suspected, victims should remove all clothing and wash skin with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller’s earth. If exposure to vapor only is certain, remove outer clothing and wash with soap and water or 0.5% solution of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to phosgene oxime vapor pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

**ABC Reminders**

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor. Direct pressure should be applied to stop bleeding, if present.

**Additional Decontamination**

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, do not induce emesis. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink. There are no data regarding the efficacy of activated charcoal.

**Advanced Treatment**

Intubate the trachea in cases of respiratory compromise. When the patient’s condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated according to advanced life support (ALS) protocols.
<table>
<thead>
<tr>
<th><strong>Transport to Medical Facility</strong></th>
<th>Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multi-Casualty Triage</strong></td>
<td>Consult with the base station physician, closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.</td>
</tr>
</tbody>
</table>

Patients who have sustained skin, eye, or respiratory lesions and those who have ingested phosgene oxime should be transported to a medical facility for evaluation.

Patients who have no symptoms may be discharged from the scene, after their names, addresses, and telephone numbers have been recorded. They should be advised to rest and to seek medical care promptly if additional symptoms develop (see *Follow-up Instructions*, included with the *Phosgene Oxime Patient Information Sheet* below).
Emergency Department Management

- Patients whose skin or clothing is contaminated with liquid or solid phosgene oxime can contaminate rescuers by direct contact or through off-gassing vapor.
- Phosgene oxime is extremely toxic and may cause immediate pain and necrotic lesions of the eyes, skin, and respiratory tract.
- There is no antidote for phosgene oxime toxicity. Treatment consists of supportive measures.

Decontamination Area
Previously decontaminated patients may be transferred immediately to the Treatment Area. Others require decontamination as described below.

ABC Reminders
Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

- Treat patients who have bronchospasm with bronchodilators.
- Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Personal Protection
If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can take place inside the hospital only if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

Basic Decontamination
Flush the eyes with water for about 5 to 10 minutes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.

- If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.
In cases of ingestion, do not induce emesis. If the patient is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered.

Treatment Area

Be certain that appropriate decontamination has been carried out (see Decontamination Area above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in ABC Reminders, previous page). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose, hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Triage

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will have pain or irritation if they were exposed. If they have no pain or irritation, they can safely be sent home and told to return with the onset of symptoms. Patients with skin or eye lesions or with respiratory symptoms should undergo decontamination and be admitted. Those with large burns or with shortness of breath should be admitted to the Critical Care Unit following appropriate decontamination. Patients with other symptoms should be observed for at least 6 hours.

Airway Exposure

Patients with minor upper-respiratory symptoms (nose, sinus, pharyngitis) should be admitted to a routine care ward for treatment. Pulmonary edema may develop several hours after exposure. Patients with symptoms or signs of severe respiratory injury should be admitted to the Critical Care Unit for treatment in a conventional manner for non-cardiac pulmonary edema.

Skin Exposure

If the skin was in contact with phosgene oxime, treat tissue damage in the same manner as for any corrosive lesion. If the burned area is large, the patient should be transferred to a Burn Unit with reverse isolation. Most burns are second degree although third degree burns may occur after liquid exposure. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism.
Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity), treatment with a soothing eye solution such as Visine or Murine, and be advised to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate need for inpatient care and observation.

Lesions more severe than conjunctivitis may be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Consult an ophthalmologist for patients with severe corneal injuries. Topical analgesics should be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain may be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia.

Ingestion Exposure

Do not induce emesis. Treat nausea and vomiting with antiemetics.

Antidotes and Other Treatments

There is no antidote for phosgene oxime. Treatment is supportive.

Laboratory Tests

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, serum electrolytes, liver enzymes, and kidney function tests. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for inhalation exposures.

Disposition and Follow-up

Patients with moderate to severe exposures will require hospitalization, as discussed above.

Patient Release

Patients with no symptoms may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop (see Follow-up Instructions, included with the Phosgene Oxime Patient Information Sheet below).

Follow-up

Patients who have mild skin burns should be reexamined within 24 hours.

Reporting

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.
Phosgene Oxime (CHCl₂NO)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phosgene oxime.

What is phosgene oxime?
Phosgene oxime is a colorless, crystalline solid or a yellowish-brown liquid. It is classified as a urticant or nettle chemical warfare agent; however, it has not been used on the battlefield.

What immediate health effects can be caused by exposure to phosgene oxime?
Phosgene oxime causes immediate and painful skin and eye lesions. Inhalation causes fluid to accumulate in the lungs and severe bronchitis.

Can phosgene oxime poisoning be treated?
There is no antidote for phosgene oxime. Its effects can be treated in the same way as burns from other causes (e.g., strong acids). Exposed persons may need to be hospitalized.

Are any future health effects likely to occur?
There is no information evaluating future health effects.

What tests can be done if a person has been exposed to phosgene oxime?
There are no specific tests to confirm exposure.

Where can more information about phosgene oxime be found?
Phosgene oxime is one of the least well studied chemical warfare agents; therefore, specific information is limited. More information about phosgene oxime may be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

• coughing, wheezing, or shortness of breath
• increased pain or discharge from injured eyes
• increased redness, pain, or a pus-like discharge from injured skin

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _________________ in the practice of ________________.
   When you call for your appointment, please say that you were treated in the Emergency Department at ________________ Hospital by __________________ and were advised to be seen again in _______ days.

[ ] Return to the Emergency Department/__________________ Clinic on (date) _____________
   at ______________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: ____________________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __________

[ ] Other instructions: ___________________________________________________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ________________
   ________________ or ________________, or by checking out the following Internet Web sites: ____________________; _____________________.

Signature of patient __________________________________ Date __________________

Signature of physician ____________________________ Date __________________
Arsine (AsH₃)
CAS 7784-42-1; UN 2188

Synonyms include arsenic hydride, arsenic trihydride, arseniuretted hydrogen, arsenious hydride, and hydrogen arsenide.

- Persons exposed to arsine pose no serious risks of secondary contamination to personnel outside the Hot Zone.
- Arsine is a flammable and highly toxic gas with a garlic-like or fishy odor that does not provide adequate warning of hazardous levels.
- Inhalation is the major route of arsine exposure. There is little information about absorption through the skin or toxic effects on the skin or eyes. However, contact with liquid arsine may result in frostbite injury.

Description
Arsine is a colorless, flammable, and highly toxic gas. It has a garlic-like or fishy odor that can be detected at concentrations of 0.5 ppm and above. Because arsine is nonirritating and produces no immediate symptoms, persons exposed to hazardous levels may be unaware of its presence. Arsine is water soluble. It is generally shipped in cylinders as a liquefied compressed gas. Exposure frequently occurs when arsine gas is generated while metals or crude ores containing arsenic impurities are treated with acid and this is a common source of exposure.

Routes of Exposure

Inhalation
Inhalation is the major route of exposure. The odor threshold of arsine is 10-fold greater than the OSHA permissible exposure limit. Odor is not an adequate indicator of arsine's presence and does not provide reliable warning of hazardous concentrations. Arsine is heavier than air and hazardous concentrations may develop quickly in enclosed, poorly ventilated, or low-lying areas. Initial symptoms (malaise, dizziness, nausea, abdominal pain, and dyspnea) may develop within several hours of exposure to 3 ppm of arsine.

Children exposed to the same levels of arsine as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of arsine found nearer to the ground.
### Skin/Eye Contact
There is little information about direct toxic effects of arsine on the skin or eyes, or about absorption through the skin. Exposure to liquid arsine (the compressed gas) can result in frostbite.

### Ingestion
Ingestion of arsine itself is unlikely because it is a gas at room temperature. However, metal arsenides are solids that can react with acidic gastric contents, releasing arsine gas in the stomach.

### Sources/Uses
Arsine gas is formed when arsenic-containing materials react with freshly formed hydrogen in water or acids. Frequently exposure results when arsenic containing metals (i.e., metal vats) undergo acid washes. Unintentional exposures have also occurred during refining of ores (e.g., lead, copper, zinc, iron, and antimony ores) that contain arsenic. Arsine is used as a dopant in the semiconductor industry and in the manufacture of crystals for fiberoptics and computer chips. It is used infrequently in galvanizing, soldering, etching, burnishing, and lead plating.

### Standards and Guidelines
- **OSHA PEL** (permissible exposure limit) = 0.05 ppm (averaged over an 8-hour workshift)
- **NIOSH IDLH** (immediately dangerous to life or health) = 3 ppm
- **AIHA ERPG-2** (emergency response planning guideline) = 0.5 ppm (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action).

### Physical Properties
**Description:** Colorless, nonirritating gas at room temperature

**Warning properties:** Inadequate; garlic-like or fishy odor at 0.5 ppm

**Molecular weight:** 78.0 daltons

**Boiling point** (760 mm Hg): -80.4 °F (-62.5 °C)

**Vapor pressure:** >760 mm Hg at 68 °F (20 °C)

**Gas density:** 2.7 (air = 1)

**Water solubility:** Soluble, 20% at 68 °F (20 °C)
**Arsine**

*Flammability:* Extremely flammable; may be ignited by heat, sparks, or flames. Vapors may travel to a source of ignition and flash back.

**Incompatibilities**

Arsine reacts with strong oxidizers, chlorine, and nitric acid. Arsine decomposes above 446 °F (230 °C).
Health Effects

- Arsine is a highly toxic gas and may be fatal if inhaled in sufficient quantities. Its primary toxic effect is due to hemolysis resulting in renal failure.

- Initially some patients may look relatively well. Common initial symptoms of exposure include malaise, headache, thirst, shivering, abdominal pain and dyspnea. These symptoms usually occur within 30 to 60 minutes with heavy exposure, but can be delayed for 2 to 24 hours.

- Hemoglobinuria usually occurs within hours, jaundice within 1 or 2 days.

**Acute Exposure**

After absorption by the lungs, arsine enters red blood cells (RBC) where different processes may contribute to hemolysis and impairment of oxygen transport. Inhibition of catalase may lead to accumulation of hydrogen peroxide which, as an oxidizer, destroys red cell membranes and may contribute to arsine-induced conversion of Fe^{2+} to Fe^{3+}, which also impairs oxygen transport. Arsine preferentially binds to hemoglobin, and is oxidized to an arsenic dihydride intermediate and elemental arsenic, both of which are hemolytic agents. Arsine toxicity involves depletion of reduced glutathione. Therefore, people deficient in the enzyme glucose-6-phosphate-dehydrogenase (G6PD) are more susceptible to hemolysis following arsine exposure. Pre-existing cardiopulmonary or renal conditions, iron deficiency, and/or pre-existing anemia may result in more severe outcomes if hemolysis occurs.

Contact with the skin or eyes does not result in systemic toxicity. Ingestion of arsine is unlikely, but ingestion of metallic arsenides can lead to arsine gas production and toxicity.

**Hematologic**

Acute intravascular hemolysis develops within hours and may continue for up to 96 hours. Haptoglobin levels decline rapidly. Free hemoglobin levels in plasma rise (levels greater than 2 g/dL have been reported). Anemia develops; the peripheral smear shows variation in the size of the red blood cells, irregularly shaped blood cells, red-cell fragments, components that have an affinity for basic dyes, Heinz bodies, and ghost cells. The bone marrow usually shows no abnormalities. Coombs and Ham tests are negative, and RBC fragility is normal.
Methemoglobinemia can be of concern in infants up to 1 year old. Children may be more vulnerable to loss of effectiveness of hemoglobin because of their relative anemia compared to adults.

**Respiratory**

Difficult breathing is among the early symptoms of arsine poisoning. A garlic odor may be present on the breath. Delayed accumulation of fluid in the lungs may occur after massive exposure. Dyspnea may be due to lack of oxygen secondary to hemolysis.

Children may be more vulnerable because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Renal**

Kidney failure due to acute tubular destruction is a significant sequela of arsine exposure. Hemoglobin in the urine is thought to be the major cause of damage to the kidneys; however, a direct toxic effect of arsine or deposition of the arsine-hemoglobin-haptoglobin complex may also play a role. Urinalysis shows large amounts of protein and free hemoglobin usually without intact RBCs. Urine may be colored (e.g., brown, red, orange, or greenish). Decreased urinary output may develop within 24 to 48 hours.

**Gastrointestinal**

Nausea, vomiting, and crampy abdominal pain are among the first signs of arsine poisoning. Onset varies from a few minutes to 24 hours after exposure.

**Dermal**

The characteristic bronze tint of the skin caused by arsine toxicity is induced by hemolysis and may be caused by hemoglobin deposits. This is not true jaundice which can occur in severe cases.

Contact with the liquid (compressed gas) can cause frostbite.

**CNS**

Headache is often an early sign of exposure. CNS disorders can develop several days after severe exposure; signs include restlessness, memory loss, disorientation, and agitation. Some exposed persons experience signs of peripheral nerve damage 1 to 2 weeks after exposure. There are case reports of polyneuropathy developing 1 to 6 months after arsine exposure.

**Hepatic**

Right upper quadrant pain, hepatomegaly, elevated serum globulin, elevated liver enzymes and prolonged prothrombin time have been observed.
| **Musculoskeletal** | Skeletal muscle injury or necrosis have been reported. Muscle pain and twitches, myoglobinuria, elevated levels of serum creatine phosphokinase (CPK) and aldolase have been observed. |
| **Cardiovascular** | Hypotension may occur with severe exposures. EKG changes and dysrhythmias associated with hypocalaemia can occur. |
| **Ocular** | Red staining of the conjuctiva may be an early sign of arsine poisoning. |
| **Chronic Exposure** | Chronic arsine exposure can result in gastrointestinal upset, anemia, and damage to lungs, kidneys, liver, nervous system, heart, and blood-forming organs. There is little information regarding health effects of chronic low-level exposures to arsine. |
| **Carcinogenicity** | Arsine has not been classified for carcinogenic effects. However, arsenic compounds and metabolites have been classified as known human carcinogens by IARC and EPA. |
| **Reproductive and Developmental Effects** | Arsine should be treated as a potential teratogenic agent. Although the reproductive effects of acute or chronic exposure to arsine are unknown, some related inorganic arsenicals produce a broad spectrum of adverse developmental effects in animals. Arsine is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Animal studies indicated that in arsine-exposed mothers, arsenic crosses the placenta and reaches the fetus; however, no adverse developmental effects were observed. |
Prehospital Management

- Although small amounts of arsine gas can be trapped in the victim’s clothing or hair after an overwhelming exposure, these quantities are not likely to create a hazard for response personnel outside the Hot Zone.

- The odor of arsine is not always detected during serious exposures; since symptoms may be delayed, ALL exposure victims should be evaluated at a medical facility.

- Toxic effects may be delayed for up to 2 to 24 hours after exposure.

- There is no specific antidote for arsine. Treatment is symptomatic and consists of measures to support respiratory, vascular, and renal function.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Arsine is a highly toxic systemic poison.

**Respiratory Protection:** Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of arsine. Full-facepiece respirators are recommended.

**Skin Protection:** Chemical-protective clothing is not generally required because arsine gas is not absorbed through the skin and does not cause skin irritation. However, contact with the liquid (compressed gas) can cause frostbite injury to the skin or eyes.

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.
**Decontamination Zone**

Victims who have exposure only to arsine gas do not need decontamination. They may be transferred immediately to the Support Zone.

**Support Zone**

Support Zone personnel require no specialized protective gear if the victim has been exposed only to arsine gas.

**ABC Reminders**

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Evaluate for respiratory tract irritation, bronchitis, or pneumonitis. Ensure adequate respiration and pulse. Administer supplemental oxygen as required. Establish intravenous access if necessary. Place on a cardiac monitor.

In cases of contact with liquid (compressed gas), gently wash frosted skin with water; gently remove clothing from affected area. Dry with clean towels and keep victim warm and quiet.

**Advanced Treatment**

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

If massive exposure is suspected or if the patient is hypotensive, ensure adequate hydration by infusing intravenous saline or lactated Ringer’s solution. For adults, bolus 1,000 mL/hour if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Monitor fluid balance and avoid fluid overload if renal failure supervenes; monitor plasma electrolytes to detect disturbances (particularly hyperkalemia) as early as possible. Monitor hematocrit.

Because of possible severe hemolysis ensure adequate oxygenation by arterial blood gas measurement or pulse oxygenation monitoring. The use of diuretics such as furosimide to maintain urinary flow is an important consideration and should be performed under medical base control.

**Transport to Medical Facility**

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.
**Multi-Casualty Triage**

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

It is difficult to determine at the scene which persons have had the most serious exposures and are likely to develop severe hemolysis; therefore, *all* persons who have potential exposure should be transported to a medical facility for evaluation.

Persons who have smelled a garlic- or fish-like odor should be transported first.
Arsine
Emergency Department Management

- Although small amounts of arsine gas can be trapped in the victim’s clothing or hair after an overwhelming exposure, these quantities are not likely to create a hazard for hospital personnel away from the scene.

- Arsine poisoning causes acute intravascular hemolysis, which may lead to renal failure. Arsine gas does not produce arsenic intoxication.

- Even if arsine’s odor was not detected at the scene, those present could have been seriously exposed. All exposure victims should be evaluated and observed.

- There is no specific antidote for arsine. Treatment consists of measures to support vascular, renal, hematologic and respiratory function.

<table>
<thead>
<tr>
<th>Critical Care Area</th>
<th>Patients exposed only to arsine gas do not need decontamination.</th>
</tr>
</thead>
</table>

**ABC Reminders**

Evaluate and support airway, breathing, and circulation. Establish intravenous access in symptomatic patients. Monitor cardiac rhythm.

Monitor fluid balance carefully to avoid fluid overload if renal failure supervenes; monitor plasma electrolytes to detect disturbances (particularly hyperkalemia) as early as possible, and monitor hematocrit.

- Patients who are comatose or hypotensive should be treated in the conventional manner.

- Consider dopamine for hypotension or oligonuria, or norepinephrine in cases of severe resistant shock.

- Observe patients who have inhaled arsine for up to 24 hours. Follow up as clinically indicated.

**Inhalation Exposure**

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Arsine poisoning is not
known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

If hemolysis develops, initiate urinary alkalization. Add 50 to 100 mEq of sodium bicarbonate to one liter of 5% dextrose in 0.25 normal saline and administer intravenously at a rate that maintains urine output at 2 to 3 mL/kg/hour. Maintain alkaline urine (i.e., pH >7.5) until urine is hemoglobin free. Closely monitor serum electrolytes, calcium, BUN, creatinine, hemoglobin, and hematocrit.

Consider hemodialysis if renal failure is severe. (Although hemodialysis will assist the patient who has renal failure, it will not effectively remove the arsine-hemoglobin or arsine-haptoglobin complexes deposited in the renal tubules.) Blood transfusions may be necessary if hemolysis causes severe anemia.

**Skin Exposure**

In case of frostbite injury, irrigate with lukewarm (42 °C) water according to standard treatment.

**Eye Exposure**

In case of frostbite injury, ensure that thorough warming with lukewarm water or saline has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

**Antidotes and Other Treatments**

There are no antidotes for arsine poisoning.

**Do not administer arsenic chelating drugs.** Although BAL (British Anti-Lewisite, dimercaprol) and other chelating agents are acceptable for arsenic poisoning, they are not effective antidotes for arsine poisoning and are not recommended.

**Laboratory Tests**

If significant exposure is a possibility and transfusion is considered, obtain a blood sample for type and screen. Laboratory tests to determine hemolysis include CBC with peripheral smear, urinalysis, and plasma free hemoglobin and haptoglobin analyses. Other useful studies include renal-function tests (e.g., BUN, creatinine), and determinations of serum electrolytes and bilirubin levels.
Consider monitoring urinary arsenic excretion to assess the severity of poisoning. Note that the amount of arsine that must be absorbed to cause significant poisoning may not be large.

### Disposition and Follow-up

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results.

### Delayed Effects

All patients who have suspected arsine exposure should be carefully observed for 24 hours, including hourly urine output. Onset of hemolysis may be delayed for up to 24 hours, and acute renal failure may not become evident for as long as 72 hours after exposure.

### Patient Release

Patients who have no signs of hemolysis may be discharged after 24 hours of observation with instructions to seek medical care promptly if symptoms develop (see the Arsine—Patient Information Sheet below). Released patients should also be instructed to rest and to drink plenty of fluids.

### Follow-up

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

All patients should have repeat urine and blood laboratory tests in 12 to 24 hours. Patients who have corneal injuries should be reexamined within 24 hours.

If severe hemolysis has occurred, anemia may persist for several weeks.

Polyneuropathy and alteration in mental status are reported to have followed arsine poisoning after a latency of 1 to 6 months. Patients should be evaluated periodically by their physician for several months; these examinations should include hematological and urinalysis tests.

### Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation
of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Arsine
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to arsine.

What is arsine?
Arsine is a colorless, flammable gas that does not burn the eyes, nose, or throat. At high concentrations it has a garlic-like or fishy smell, but a person can be exposed to a hazardous concentration of arsine and may not be able to smell it. Arsine is widely used in the manufacturing of fiberoptic equipment and computer microchips. It is sometimes used in galvanizing, soldering, etching, and lead plating. Certain ores or metals may contain traces of arsenic. If water or acid contacts these ores or metals, they may release arsine gas at hazardous levels.

What immediate health effects can result from arsine exposure?
Breathing in arsine gas can be very harmful, even in small quantities. The main effect of arsine poisoning is to destroy red blood cells, causing anemia (lack of red blood cells) and kidney damage (from circulating red-blood-cell debris). Initially, exposed individuals may feel relatively well. Within hours after a serious exposure, the victim may develop headache, weakness, shortness of breath, and back or stomach pain with nausea and vomiting; the urine may turn a dark red, brown or greenish color. The skin may become yellow or bronze in color, the eyes red or green. Generally, the more serious the exposure, the worse the symptoms. Although arsine is related to arsenic, it does not produce the usual signs and symptoms of arsenic poisoning.

Can arsine poisoning be treated?
There is no antidote for arsine, but its effects can be treated. A doctor may give the exposed patient fluids through a vein to protect the kidneys from damage. For severe poisoning, blood transfusions and cleansing of the blood (hemodialysis) may be needed to prevent worsening kidney damage.

Are any future health effects likely to occur?
After a serious exposure, symptoms usually begin within 2–24 hours (see the Follow-up Instructions). Most people do not develop long-term effects from a single, small exposure to arsine. In rare cases, permanent kidney damage or nerve damage has developed after a severe exposure. Repeated exposures to arsine over a long period of time might cause skin or lung cancer, but this has not been studied.

What tests can be done if a person has been exposed to arsine?
Specific tests can show the amount of arsenic in urine, but this information may or may not be helpful to the doctor. Standard tests of blood, urine, and other measures of health may show whether exposure has caused serious injury to the lungs, blood cells, kidneys, or nerves. Since toxic effects of arsine poisoning may be delayed, testing should be done in all cases of suspected exposure to arsine.

Where can more information about arsine be found?
More information about arsine can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety
and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24–72 hours, especially:
• unusual fatigue or weakness
• shortness of breath
• abnormal urine color (red or brown)
• stomach pain or tenderness
• unusual skin color (yellow or bronze)

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. ______________ in the practice of ______________.
When you call for your appointment, please say that you were treated in the Emergency Department at __________________________ Hospital by __________________________ and were advised to be seen again in ________ days.
[ ] Return to the Emergency Department/ Clinic on (date) ________ at ________ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for ________ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: ____________________________
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _________
____________________________________________________
____________________________________________________
[ ] Other instructions: __________________________________________
____________________________________________________
____________________________________________________
• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
• You or your physician can get more information on the chemical by contacting: ____________________________
____________ or ____________________________, or by checking out the following Internet Web sites: ____________________________; ____________________________

Signature of patient ____________________________ Date ________________

Signature of physician ____________________________ Date ________________
Hydrogen Cyanide (HCN)
CAS 74-90-8; UN 1051

Synonyms include formonitrile. Aqueous solutions are referred to as hydrocyanic acid and prussic acid.

Persons whose clothing or skin is contaminated with cyanide-containing solutions can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrogen cyanide is a colorless or pale-blue liquid at room temperature. It is very volatile, readily producing flammable and toxic concentrations at room temperature. Hydrogen cyanide gas mixes well with air, and explosive mixtures are easily formed.

- Hydrogen cyanide has a distinctive bitter almond odor, but some individuals cannot detect it and consequently, it may not provide adequate warning of hazardous concentrations.

Hydrogen cyanide is absorbed well by inhalation and can produce death within minutes. Substantial absorption can occur through intact skin if vapor concentration is high or with direct contact with solutions, especially at high ambient temperatures and relative humidity. Exposure by any route may cause systemic effects.

Description

At temperatures below 78 °F, hydrogen cyanide is a colorless or pale-blue liquid (hydrocyanic acid); at higher temperatures, it is a colorless gas. Hydrogen cyanide is very volatile, producing potentially lethal concentrations at room temperature. The vapor is flammable and potentially explosive. Hydrogen cyanide has a faint, bitter almond odor and a bitter, burning taste. It is soluble in water and is often used as a 96% aqueous solution.

Routes of Exposure

Inhalation

Hydrogen cyanide is readily absorbed from the lungs; symptoms of poisoning begin within seconds to minutes. The odor of hydrogen cyanide is detectable at 2–10 ppm (OSHA PEL = 10 ppm), but does not provide adequate warning of hazardous concentrations. Perception of the odor is a genetic trait (20% to 40% of the general population cannot detect hydrogen cyanide); also, rapid olfactory fatigue can occur. Hydrogen cyanide is lighter than air.

Children exposed to the same levels of hydrogen cyanide as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios.
**Skin/Eye Contact**

Exposure to hydrogen cyanide can cause skin and eye irritation. More importantly, skin or eye absorption is rapid and contributes to systemic poisoning. After skin exposure, onset of symptoms may be immediate or delayed for 30 to 60 minutes. Most cases of toxicity from dermal exposure have been from industrial accidents involving partial immersion in liquid cyanide or cyanide solutions or from contact with molten cyanide salts, resulting in large surface-area burns.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

**Ingestion**

Ingestion of hydrogen cyanide solutions or cyanide salts can be rapidly fatal.

**Sources/Uses**

Hydrogen cyanide is manufactured by oxidation of ammonia-methane mixtures under controlled conditions and by the catalytic decomposition of formamide. It may be generated by treating cyanide salts with acid, and it is a combustion by-product of nitrogen-containing materials such as wool, silk, and plastics. It is also produced by enzymatic hydrolysis of nitriles and related chemicals. Hydrogen cyanide gas is a by-product of coke-oven and blast-furnace operations.

Hydrogen cyanide is used in fumigating; electroplating; mining; and in producing synthetic fibers, plastics, dyes, and pesticides. It also is used as an intermediate in chemical syntheses.

**Standards and Guidelines**

OSHA PEL (permissible exposure limit) (ceiling) = 10 ppm (skin) (averaged over 15 minutes)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

AIHA ERPG-2 (emergency response planning guideline) (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 individual’s ability to take protective action) = 10 ppm

**Physical Properties**

*Description:* Colorless gas or colorless or pale-blue liquid

*Warning properties:* Almond odor at >1 ppm; inadequate warning for acute or chronic exposure
Molecular weight: 27.03 daltons

Boiling point (760 mm Hg): 78 °F (25.6 °C)

Freezing point: 8 °F (-13.4 °C)

Specific gravity: 0.69 (water = 1)

Vapor pressure: 630 mm Hg at 68 °F (20 °C)

Gas density: 0.94 (air = 1)

Water solubility: Miscible with water

Flammability: Flammable at temperatures > 0 °F (-18 °C)

Flammable range: 5.6% to 40% (concentration in air)

Incompatibilities

Hydrogen cyanide reacts with amines, oxidizers, acids, sodium hydroxide, calcium hydroxide, sodium carbonate, caustic substances, and ammonia. Hydrogen cyanide may polymerize at 122 °F to 140 °F.
Hydrogen cyanide is highly toxic by all routes of exposure and may cause abrupt onset of profound CNS, cardiovascular, and respiratory effects, leading to death within minutes.

- Exposure to lower concentrations of hydrogen cyanide may produce eye irritation, headache, confusion, nausea, and vomiting followed in some cases by coma and death.

Hydrogen cyanide acts as a cellular asphyxiant. By binding to mitochondrial cytochrome oxidase, it prevents the utilization of oxygen in cellular metabolism. The CNS and myocardium are particularly sensitive to the toxic effects of cyanide.

### Acute Exposure

In humans, cyanide combines with the ferric ion in mitochondrial cytochrome oxidase, preventing electron transport in the cytochrome system and bringing oxidative phosphorylation and ATP production to a halt. The inhibition of oxidative metabolism puts increased demands on anaerobic glycolysis, which results in lactic acid production and may produce severe acid-base imbalance. The CNS is particularly sensitive to the toxic effects of cyanide, and exposure to hydrogen cyanide generally produces symptoms within a short period of time.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

- **CNS**
  
  CNS signs and symptoms usually develop rapidly. Initial symptoms are nonspecific and include excitement, dizziness, nausea, vomiting, headache, and weakness. As poisoning progresses, drowsiness, tetanic spasm, lockjaw, convulsions, hallucinations, loss of consciousness, and coma may occur.

- **Cardiovascular**
  
  Abnormal heartbeat can occur in cases of severe poisoning. Slow heartbeat, intractable low blood pressure, and death may result. High blood pressure and a rapid heartbeat may be early, transient findings.

- **Respiratory**
  
  After systemic poisoning begins, victims may complain of shortness of breath and chest tightness. Pulmonary findings may include rapid breathing and increased depth of respirations. As poisoning progresses, respirations become slow and gasping; a bluish skin color may or may not be present. Accumulation of fluid in the lungs may develop.
Hydrogen Cyanide

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Metabolic**

An anion-gap, metabolic acidosis occurs in severe poisoning from increased blood levels of lactic acid.

Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

**Dermal**

Dermal absorption can occur, leading to systemic toxicity. Absorption occurs more readily at high ambient temperature and relative humidity.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

**Ocular**

When splashed in the eye, hydrogen cyanide can cause eye irritation and swelling. Eye contact with cyanide salts has produced systemic symptoms in experimental animals.

**Potential Sequelae**

Survivors of severe exposure may suffer brain damage due to a direct action on neurons, or to lack of oxygen, or possibly due to insufficient blood circulation. Cases of neurologic sequelae such as personality changes, memory deficits, disturbances in voluntary muscle movements, and the appearance of involuntary movements (i.e., extrapyramidal syndromes) have been reported.

**Chronic Exposure**

Chronically exposed workers may complain of headache, eye irritation, easy fatigue, chest discomfort, palpitations, loss of appetite, and nosebleeds.

Chronic exposure may be more serious for children because of their potential longer life span.

**Carcinogenicity**

Hydrogen cyanide has not been classified for carcinogenic effects, and no carcinogenic effects have been reported for hydrogen cyanide.

**Reproductive and Developmental Effects**

No reproductive or developmental effects of hydrogen cyanide have been reported in experimental animals or humans. Hydrogen cyanide is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Increased levels of thiocyanate in
the umbilical cords of fetuses whose mothers smoked compared to those whose mothers were non-smokers suggests that thiocyanate, and possibly also cyanide, can cross the placenta. No data were located pertaining to hydrogen cyanide in breast milk.
Hydrogen Cyanide

Health Effects

• ATSDR
Prehospital Management

Victims exposed only to hydrogen cyanide gas do not pose secondary contamination risks to rescuers, but do not attempt resuscitation without a barrier. Victims whose clothing or skin is contaminated with hydrogen cyanide liquid or solution can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Avoid dermal contact with cyanide-contaminated victims or with gastric contents of victims who may have ingested cyanide-containing materials.

Hydrogen cyanide poisoning is marked by abrupt onset of profound toxic effects that may include syncope, seizures, coma, gasping respirations, and cardiovascular collapse, causing death within minutes. These effects can occur from all routes of exposure.

Victims exposed to hydrogen cyanide require supportive care and rapid administration of specific antidotes.

<table>
<thead>
<tr>
<th>Hot Zone</th>
<th>Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rescuer Protection</td>
<td>Hydrogen cyanide is a highly toxic systemic poison that is absorbed well by inhalation and through the skin.</td>
</tr>
<tr>
<td>Respiratory Protection:</td>
<td>Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen cyanide.</td>
</tr>
<tr>
<td>Skin Protection:</td>
<td>Chemical-protective clothing is recommended because both hydrogen cyanide vapor and liquid can be absorbed through the skin to produce systemic toxicity.</td>
</tr>
<tr>
<td>ABC Reminders</td>
<td>Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.</td>
</tr>
<tr>
<td>Victim Removal</td>
<td>If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.</td>
</tr>
</tbody>
</table>
Hydrogen Cyanide

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**

Patients exposed only to hydrogen cyanide gas who have no eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above). **However, do not attempt resuscitation without a barrier.**

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

**Speed is critical.** For symptomatic victims, provide treatment with 100% oxygen and specific antidotes as needed. Treatment should be given simultaneously with decontamination procedures. (For treatment, see *ABC Reminders, Advanced Treatment, and Antidotes* below).

Victims who are able may assist with their own decontamination. Rapidly remove contaminated clothing while flushing exposed skin and hair with plain water for 2 to 3 minutes, then wash twice with mild soap. Rinse thoroughly with water. Double-bag contaminated clothing and personal belongings. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 5 minutes. Continue eye irrigation during other basic care or transport. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis.** If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. **If the victim is symptomatic, immediately institute emergency life support measures including the use of the cyanide antidote kit** (see *Antidotes* below).
Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have been decontaminated or who have been exposed only to vapor generally pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

**ABC Reminders**

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Patients who rapidly regain consciousness and who have no other signs or symptoms may not require antidotal treatment. Those who remain comatose or develop shock should be treated promptly with the antidotes in the cyanide antidote kit (see Antidotes below).

**Additional Decontamination**

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, do not induce emesis. If activated charcoal has not been administered previously, and the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. If the patient is symptomatic, immediately institute emergency life support measures, including the use of a cyanide antidote kit (see Antidotes below).

**Advanced Treatment**

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who are in shock or have seizures should be treated according to advanced life support (ALS) protocols. These patients or those who have arrhythmias may be seriously
Acidotic; consider giving, under medical supervision, each patient 1 mEq/kg intravenous sodium bicarbonate.

**Antidotes**

When possible, treatment with cyanide antidotes should be given under medical supervision to unconscious victims who have known or strongly suspected cyanide poisoning. Cyanide antidotes—amyl nitrite perles and intravenous infusions of sodium nitrite and sodium thiosulfate—are packaged in the cyanide antidote kit.

Amyl nitrite perles should be broken onto a gauze pad and held under the nose, over the Ambu-valve intake, or placed under the lip of the face mask. Inhale for 30 seconds every minute and use a new perle every 3 minutes if sodium nitrite infusions will be delayed.

If the patient has not responded to oxygen and amyl nitrite treatment, infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 mL of a 3% solution (300 mg) infused over *absolutely no less than 5 minutes*; the average pediatric dose is 0.12 to 0.33 mL/kg body weight up to 10 mL infused as above. Monitor blood pressure during sodium nitrite administration, and slow the rate of infusion if hypotension develops.

Next, infuse sodium thiosulfate intravenously. The usual adult dose is 50 mL of a 25% solution (12.5 g) infused over 10 to 20 minutes; the average pediatric dose is 1.65 mL/kg of a 25% solution. Repeat one-half of the initial dose 30 minutes later if there is an inadequate clinical response.

**Transport to Medical Facility**

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a cyanide-containing solution has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

**Multi-Casualty Triage**

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.
Patients with evidence of significant hydrogen cyanide exposure, and all patients who have hydrogen cyanide ingestion should be transported to a medical facility for evaluation.

Patients who have only brief inhalation exposure and mild or transient symptoms may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see Patient Information Sheet below).
**Emergency Department Management**

Hospital personnel in an enclosed area can be secondarily contaminated by vapor off-gassing from heavily soaked clothing or skin, or from toxic vomitus. Avoid dermal contact with cyanide-contaminated patients or with gastric contents of patients who may have ingested cyanide-containing materials. Patients do not pose secondary contamination risks after contaminated clothing is removed and the skin is washed.

Hydrogen cyanide poisoning is marked by abrupt onset of profound toxic effects that may include syncope, seizures, coma, gasping respirations, and cardiovascular collapse, causing death within minutes.

Patients exposed to hydrogen cyanide can survive with supportive care and rapid administration of specific antidotes.

### Decontamination Area

Previously decontaminated patients and patients exposed only to hydrogen cyanide gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients require decontamination as described below.

ED personnel should don butyl rubber gloves and aprons before treating patients who have been exposed to hydrogen cyanide liquid or solutions. (Hydrogen cyanide readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection for a short period of time.)

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

### ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated in the conventional manner. If not previously administered, give sodium bicarbonate...
intravenously to these patients. Further bicarbonate therapy should be guided by ABG measurements.

**Basic Decontamination**

Patients who are able may assist with their own decontamination.

**Speed is critical. If the patient is symptomatic, immediately institute emergency life support measures, including the use of the cyanide antidote kit (see Antidotes and Other Treatments below).**

If the patient’s clothing is wet with hydrogen cyanide solution, quickly remove contaminated clothing while flushing exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash twice with mild soap. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Rinse thoroughly with water. Double-bag contaminated clothing and personal belongings.

Irrigate exposed eyes for at least 5 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis.** If activated charcoal has not been administered previously, and the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. Consider gastric lavage if the patient is conscious and it can be performed shortly after ingestion. Because cyanide absorption from the gut is rapid, the effectiveness of activated charcoal will depend on how quickly after ingestion it can be administered. Isolate gastric washings and vomitus; they may off-gas hydrogen cyanide.

**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see Decontamination Area above).

**ABC Reminders**

Evaluate and support airway, breathing, and circulation as in **ABC Reminders** above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are in shock or have seizures should be treated according to ALS protocols. These patients or those who have
dysrhythmias may be seriously acidotic; consider giving 1 mEq/kg intravenous sodium bicarbonate.

Inhalation Exposure
Inhalation is the primary route of exposure to hydrogen cyanide. Refer to Antidotes and Other Treatments below for appropriate clinical treatment of systemic effects.

Skin Exposure
If the skin contacted hydrogen cyanide liquid or cyanide solutions, chemical burns may occur; treat as thermal burns. Watch for signs or symptoms of systemic toxicity, which may be delayed in onset for up to 1 hour.

Eye Exposure
Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure
Do not induce emesis.

If the victim is symptomatic, immediately institute emergency life support measures including the use of a cyanide antidote kit (see Antidotes and Other Treatments below). If the victim is alert, asymptomatic, has a gag reflex, and it has not been done previously, perform gastric lavage and give activated charcoal as soon as possible. Because cyanide absorption from the gut is rapid, the usefulness of activated charcoal will depend on how quickly after ingestion it can be administered.

Administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatments
Patients who have signs or symptoms of significant systemic toxicity should be evaluated for antidotal treatment. In the United States, antidotes for cyanide include amyl nitrite perles and intravenous infusions of sodium nitrite and sodium thiosulfate, which are packaged in the cyanide antidote kit.

If one dose of the antidotes from the kit has been administered previously by prehospital personnel and inadequate clinical response has occurred, a second dose of one-half the initial amounts may be given 30 minutes after the initial dose. Further
doses should be guided by the patient’s clinical condition and not by the percentage of methemoglobin induced. The usual methods of monitoring methemoglobin levels are unreliable in cases of cyanide poisoning and may seriously underestimate the levels of inactive hemoglobin.

Amyl nitrite perles should be broken onto a gauze pad and held under the nose, over the Ambu-valve intake, or placed under the lip of the face mask. Inhale for 30 seconds every minute and use a new perle every 3 minutes if sodium nitrite infusions will be delayed.

If the patient has not responded to oxygen and amyl nitrite treatment, infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 mL of a 3% solution (300 mg) infused over absolutely no less than 5 minutes; the average pediatric dose is 0.12 to 0.33 mL/kg body weight up to 10 mL infused as above. Monitor blood pressure during sodium nitrite administration, and slow the rate of infusion if hypotension develops.

Next, infuse sodium thiosulfate intravenously. The usual adult dose is 50 mL of a 25% solution (12.5 g) infused over 10 to 20 minutes; the average pediatric dose is 1.65 mL/kg of a 25% solution. Repeat one-half of the initial dose 30 minutes later if there is an inadequate clinical response.

Amyl nitrite and sodium nitrite oxidize the ferrous iron of hemoglobin to methemoglobin. Methemoglobin levels should not exceed 20%. Repeat treatment with nitrite and thiosulfate as required.

The efficacy of hyperbaric oxygen in cyanide poisoning is unproven. It has been reported to be useful in severe cases of smoke inhalation combined with exposure to hydrogen cyanide and carbon monoxide.

**Laboratory Tests**

The diagnosis of acute cyanide toxicity is primarily a clinical one (based on rapid onset of CNS toxicity and cardiorespiratory collapse). Laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, blood glucose, and electrolyte determinations. Additional studies for patients exposed to hydrogen cyanide include ECG monitoring, determinations of serum lactate, chest radiography, and pulse oximetry (or ABG measurements).
In severe poisonings, venous blood is oxygenated and has a bright red color. Elevated venous PO$_2$ and venous percent O$_2$ saturation occurs, narrowing the gap between arterial and central venous PO$_2$ or percent O$_2$ saturation.

After treatment with nitrites, serum methemoglobin levels may be monitored. However, the usual methods of monitoring methemoglobin levels are unreliable in cases of cyanide poisoning and may seriously underestimate the levels of inactive hemoglobin. Alternative methods exist, but may not be available. Whole blood cyanide tests generally require several hours and cannot be used to guide emergency treatment. However, blood cyanide levels may be useful in documenting exposure.

**Disposition and Follow-up**

Consider hospitalizing patients who have histories of significant exposure and are symptomatic. Whenever infusions from the cyanide antidote kit are used, the patient should be admitted to the intensive care unit.

**Delayed Effects**

Patients who have ingested hydrogen cyanide solutions or patients who have direct skin or eye contact should be observed in the Emergency Department for at least 4 to 6 hours.

**Patient Release**

Patients who remain asymptomatic 4 to 6 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the Hydrogen Cyanide—Patient Information Sheet below).

**Follow-up**

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Survivors of a serious exposure should be evaluated for ischemic damage to the brain and heart. Patients who have serious systemic cyanide poisoning may be at risk for CNS sequelae including Parkinsonian-like syndromes; they should be monitored for several weeks to months.

Patients who have corneal injuries should be reexamined within 24 hours.

**Reporting**

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.
Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Hydrogen Cyanide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen cyanide.

What is hydrogen cyanide?
At room temperature, hydrogen cyanide is a volatile, colorless-to-blue liquid (also called hydrocyanic acid). It rapidly becomes a gas that can produce death in minutes if breathed. Hydrogen cyanide is used in making fibers, plastics, dyes, pesticides, and other chemicals, and as a fumigant to kill rats. It is also used in electroplating metals and in developing photographic film.

What immediate health effects can be caused by exposure to hydrogen cyanide?
Breathing small amounts of hydrogen cyanide may cause headache, dizziness, weakness, nausea, and vomiting. Larger amounts may cause gasping, irregular heartbeats, seizures, fainting, and even rapid death. Generally, the more serious the exposure, the more severe the symptoms. Similar symptoms may be produced when solutions of hydrogen cyanide are ingested or come in contact with the skin.

Can hydrogen cyanide poisoning be treated?
The treatment for cyanide poisoning includes breathing pure oxygen, and in the case of serious symptoms, treatment with specific cyanide antidotes. Persons with serious symptoms will need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, a patient may have brain or heart damage.

What tests can be done if a person has been exposed to hydrogen cyanide?
Specific tests for the presence of cyanide in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the brain or heart has been injured. Testing is not needed in every case.

Where can more information about hydrogen cyanide be found?
More information about hydrogen cyanide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- difficulty breathing, shortness of breath, or chest pain
- confusion or fainting
- increased pain or a discharge from your eyes
- increased redness, pain, or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. ______________________ in the practice of ________________________.

When you call for your appointment, please say that you were treated in the Emergency Department at ______________________ Hospital by ______________________ and were advised to be seen again in ______ days.

[ ] Return to the Emergency Department/ ______________________ Clinic on (date) ______ at _______________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: ______________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ______________________

[ ] Other instructions: ______________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ______________________

or ______________________, or by checking out the following Internet Web sites: ______________________

_____________________.

Signature of patient ______________________           Date ______________________

Signature of physician ______________________           Date ______________________
Hydrogen Fluoride (HF)  
CAS 7664-39-3; UN 1052 (anhydrous), UN 1790 (solution)

Synonyms include hydrogen fluoride, fluoric acid, hydrofluoride, hydrofluoric acid, and fluorine monohydride.

Victims exposed only to hydrogen fluoride vapor do not pose substantial risks of secondary contamination; however, victims whose clothing or skin is contaminated with hydrogen fluoride liquid or solution can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrofluoric acid is a serious systemic poison. It is highly corrosive. Its severe and sometimes delayed health effects are due to deep tissue penetration by the fluoride ion. The surface area of the burn is not predictive of its effects.

Most hydrogen fluoride exposures occur by inhalation of the gas and dermal contact with hydrofluoric acid.

Description

Hydrogen fluoride is a colorless, fuming liquid or gas with a strong, irritating odor. It is usually shipped in steel cylinders as a compressed gas. Hydrogen fluoride readily dissolves in water to form colorless hydrofluoric acid solutions; dilute solutions are visibly indistinguishable from water. It is present in a variety of over-the-counter products at concentrations of 6% to 12%.

Although hydrofluoric acid is weak compared with most other mineral acids, it can produce serious health effects by any route of exposure. These effects are due to the fluoride ion’s aggressive, destructive penetration of tissues.

Routes of Exposure

Inhalation

Inhalation hazards result not only from exposure to hydrogen fluoride gas, but also from fumes arising from concentrated hydrogen fluoride liquid. Hydrogen fluoride gas is lighter than air. Even fairly low airborne concentrations of hydrogen fluoride produce rapid onset of eye, nose, and throat irritation. Hydrogen fluoride has a strong irritating odor that is discernable at concentrations of about 0.04 ppm, which is considerably less than the OSHA PEL of 3 ppm. Therefore, odor generally provides adequate warning of hazardous concentrations.

Children exposed to the same levels of hydrogen fluoride as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. Children may also be more vulnerable to
corrosive agents than adults because of the relatively smaller diameter of their airways.

**Skin/Eye Contact**

Most hydrogen fluoride exposures occur by cutaneous contact with the aqueous solution. The fluoride ion, which penetrates tissues deeply, can cause both local cellular destruction and systemic toxicity and is readily absorbed through both intact and damaged skin. Hydrogen fluoride is irritating to the skin, eyes, and mucous membranes.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

**Ingestion**

Ingestion of even a small amount of hydrofluoric acid is likely to produce systemic effects and may be fatal.

**Sources/Uses**

Hydrogen fluoride is primarily an industrial raw material. It is produced commercially by action of sulfuric acid on the mineral fluorspar. Hydrogen fluoride is used in separating uranium isotopes, as a cracking catalyst in oil refineries, and for etching glass and enamel, removing rust, and cleaning brass and crystal. It also is used in manufacturing silicon semiconductor chips and as a laboratory reagent. Some consumer products that may contain hydrogen fluoride include automotive cleaning products (e.g., for aluminum and chrome), rust inhibitors, rust removers (e.g., for ceramic tubs, sinks, and fabrics), and water-spot removers.

**Standards and Guidelines**

OSHA PEL (permissible exposure limit) = 3 ppm (averaged over an 8 hour work shift)

NIOSH IDLH (immediately dangerous to life or health) = 30 ppm

AIHA ERPG-2 (emergency response planning guideline) (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 individual’s ability to take protective action) = 20 ppm

**Physical Properties**

*Description:* Colorless gas or fuming liquid; weak solutions have the appearance of water.
**Warning properties:** Disagreeable, pungent odor at 0.04 ppm; irritation of eyes and throat at 3 ppm.

**Molecular weight:** 20.0 daltons

**Boiling point** (760 mm Hg): 68 ° (20 °C)

**Freezing point:** -118 ° (-83 °)

**Specific gravity:** 1 for liquid at 67 °F (20 °C) (water = 1)

**Vapor pressure** (68 °F): 783 mm Hg

**Gas density:** 0.7 (air = 1)

**Water solubility:** Miscible with water with release of heat

**Flammability:** Nonflammable

**Incompatibilities**

Hydrogen fluoride reacts with metals and water or steam. It will attack glass and concrete.
Hydrogen fluoride is irritating to the skin, eyes, and mucous membranes, and inhalation may cause respiratory irritation or hemorrhage. Systemic effects can occur from all routes of exposure and may include nausea, vomiting, gastric pain, or cardiac arrhythmia. Symptoms may be delayed for several days, especially in the case of exposure to dilute solutions of hydrogen fluoride (less than 20%).

- Hydrofluoric acid is corrosive and also causes destruction of deep tissues when fluoride ions penetrate the skin. Absorption of substantial amounts of hydrogen fluoride by any route may be fatal.

The systemic effects of hydrogen fluoride are due to increased fluoride concentrations in the body which can change the levels of calcium, magnesium, and potassium in the blood.

- Hypocalcemia can cause tetany, decreased myocardial contractility, and possible cardiovascular collapse while hyperkalemia has been suggested to cause ventricular fibrillation leading to death.

### Acute Exposure

The toxic effects of hydrogen fluoride are due primarily to the fluoride ion, which is able to penetrate tissues and bind intracellular calcium and magnesium. This results in cell destruction and local bone demineralization. Systemic deficiency of calcium and magnesium and excess of potassium can occur. Hypocalcemia can cause tetany, decreased myocardial contractility, and possible cardiovascular collapse, while hyperkalemia has been suggested to cause ventricular fibrillation leading to death. The adverse action of the fluoride ion may progress for several days before symptoms appear.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

### Respiratory

Inhaled hydrogen fluoride mist or vapor initially affects the nose, throat, and eyes. Mild clinical effects include mucous-membrane irritation and inflammation, cough, and narrowing of the bronchi. Severe clinical effects include almost immediate narrowing and swelling of the throat, causing upper airway obstruction. Lung injury may evolve rapidly or may be delayed in onset for 12 to 36 hours. Accumulation of fluid in the lungs, constriction of the bronchi, and partial or complete lung collapse can occur. Pulmonary effects can result even from splashes on the skin.
Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Dermal**

Depending on the concentration and duration of exposure, skin contact may produce pain, redness of the skin, and deep, slow-healing burns.

Acid concentrations of more than 50% (including anhydrous hydrogen fluoride) cause immediate severe, throbbing pain and a whitish discoloration of the skin, which usually forms blisters. Hydrogen fluoride solutions from 20% to 50% may produce pain and swelling, which may be delayed up to 8 hours. Hydrogen fluoride solutions of less than 20% cause almost no immediate pain on contact but may cause delayed serious injury 12 to 24 hours later.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

**Ocular**

Mild effects of hydrogen fluoride exposure include rapid onset of eye irritation. More severe effects, which may result from even minor hydrofluoric acid splashes, include sloughing of the surface of the eye, swelling of various structures of the eye, and cell death due to lack of blood supply. Potentially permanent clouding of the eye surface may develop immediately or after several days.

**Gastrointestinal**

Ingestion of hydrofluoric acid may cause corrosive injury to the mouth, throat, and esophagus. Inflammation of the stomach with bleeding occurs commonly. Nausea, vomiting, diarrhea, and abdominal pain may occur. Systemic effects are likely. An acid-base imbalance can occur after acute ingestion. Pulmonary aspiration may lead to respiratory complications.

**Electrolyte**

Exposure by any route may result in systemic effects, namely, low levels of calcium and magnesium and high levels of potassium in the blood. Low blood pressure, irregular heartbeat, involuntary muscle contractions, seizures, and death may ensue.
Potential Sequelae

Survivors of severe inhalation injury may suffer residual chronic lung disease. Healing of skin burns caused by concentrated hydrogen fluoride may be prolonged, and extensive scarring may result. Fingertip injuries are troublesome with persistent pain, bone loss, and nail-bed injury. After eye exposure, prolonged or permanent visual defects, blindness, or total eye destruction may occur. Hydrogen fluoride ingestion may damage the esophagus and stomach progressively for weeks. Persistent narrowing of the esophagus may result.

Chronic Exposure

Repeated ingestion of more than 6 mg of fluoride per day may result in mottling of the teeth in developing children, accumulation of fluoride in the bone, and hardening of the bone in adults and children. Long-term hydrogen fluoride exposure has been reported to damage the kidneys and liver.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

Hydrogen fluoride has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

Hydrogen fluoride is not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Fluoride crosses the placenta, and at low doses is thought to be essential for normal fetal development in humans. It is rarely excreted in breast milk. There have been rare cases of mottling of deciduous teeth in infants born to mothers who had high daily intakes of fluoride during pregnancy; skeletal abnormalities are considered unlikely. No reproductive effects due to hydrogen fluoride are known.
Hydrogen Fluoride

Prehospital Management

Victims exposed only to hydrogen fluoride gas or vapor do not pose substantial risks of secondary contamination to rescuers. However, victims whose clothing or skin is contaminated with hydrogen fluoride liquid, solution, or condensed vapor can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrogen fluoride is irritating to the skin, eyes, and mucous membranes. It is a corrosive chemical that can cause immediate or delayed onset of deep, penetrating injury. Systemic effects can occur from all routes of exposure and include pulmonary edema, nausea, vomiting, gastric pain, and cardiac arrhythmia. Absorption of fluoride ions can cause hypocalcemia, hypomagnesemia, and hyperkalemia, which can result in cardiac arrest.

Rapid decontamination is critical. Calcium-containing gels, solutions, and medications are used to neutralize the effects of hydrogen fluoride. Patients may require support of respiratory and cardiovascular functions.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained to use it, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Hydrogen fluoride is corrosive to the respiratory tract and skin and is a serious systemic poison.

*Respiratory Protection:* Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen fluoride.

*Skin Protection:* Chemical-protective clothing is recommended because skin exposure to either vapor or liquid may cause severe burns and systemic toxicity.

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be
removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**

Victims exposed only to hydrogen fluoride gas or vapor who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

**Rapid decontamination is critical.** Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing while flushing exposed skin and hair with plain water or saline for at least 30 minutes. Cover exposed skin with a calcium-containing slurry or gel (2.5 g calcium gluconate in 100 mL of water-soluble lubricant, such as K-Y Jelly, or 1 ampule of 10% calcium gluconate per ounce of K-Y Jelly).

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation during other decontamination procedures. Use of ophthalmic anesthetic eyedrops will increase patient comfort and efficiency of irritation.

In case of hydrofluoric acid ingestion, **do not induce emesis.** Do not administer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. If available, also give 2 to 4 ounces of an antacid...
containing magnesium (e.g., Maalox, milk of magnesia) or calcium (e.g., Tums).

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to vapor generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Monitor ECG for prolonged Q-T interval or QRS duration.

Additional Decontamination

Continue flushing exposed skin for 15 minutes. Do not inject or use calcium chloride for treating skin burns. It will cause extreme pain and may further injure tissues.

Treat the burned areas with calcium gluconate gel (2.5 g in 100 mL water-soluble lubricant, such as K-Y Jelly, or 1 ampule of 10% calcium gluconate per ounce of K-Y Jelly). Initially, the health care provider should wear rubber or latex gloves to prevent secondary contamination. Continue this procedure until pain is relieved or more definitive care is rendered.

If the eyes are still irritated, continue irrigating with water or saline. Remove contact lenses if present and easily removable without additional trauma. Continue irrigating the eyes with saline during transport. Use of ophthalmic anesthetic eyedrops will increase patient comfort and efficiency of irrigation.

In cases of ingestion, do not induce emesis. Do not administer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. If available, also give 2 to 4 ounces of an antacid containing
Hydrogen Fluoride

magnesium (e.g., Maalox, milk of magnesia) or calcium (e.g., Tums).

**Advanced Treatment**

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen cyanide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Hypocalcemia (manifested by tetany and dysrhythmias) is probable after ingestion of even small amounts of hydrogen fluoride. With medical consultation, treat hypocalcemia with intravenous injections of a 10% solution of calcium gluconate.

For inhalation victims, 2.5% calcium gluconate (2.5 g of calcium gluconate in 100 mL of water or 25 mL of 10% calcium gluconate diluted to 100 mL with water) administered by nebulizer with oxygen has been recommended, but the success of this therapy has not been demonstrated.

**Transport to Medical Facility**

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.
If hydrofluoric acid has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

**Multi-Casualty Triage**

Consult with the base station physician or regional poison control center for advice regarding triage of multiple victims.

Persons who have had only minor or brief exposure to hydrogen fluoride gas or vapor and are initially asymptomatic are not likely to develop complications. After their names, addresses, and telephone numbers are recorded, patients may be released from the scene with follow-up instructions (see *Patient Information Sheet* below).

**Inhalation Exposure**

Immediately transport to a medical facility those patients who have inhaled hydrogen fluoride and have upper respiratory irritation or other acute symptoms.

**Skin/Eye Contact**

All persons who have eye exposure or serious skin exposure (i.e., fingertip exposure or skin exposure greater than the total surface area of the palm) or any evidence of burns (e.g., erythema, pain, or blisters) should be transported to a hospital as soon as possible. Continue skin and eye irrigation or treatment during transport. Patients who have had even mild skin or eye contact with hydrogen fluoride should be brought to the attention of a physician as soon as possible because they may have delayed pain and systemic complications.

**Ingestion Exposure**

In cases of ingestion, patients should be transported to a hospital without delay. Watch patients carefully because systemic effects are likely to occur.
Hydrogen Fluoride

Emergency Department Management

Patients exposed only to hydrogen fluoride gas or vapor do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. However, patients whose clothing or skin is contaminated with hydrogen fluoride liquid or solution can secondarily contaminate personnel by direct contact or through off-gassing vapor.

Hydrogen fluoride is a corrosive chemical that can cause deep, penetrating injury. Absorption of fluoride ions can result in hypocalcemia and cardiac arrest. Hypocalcemia should be considered a risk in all instances of inhalation or ingestion and whenever skin burns exceed 25 square inches (an area about the size of the palm).

Because of hydrogen fluoride’s rapid skin penetration and the serious toxicity of the fluoride ion, rapid decontamination is critical. Calcium-containing gels, solutions, and medications can be used to neutralize the fluoride ion. The intense pain of hydrogen fluoride burns should not be suppressed with local anesthetics because the degree of pain is an indicator of treatment efficacy. Treatment may also include support of respiratory and cardiovascular functions.

Decontamination Area

 Previously decontaminated patients and patients exposed only to hydrogen fluoride gas or vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Because coming in contact with hydrogen fluoride-soaked clothing or skin can cause burns, ED personnel should don chemical resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, multiple layers of latex gloves, and eye protection.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via
endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen cyanide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

**Basic Decontamination**

**Rapid skin decontamination is critical.** Patients who are able may assist with their own decontamination. If the patient’s clothing is wet with hydrogen fluoride, remove and double-bag the clothing while flushing the skin with water (preferably under a shower). Flush exposed skin for at least 20 minutes. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for at least 20 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

In cases of ingestion, **do not induce emesis.** Do not administer activated charcoal. If it has not been given previously and the patient is alert and able to swallow, administer 4 to 8 ounces of water. (More information is provided in *Ingestion Exposure* under **Critical Care Area** below.)
**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

**ABC Reminders**

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not already been done.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Monitor heart, renal, and liver functions. Hypocalcemia may cause prolonged Q-T interval and cardiac rhythm abnormalities.

**Inhalation Exposure**

Calcium gluconate (2.5 grams of calcium gluconate in 100 mL of water or 25 mL of 10% calcium gluconate diluted to 100 mL with water) may be administered with oxygen by nebulizer to victims who have severe respiratory distress.

Pulmonary edema or edema of the upper airway may occur. Observe the patient for at least 24 hours and monitor with repeated chest examinations, blood gas determinations, and other appropriate tests. Follow up as clinically indicated.

**Skin Contact**

A burn specialist or plastic surgeon should be consulted early in the treatment of fluoride burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

If blisters have formed, they should be opened and drained and debrided of necrotic tissue before treatment; early debridement may facilitate healing.

**Do not inject calcium chloride to treat skin burns.** It will cause extreme pain and may further injure tissues.

Treat the burned area with calcium gluconate gel (2.5 grams in 100 mL water-soluble lubricant, such as K-Y Jelly) until the pain is relieved. If used as definitive treatment, the gel should be applied 4 to 6 times daily for 3 to 4 days. Initially, health care providers should wear rubber gloves to protect their fingers from secondary contamination. If some relief of pain is not obtained within 30 to 60 minutes, consider calcium gluconate injections.
Subungual (under the nail) burns often do not respond to immersion treatment. The treatments for hand burns require expert assistance; consult a poison center, medical toxicologist, or hand surgeon. Care must be used because multiple injections into the fingers can lead to pressure necrosis. It will be necessary to split or remove the nail.

Large burns or deeply penetrating burns (i.e., from delayed treatment or exposure to hydrogen fluoride concentrations greater than 50%) may require injections of sterile aqueous calcium gluconate into and around the burned area. The recommended dose is to inject up to 0.5 mL of 10% calcium gluconate solution per cm² of affected skin surface using a small-gauge needle (#30). No local infiltration of anesthetic should be used, but in the case of severe burns, regional or general anesthesia may be considered. Injection may not be feasible in the case of burns to the fingers; in such cases, intra-arterial infusion should be considered.

Intra-arterial calcium gluconate has been found to be effective for the treatment of burned digits and upper extremities. The radial artery has been preferentially used, with the brachial artery used if there is incomplete anastomotic flow between the radial and ulnar circulations. The initial dosage is 10 mL of 10% calcium gluconate diluted with 40 mL D₂W given intra-arterially over 4 hours. If pain is unrelieved, 20% concentrations have been used. After the first dose, the infusion can be stopped, but the line should be maintained so that further doses can be infused if pain recurs. Once the patient has been pain-free for 4 hours, the catheter can be removed. Although anesthesia can be used, it is not recommended since it invalidates the pain relief which is a titration endpoint for effective treatment.

Eye Contact

Immediate consultation with an ophthalmologist is indicated.

Do not use oils, salves, or ointments for injured eyes. Do not use the gel form of calcium gluconate in eyes, as described for skin treatment.

Irrigate exposed eyes with 1 to 2 L of plain water or saline. Administering drops of a 1% aqueous solution of calcium gluconate (50 mL of 10% solution in 450 mL of sterile saline) has also been suggested as a possible therapy. After irrigation, the pH of the eye should be checked and a complete ophthalmic examination should be carried out.
A topical anesthetic can minimize the tendency for eyelid closure and facilitate irrigation. One or two drops of proparacaine or tetracaine will usually provide rapid-onset ocular anesthesia for 20 minutes to an hour. If exposure was minor, perform visual acuity testing. Examine the eyes for corneal damage and treat appropriately.

**Ingestion Exposure**

Do not give emetics and do not administer activated charcoal. If the patient is conscious and alert, and treatment has not been administered previously, immediately give 4 to 12 ounces of water to dilute the acid. Orally administer a one-time dose of several ounces of Mylanta, Maalox, or milk of magnesia; the magnesium in these products may act chemically to bind the fluoride in the stomach. Do not give sodium bicarbonate to neutralize acid because it can cause burns.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient’s condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

**Systemic Toxicity**

Treat hypocalcemia using intravenous 10% calcium gluconate infusions with doses of 0.1 to 0.2 mL/kg up to 10 mL. Infusions can be repeated until serum calcium, ECG, or symptoms improve. Calcium levels should be checked hourly. Treat hypomagnesemia with 2 to 4 mL of 50% of magnesium sulfate intravenously over 40 minutes.
### Laboratory Tests
Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients exposed to hydrogen fluoride should also have serum calcium, potassium, and magnesium levels monitored. Chest radiography and pulse oximetry (or ABG measurements) may be useful for patients exposed through inhalation.

### Disposition and Follow-up
Patients in whom treatment fails to diminish pain and those who have respiratory distress, ingestion exposure, fingertip or eye burns, or substantial skin burns should be admitted to an intensive care unit and watched carefully for 24 hours. (Substantial skin burns are those covering an area greater than the palm of a hand, and causing skin change, or producing pain within 1 hour of exposure.) ECG monitoring may help determine treatment need and effectiveness.

### Patient Release
Patients who have eye exposure who have no signs of irritation after treatment do not require hospitalization.

Patients in the ED who have burns covering less than an area equivalent to the palm of the hand and who have normal serum calcium levels who have responded to treatment can be discharged for outpatient follow-up after remaining stable for at least 6 hours. They should be advised to seek medical care promptly if pain recurs (see the Hydrogen Fluoride—Patient Information Sheet).

### Follow-up
Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Survivors of a serious exposure should be evaluated for damage to the lungs and heart. Patients who have serious systemic hydrogen fluoride poisoning may be at risk for respiratory sequelae and should be monitored for several weeks to months. Healing of skin burns may be prolonged and eye exposure can lead to permanent damage. Ingestion may produce progressive damage to the stomach and esophagus for weeks after exposure and may result in persistent narrowing of the esophagus.

Patients who have corneal injuries should be reexamined within 24 hours.

### Reporting
If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.
Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Hydrogen Fluoride  
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen fluoride gas or hydrofluoric acid solution or vapor.

What is hydrogen fluoride?
Hydrogen fluoride is a colorless, highly irritating gas with a pungent odor. It dissolves easily in water to form hydrofluoric acid. Consumer products that contain hydrogen fluoride include rust removers, water-spot removers, and chrome cleaners.

What immediate health effects can be caused by exposure to hydrogen fluoride?
Most poisonings occur when hydrogen fluoride gets on the skin or in the eyes. Concentrated hydrogen fluoride solutions can cause severe, deep, and disfiguring burns. Absorption of the chemical into the body can cause the heart to beat irregularly, leading to death. Exposure to dilute solutions (less than 20% concentration) may cause few or no symptoms at first, but may cause severe pain later. Drinking hydrofluoric acid can cause severe burns to the throat and stomach and even death. Injury can also occur from breathing hydrogen fluoride gas or the vapor from concentrated hydrogen fluoride solutions. Breathing high concentrations of hydrogen fluoride vapor can cause rapid death from throat swelling or from chemical burns to the lungs.

Can hydrogen fluoride poisoning be treated?
Patients who have experienced serious symptoms, such as severe or persistent coughing or skin or eye burns, may need to be hospitalized. Calcium- or magnesium-containing medicines may be used to treat the skin, and doctors may inject calcium-containing medicines into burned areas or into the blood. If hydrofluoric acid is swallowed, a solution containing calcium or magnesium may be given.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, you may not notice any symptoms for up to 36 hours. Scarring may result from skin contact with hydrogen fluoride.

What tests can be done if a person has been exposed to hydrogen fluoride?
The doctor may order blood tests, urine tests, chest x-ray, and heart monitoring to see whether damage has been done to the heart, lungs, or other organs. Testing is not needed in every case. If hydrogen fluoride contacts the eyes, the doctor may put a special dye into the eyes and examine them with a magnifying device.

Where can more information about hydrogen fluoride be found?
More information about hydrogen fluoride or hydrofluoric acid can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
   • difficulty breathing, shortness of breath or wheezing
   • hoarseness, high-pitched voice, or difficulty speaking
   • chest pain or tightness
   • any skin changes, discharge, or increased pain where skin is burned
   • stomach pain, vomiting, or diarrhea
   • increased pain or a discharge from exposed eyes

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____________________ in the practice of ___________________.
   When you call for your appointment, please say that you were treated in the Emergency Department at _____________________ Hospital by _____________________ and were advised to be seen again in ________ days.

[ ] Return to the Emergency Department/ _____________________ Clinic on (date) ____________ at __ _____________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications:
   _____________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____________________

[ ] Other instructions:
   _____________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: _____________________ or _____________________, or by checking out the following Internet Web sites: _____________________; _____________________.

Signature of patient _____________________ Date ______________

Signature of physician _____________________ Date ______________
Ammonia (NH₃)
CAS 7664-41-7; UN 2672 (between 12% and 44% solution), UN 2073 (>44% solution), UN 1005 (anhydrous gas or >50% solution)

Synonyms include ammonia gas, anhydrous ammonia, and liquid ammonia. Aqueous solutions are referred to as aqueous ammonia, ammonia solution, and ammonium hydroxide.

Persons exposed only to ammonia gas do not pose significant risks of secondary contamination to personnel outside the Hot Zone. Persons whose clothing or skin is contaminated with liquid ammonium hydroxide can secondarily contaminate response personnel by direct contact or through off-gassing ammonia vapor.

Ammonia dissolves readily in water to form ammonium hydroxide a corrosive, alkaline solution at high concentrations.

Ammonia’s pungent odor and irritating properties usually provide adequate warning of its presence; however, olfactory fatigue can occur. Inhalation can result in fatalities.

Description
At room temperature, anhydrous ammonia is a colorless, highly irritating gas with a pungent, suffocating odor. It is lighter than air and flammable, with difficulty, at high concentrations and temperatures. It is easily compressed and forms a clear, colorless liquid under pressure. Anhydrous ammonia is hygroscopic. Ammonia dissolves readily in water to form ammonium hydroxide—an alkaline solution. The concentration of aqueous ammonia solutions for household use is typically 5% to 10% (weight:volume), but solutions for commercial use may be 25% (weight:volume) or more and are corrosive. Aqueous ammonia is commonly stored in steel drums. Anhydrous ammonia is stored and shipped in pressurized containers, fitted with pressure-relief safety devices, and bears the label “Nonflammable Compressed Gas”. Despite not meeting the Department of Transport definition of flammable it should be treated as such.

Routes of Exposure
Inhalation
Inhalation of ammonia may cause nasopharyngeal and tracheal burns, bronchiolar and alveolar edema, and airway destruction resulting in respiratory distress or failure. Ammonia’s odor threshold is sufficiently low to acutely provide adequate warning of its presence (odor threshold = 5 ppm; OSHA PEL = 50 ppm). However, ammonia causes olfactory fatigue or adaptation, making its presence difficult to detect when exposure is prolonged. Anhydrous ammonia is lighter than air and will
therefore rise (will not settle in low-lying areas); however, vapors from liquefied gas are initially heavier than air and may spread along the ground. Asphyxiation may occur in poorly ventilated or enclosed.

Children exposed to the same levels of ammonia vapor as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of ammonia vapor found nearer to the ground.

**Skin/Eye Contact**

The extent of injury produced by exposure to ammonia depends on the duration of the exposure and the concentration of the gas or liquid. Even low airborne concentrations (100 ppm) of ammonia may produce rapid eye and nose irritation. Higher concentrations may cause severe eye injury. Contact with concentrated ammonia solutions, such as some industrial cleaners (25%), may cause serious corrosive injury, including skin burns, permanent eye damage, or blindness. The full extent of damage to the eyes may not be clear until up to 1 week after the injury is sustained. Contact with liquefied ammonia can cause frostbite injury.

Children are more vulnerable to toxicants that affect the skin because of their relatively larger surface area:body weight ratio.

**Ingestion**

Ingestion of ammonium hydroxide, while uncommon, results in corrosive damage to the mouth, throat, and stomach. Ingestion of ammonia does not normally result in systemic poisoning.

**Sources/Uses**

Ammonia is manufactured by reacting hydrogen with nitrogen. About 80% of the ammonia produced is used in fertilizers. It is also used as a refrigerant gas, and in the manufacture of plastics, explosives, pesticides, and other chemicals, as a corrosion inhibitor, in the purification of water supplies, as a component of household cleaners, in the pulp and paper, metallurgy, rubber, food and beverage, textile and leather industries, and in the manufacture of pharmaceuticals. Ammonia is also produced naturally from decomposition of organic matter and under unusual conditions, can reach dangerous concentrations.
<table>
<thead>
<tr>
<th>Standards and Guidelines</th>
<th>OSHA PEL (permissible exposure limit) = 50 ppm (8-hour TWA).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NIOSH IDLH (immediately dangerous to life or health) = 300 ppm.</td>
</tr>
<tr>
<td></td>
<td>AIHA ERPG-2 (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 individual’s ability to take protective action) = 200 ppm.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Description: Clear, colorless gas at room temperature; easily liquefied; readily dissolves in water to form caustic solutions.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warning properties: Pungent odor at ~5 ppm; eye irritation at 20 ppm</td>
</tr>
<tr>
<td></td>
<td>Molecular weight: 17.0 daltons</td>
</tr>
<tr>
<td></td>
<td>Boiling point (760 mm Hg): -28 °F (-33.4 °C)</td>
</tr>
<tr>
<td></td>
<td>Vapor pressure: &gt;6,000 mm Hg at 68 °F (20 °C)</td>
</tr>
<tr>
<td></td>
<td>Gas density: 0.59 (air = 1)</td>
</tr>
<tr>
<td></td>
<td>Water solubility: 33.1% at 68 °F (20 °C)</td>
</tr>
<tr>
<td></td>
<td>Autoignition temperature: 1,204 °F (650 °C)</td>
</tr>
<tr>
<td></td>
<td>Flammable range: 16–25% (concentration in air) Combustible gas, but difficult to burn</td>
</tr>
</tbody>
</table>

| Incompatibilities | Ammonia reacts with strong oxidizers, acids, halogens (including chlorine bleach), and salts of silver, zinc, copper, and other heavy metals. It is corrosive to copper and galvanized surfaces. |
Health Effects

Ammonia is highly irritating to the eyes and respiratory tract. Swelling and narrowing of the throat and bronchi, coughing, and an accumulation of fluid in the lungs can occur.

Ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling and pulmonary edema may lead to airway obstruction.

Prolonged skin contact is prolonged (more than a few minutes) can cause pain and corrosive injury.

**Acute Exposure**

Anhydrous ammonia reacts with moisture in the mucous membranes to produce an alkaline solution (ammonium hydroxide). Exposure to ammonia gas or ammonium hydroxide can result in corrosive injury to the mucous membranes of the eyes, lungs, and gastrointestinal tract and to the skin due to the alkaline pH and the hygroscopic nature of ammonia.

**Respiratory**

The extent of injury produced by exposure to ammonia depends on the duration of the exposure, the concentration of the gas, and the depth of inhalation. Even fairly low airborne concentrations (50 ppm) of ammonia produce rapid onset of eye, nose, and throat irritation; coughing; and narrowing of the bronchi. More severe clinical signs include immediate narrowing of the throat and swelling, causing upper airway obstruction and accumulation of fluid in the lungs. This may result in low blood oxygen levels and an altered mental status. Mucosal burns to the tracheobronchial tree can also occur.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children may also be more vulnerable because of failure to evacuate an area promptly when exposed.

**Dermal**

Dilute aqueous solutions (less than 5%) rarely cause serious burns but can be moderately irritating. Exposure to concentrated vapor or solution can cause pain, inflammation, blisters, necrosis and deep penetrating burns, especially on moist skin areas. Skin contact with compressed, liquid ammonia (which is stored at -28 °F) causes frostbite injury, and may also result in severe burns with deep ulcerations.
Ammonia

**Ocular**
Ammonia has a greater tendency to penetrate and damage the eyes than does any other alkali. Even low concentrations of ammonia vapor (100 ppm) produce rapid onset of eye irritation. Contact with high concentrations of the gas or with concentrated ammonium hydroxide may cause swelling and sloughing of the surface cells of the eye, which may result in temporary or permanent blindness.

**Gastrointestinal**
Nausea, vomiting, and abdominal pain are common symptoms following ingestion of ammonia. On rare occasions, deliberate ingestion of household ammonia (5–10%) has resulted in severe esophageal burns. Ingestion of more concentrated ammonia can cause severe corrosive injury to the mouth, throat, esophagus and stomach.

**Potential Sequelae**
Survivors of severe inhalation injury may suffer residual chronic lung disease. In cases of eye contact, ulceration and perforation of the cornea can occur after weeks or months, and blindness may ensue. Cataracts and glaucoma have been reported in persons acutely exposed. Ingestion of ammonia may cause permanent damage to the mucous membranes of the alimentary canal, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

**Chronic Exposure**
Repeated exposure to ammonia may cause chronic irritation of the respiratory tract. Chronic cough, asthma and lung fibrosis have been reported. Chronic irritation of the eye membranes and dermatitis have also been reported.

**Carcinogenicity**
Ammonia has not been classified for carcinogenic effects.

**Reproductive and Developmental Effects**
No data exist to evaluate the reproductive and developmental effects of ammonia in humans. Ammonia is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Decreased egg production and conception rates have been observed in animals, and ammonia has been shown to cross the ovine placental barrier.
Victims exposed only to ammonia gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid ammonium hydroxide can secondarily contaminate response personnel by direct contact or through off-gassing ammonia vapor.

Ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling and pulmonary edema may lead to airway obstruction.

Ammonia gas or solution can cause serious corrosive burns on contact.

There is no antidote for ammonia poisoning. Treatment consists of supportive measures. These include administration of humidified oxygen and bronchodilators and airway management; treatment of skin and eyes with copious irrigation; and dilution of ingested ammonia with milk or water.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Ammonia is a caustic and corrosive chemical that causes irritation and chemical burns upon contact of the gas or liquid with the eyes, skin, respiratory tract, or alimentary canal.

*Respiratory Protection:* Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of ammonia.

*Skin Protection:* Chemical-protective clothing is recommended because ammonia can cause skin irritation and burns.

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.
Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**

Vicrims exposed only to ammonia gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe (<20 ppm), decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

*Rapid skin and eye decontamination is critical.* Victims who are able, may assist with their own decontamination. Remove contaminated clothing while flushing exposed areas. Double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with water for at least 5 minutes. If feasible, wash exposed skin extremely thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating of children or the elderly. Use blankets when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses, if easily removable without additional trauma to the eye. Continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion *do not induce emesis*, perform gastric lavage, or attempt neutralization. Do not administer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.
Transport to Support Zone  
As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone  
Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders  
Quickly access a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse; administer supplemental oxygen as required. Establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination  
Continue irrigating exposed skin and eyes, as appropriate. In cases of ingestion, do not induce emesis, do not administer activated charcoal, and do not attempt to neutralize with weak acids. If the patient is conscious and able to swallow, administer 4 to 8 ounces of water or milk if it has not been given previously.

Advanced Treatment  
In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so. Patients who are hypotensive or have seizures should be treated according to advanced life support (ALS) protocols.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ammonia poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.
Patients who are comatose, hypotensive, or are having seizures or have cardiac arrhythmias should be treated according to ALS protocols.

Monitor fluid and electrolyte balance and restore if abnormal. Fluids should be administered cautiously to patients with pulmonary edema.

**Transport to Medical Facility**

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If ammonia has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

**Multi-Casualty Triage**

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

The following exposed persons should be evaluated at a medical facility: those who have ingested ammonia, those who have persistent upper respiratory irritation or other acute symptoms of severe inhalation exposure, and those who have eye or skin burns that cover a large surface area.

Persons who have been exposed only to ammonia gas and are currently asymptomatic are not likely to develop complications. After their names, addresses, and telephone numbers are recorded, these patients may be released from the scene with follow-up instructions to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).
Emergency Department Management

Hospital personnel in an enclosed area can be secondarily contaminated by vapor off-gassing from heavily soaked clothing or from the vomitus of victims who have ingested ammonia. Patients do not pose a contamination risk after contaminated clothing is removed and the skin and hair are washed.

Inhaling ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling may lead to airway obstruction.

Ammonia gas or solution can cause serious corrosive burns on contact.

There is no antidote for ammonia poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to ammonia gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require rapid decontamination as described in Basic Decontamination below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Watch for signs of laryngeal edema and airway compromise. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use
of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ammonia poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive or have seizures should be treated in the conventional manner. Manage hypotension and shock with intravenous fluids (use caution when pulmonary edema is present); pressor agents may be required.

Basic Decontamination

Patients who are able, may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

Because ammonia in solution can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient’s clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Flush liquid-exposed skin and hair with water for at least 5 minutes. If feasible, wash exposed skin extremely thoroughly with soap and water.

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses, if easily removable without additional trauma to the eye. Continue irrigation while transferring the victim to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelid.

In cases of ingestion, do not induce emesis; do not administer activated charcoal. If the patient is conscious and able to swallow, administer 4 to 8 ounces of water or milk if it has not been given previously (see Critical Care Area below for more information on ingestion exposure).
Critical Care Area

Be certain that appropriate decontamination has been carried out. (See Decontamination Area above.)

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, having seizures or have cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ammonia poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Observe patients carefully for 6 to 12 hours for signs of upper-airway obstruction. Patients who have had a severe exposure may develop noncardiogenic pulmonary edema.

Skin Exposure

If ammonia gas or solution was in contact with the skin, chemical burns may result; treat as thermal burns.

Eye Exposure

Continue irrigation for at least 15 minutes or until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.
**Ammonia**

**Ingestion Exposure**

**Do not induce emesis** because this may re-expose the esophagus and mouth to the caustic substance. Do not administer activated charcoal. Do not perform gastric lavage or attempt neutralization after ingestion. If not given during decontamination, give 4 to 8 ounces of water by mouth to dilute stomach contents.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy.

**Antidotes and Other Treatments**

There is no specific antidote for ammonia poisoning. Although administration of corticosteroids to limit esophageal scarring is recommended by some toxicologists, this treatment is unproven and may be harmful in patients who have perforation or serious infection. Hemodialysis is not effective.

**Laboratory Tests**

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Chest radiography and pulse oximetry (or arterial blood gases measurements) are recommended for severe inhalation exposure or if pulmonary aspiration is suspected. No specific biologic test for ammonia exposure exists.

**Disposition and Follow-up**

Consider hospitalizing patients who have evidence of respiratory distress or significant skin burns or who have ingested an ammonia solution.

**Delayed Effects**

Pulmonary injury may continue to evolve over 18 to 24 hours. Residual bronchoconstriction, bronchiectasis and small airway disease may occur, and chronic obstructive pulmonary disease can develop. Patients exposed by inhalation who are initially symptomatic should be observed carefully and reexamined periodically. Pulmonary function tests should be repeated on an annual basis. Patients who develop pulmonary edema should be admitted to an intensive care unit.

Acute ocular exposure to ammonia may result in persistent intraocular pressure, cataract formation, and glaucoma with significant reduction in visual acuity.

**Patient Release**

Patients who are asymptomatic following exposure or who experienced mild symptoms that have been treated may be released and advised to seek medical care promptly if symptoms recur or develop (see Ammonia—Patient Information Sheet below). Cigarette smoking may exacerbate pulmonary injury and should be discouraged for 72 hours after exposure.
Follow-up

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Patients with mild to moderate skin burns should be reexamined within 24 hours.

Patients who have eye injuries should be reexamined by an ophthalmologist in 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; note incident details and contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Ammonia
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to ammonia gas or ammonium hydroxide solution.

What is ammonia?
Ammonia is a colorless, highly irritating gas with a sharp, suffocating odor. It easily dissolves in water to form a caustic solution called ammonium hydroxide. It is not highly flammable, but containers of ammonia may explode when exposed to high heat. About 80% of the ammonia produced is used in fertilizers. It is also used as a refrigerant and in the manufacture of plastics, explosives, pesticides, and other chemicals. It is found in many household and industrial-strength cleaning solutions.

What immediate health effects can result from ammonia exposure?
Most people are exposed to ammonia from breathing the gas. They will notice the pungent odor and experience burning of the eyes, nose, and throat after breathing even small amounts. With higher doses, coughing or choking may occur. Exposure to high levels of ammonia can cause death from a swollen throat or from chemical burns to the lungs. Skin contact with ammonia-containing liquids may cause burns. Eye exposure to concentrated gas or liquid can cause serious corneal burns or blindness. Drinking a concentrated ammonia solution can cause burns to the mouth, throat, and stomach. Generally, the severity of symptoms depends on the degree of exposure.

Can ammonia poisoning be treated?
There is no antidote for ammonia poisoning, but ammonia’s effects can be treated, and most people recover. Persons who have experienced serious signs and symptoms (such as severe or persistent coughing or burns in the throat) may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, injury to the eyes, lungs, skin, or digestive system may continue to develop for 18 to 24 hours, and serious delayed effects, such as gastric perforation, chronic pulmonary obstructive disease, or glaucoma, are possible.

What tests can be done if a person has been exposed to ammonia?
Specific tests for the presence of ammonia in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses, chest x-rays, and other tests may show whether the lungs have been injured. Testing is not needed in every case. If ammonia contacts the eyes, the doctor may put a special dye in the eyes and examine them with a magnifying lamp.

Where can more information about ammonia be found?
More information about ammonia can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational or environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
  • coughing
  • difficulty breathing or shortness of breath
  • wheezing or high-pitched voice
  • chest pain or tightness
  • increased pain or a discharge from exposed eyes
  • increased redness or pain or a pus-like discharge in the area of a skin burn
  • stomach pain or vomiting

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. ________________ in the practice of ________________.
When you call for your appointment, please say that you were treated in the Emergency Department at ________________ Hospital by ________________________ and were advised to be seen again in ________ days.
[ ] Return to the Emergency Department/_________________________ Clinic on (date) ____________
at ____________________ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for ________ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: ____________________________________________
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _______
______________________________________________________________

[ ] Other instructions: _______________________________________________________________
_________________________________________________________________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
• You or your physician can get more information on the chemical by contacting: ____________
  __________ or ____________ ______________________, or by checking out the following Internet Web sites: _______________________________ ________________

Signature of patient _________________________________ Date ______________________

Signature of physician _________________________________ Date ______________________
Chlorine \( (\text{Cl}_2) \)
CAS 7782-50-5; UN 1017

Synonyms include molecular chlorine.

- Persons exposed only to chlorine gas pose little risk of secondary contamination to others. However, clothing or skin soaked with industrial-strength chlorine bleach or similar solutions may be corrosive to rescuers and may release harmful chlorine gas.

- Chlorine is a yellow-green, noncombustible gas with a pungent, irritating odor. It is a strong oxidizing agent and can react explosively or form explosive compounds with many common substances. Chlorine is heavier than air and may collect in low-lying areas.

- Chlorine gas is highly corrosive when it contacts moist tissues such as the eyes, skin, and upper respiratory tract. Significant dermal absorption or ingestion is unlikely.

**Description**

At room temperature, chlorine is a yellow-green gas with a pungent irritating odor. Under increased pressure or at temperatures below -30 °F, it is a clear, amber-colored liquid. It is generally shipped in steel cylinders as a compressed liquid. Chlorine is only slightly soluble in water, but on contact with moisture it forms hypochlorous acid \((\text{HClO})\) and hydrochloric acid \((\text{HCl})\); the unstable \text{HClO} readily decomposes, forming oxygen free radicals. Because of these reactions, water substantially enhances chlorine’s oxidizing and corrosive effects.

**Routes of Exposure**

### Inhalation

Most exposures to chlorine occur by inhalation. Chlorine’s odor or irritant properties are discernible by most individuals at 0.32 ppm which is less than the OSHA permissible exposure limit \((\text{PEL})\) of 1 ppm. Chlorine’s odor or irritant properties generally provide adequate warning of hazardous concentrations. However, prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of chlorine’s irritant effects. Chlorine is heavier than air and may cause asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children are at increased risk for exposure to inhaled toxicants because they have a greater lung surface area:body weight ratio and an increased minute volume:weight ratio. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children also may be at
increased risk because of their short stature, when higher concentrations of the chemical are found at low-lying areas.

**Skin/Eye Contact**

Direct contact with liquid chlorine or concentrated vapor causes severe chemical burns, leading to cell death and ulceration.

**Ingestion**

Ingestion is unlikely to occur because chlorine is a gas at room temperature. Solutions that are able to generate chlorine (e.g., sodium hypochlorite solutions) may cause corrosive injury if ingested.

**Sources/Uses**

Chlorine is produced commercially by electrolysis of sodium chloride brine. It is among the ten highest volume chemicals manufactured in the United States, with 1998 production in excess of 14 million tons.

Chlorine’s most important use is as a bleach in the manufacture of paper and cloth. Chlorine is also used widely as a chemical reagent in the synthesis and manufacture of metallic chlorides, chlorinated solvents, pesticides, polymers, synthetic rubbers, and refrigerants.

Sodium hypochlorite, which is a component of commercial bleaches, cleaning solutions, and disinfectants for drinking water and waste water purification systems and swimming pools, releases chlorine gas when it comes in contact with acids.

**Standards and Guidelines**

OSHA ceiling = 1 ppm

NIOSH IDLH (immediately dangerous to life or health) = 10 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 3 ppm.

**Physical Properties**

*Description:* Yellow-green gas at room temperature

*Warning properties:* odor and irritation are generally adequate, but olfactory fatigue can occur; pungent odor at about 0.31 ppm

*Molecular weight:* 70.9 daltons

*Boiling point:* (760 mm Hg) = -29 °F (-34 °C)
Freezing point: -150 °F (-101 °C)

Specific gravity: 1.56 at boiling point (water = 1)

Vapor pressure: 5,168 mm Hg at 68 °F (20 °C)

Gas density: 2.5 (air = 1)

Water solubility: (0.7% at 68 °F) (20 °C)

Flammability: Not flammable, but reacts explosively or forms explosive compounds with many common substances

**Incompatibilities**

Chlorine reacts explosively or forms explosive compounds with many common substances such as acetylene, ether, turpentine, ammonia, fuel gas, hydrogen, and finely divided metals.
Health Effects

- Chlorine gas is irritating and corrosive to the eyes, skin, and respiratory tract.
- Exposure to chlorine may cause burning of the eyes, nose, and throat; cough as well as constriction and edema of the airway and lungs can occur.

### Acute Exposure

The toxic effects of chlorine are primarily due to its corrosive properties. The action of chlorine is due to its strong oxidizing capability, in which chlorine splits hydrogen from water in moist tissue, causing the release of nascent oxygen and hydrogen chloride which produce major tissue damage. Alternatively, chlorine may be converted to hypochlorous acid which can penetrate cells and react with cytoplasmic proteins to form N-chloro derivatives that destroy cell structure. Symptoms may be apparent immediately or delayed for a few hours.

#### Respiratory

Chlorine is water soluble and therefore, primarily removed by the upper airways. Exposure to low concentrations of chlorine (1 to 10 ppm) may cause eye and nasal irritation, sore throat, and coughing. Inhalation of higher concentrations of chlorine gas (>15 ppm) can rapidly lead to respiratory distress with airway constriction and accumulation of fluid in the lungs (pulmonary edema). Patients may have immediate onset of rapid breathing, blue discoloration of the skin, wheezing, rales or hemoptysis. In symptomatic patients, pulmonary injury may progress over several hours. Lung collapse may occur. The lowest lethal concentration for a 30-minute exposure has been estimated as 430 ppm. Exposure to chlorine can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

#### Cardiovascular

Tachycardia and initial hypertension followed by hypotension may occur. After severe exposure, cardiovascular collapse may occur from lack of oxygen.
Metabolic

Acidosis may result from insufficient oxygenation of tissues. An unusual complication of massive chlorine inhalation is an excess of chloride ions in the blood, causing an acid-base imbalance.

Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal

Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite injury.

Ocular

Low concentrations in air can cause burning discomfort, spasmodic blinking or involuntary closing of the eyelids, redness, conjunctivitis, and tearing. Corneal burns may occur at high concentrations.

Potential Sequelae

After acute exposure, pulmonary function usually returns toward baseline within 7 to 14 days. Although complete recovery generally occurs, symptoms and prolonged pulmonary impairment may persist. Exposure to chlorine can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Chronic Exposure

Chronic exposure to chlorine, usually in the workplace, may cause corrosion of the teeth. Multiple exposures to chlorine have produced flu-like symptoms and a high risk of developing reactive airways dysfunction syndrome (RADS).

Carcinogenicity

Chlorine has not been classified for carcinogenic effects. However, the association of cigarette smoking and chlorine fumes may increase the risk of cancer.

Reproductive and Developmental Effects

No information is available regarding reproductive or developmental effects of chlorine in experimental animals or humans. Chlorine gas has been used as a chemical warfare agent, but no retrospective reproductive studies of survivors have been published. Chlorine is not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.
Chlorine

Prehospital Management

- Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to chlorine gas. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful chlorine gas.

- Acute exposure to chlorine gas initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may occur. Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite.

- There is no specific antidote for chlorine poisoning. Treatment is supportive.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Chlorine is a severe respiratory-tract and skin irritant.

*Respiratory Protection:* Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of chlorine.

*Skin Protection:* Chemical-protective clothing should be worn because chlorine gas can condense on the skin and cause irritation and burns.

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.
**Decontamination Zone**

Victims exposed only to chlorine gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 3 to 5 minutes, then wash twice with mild soap. Rinse thoroughly with water.

Do not irrigate eyes that have sustained frostbite injury. Otherwise, irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.
Support Zone

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to chlorine gas pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator. Use direct visualization to intubate. When the patient’s condition precludes endotracheal intubation, perform cricothyroidectomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Chlorine poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 m of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If frostbite is present, treat by rewarming in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.
Chlorine

**Transport to Medical Facility**

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

**Multi-Casualty Triage**

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see Patient Information Sheet below).
Emergency Department Management

- Hospital personnel are at minimal risk of secondary contamination from patients who have been exposed only to chlorine gas. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to personnel and may release harmful chlorine gas.

- Acute exposure to chlorine gas initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction, noncardiogenic pulmonary edema, hemoptysis, and bronchopneumonia may occur.

- Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite.

- There is no specific antidote for chlorine poisoning. Treatment requires supportive care.

Decontamination Area

Previously decontaminated patients and patients exposed only to chlorine gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. All others require decontamination as described below.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Chlorine poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.
Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

**Basic Decontamination**

Patients who are able and cooperative may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Otherwise, begin irrigation of exposed eyes. Remove contact lenses if it can be done without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see Decontamination Area above).

**ABC Reminders**

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

**Inhalation Exposure**

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Chlorine poisoning is not
known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Children may be more vulnerable to corrosive agents than adults because of their smaller airways.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

**Skin Exposure**

If concentrated chlorine gas or chlorine-generating solutions contact the skin, chemical burns may occur; treat as thermal burns. If the liquefied compressed gas is released and contacts the skin, frostbite may result. If a victim has frostbite, treat by rewarming affected areas in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Because of their larger surface area:body weight ratio children are more vulnerable to toxicants absorbed through the skin.

**Eye Exposure**

Chlorine-exposed eyes should be irrigated for at least 15 minutes. Test visual acuity and examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

**Antidotes and Other Treatments**

There is no specific antidote for chlorine. Treatment is supportive.

**Laboratory Tests**

The diagnosis of acute chlorine toxicity is primarily clinical, based on respiratory difficulties and irritation. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements) and chest radiography. Massive inhalation may be complicated by hyperchloremic metabolic acidosis; in addition to electrolytes, monitor blood pH.

**Disposition and Follow-up**

Consider hospitalizing patients who have a suspected significant exposure or have eye burns or serious skin burns.

**Delayed Effects**

Symptomatic patients complaining of persistent shortness of breath, severe cough, or chest tightness should be admitted to
the hospital and observed until symptom-free. Pulmonary injury may progress for several hours.

**Patient Release**

Asymptomatic patients and those who experienced only minor sensations of burning of the nose, throat, eyes, and respiratory tract (with perhaps a slight cough) may be released. In most cases, these patients will be free of symptoms in an hour or less. They should be advised to seek medical care promptly if symptoms develop or recur (see the *Chlorine—Patient Information Sheet* below).

**Follow-up**

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Follow up is recommended for all hospitalized patients because long-term respiratory problems can result. Respiratory monitoring is recommended until the patient is symptom-free. Chlorine-induced reactive airways dysfunction syndrome (RADS) has been reported to persist from 2 to 12 years.

Patients who have skin or corneal injury should be re-examined within 24 hours.

**Reporting**

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Chlorine
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to chlorine.

What is chlorine?
Chlorine is a yellowish-green gas with a sharp, burning odor. It is used widely in chemical manufacturing, bleaching, drinking-water and swimming-pool disinfecting, and in cleaning agents. Household chlorine bleach contains only a small amount of chlorine but it can release chlorine gas if mixed with other cleaning agents.

What immediate health effects can be caused by exposure to chlorine?
Even small exposures to the gas may cause immediate burning of the eyes, nose, and throat, and shortness of breath, as well as coughing, wheezing, shortness of breath, and tearing of the eyes. However, once exposure is stopped, symptoms usually clear up quickly. Breathing large amounts of chlorine may cause the lining of the throat and lungs to swell, making breathing difficult. Generally, the more serious the exposure, the more severe the symptoms.

Can chlorine poisoning be treated?
There is no antidote for chlorine, but its effects can be treated and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, symptoms may worsen for several hours.

What tests can be done if a person has been exposed to chlorine?
Specific tests for the presence of chlorine in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, heart, or brain has been injured. Testing is not needed in every case.

Where can more information about chlorine be found?
More information about chlorine can be obtained from your regional poison control center, your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from injured eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. ________________ in the practice of ________________.
   When you call for your appointment, please say that you were treated in the Emergency Department at ________________ Hospital by ________________ and were advised to be seen again in ________ days.
[ ] Return to the Emergency Department/________________________. Clinic on (date) ____________ at ____________ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for ________ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: ______________________________________________________________________
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ________________
   ______________________________________________________________________
[ ] Other instructions: ______________________________________________________________________
   ______________________________________________________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ________________
   ________________ or ________________, or by checking out the following Internet Web sites: ________________; ________________.

Signature of patient ____________________________ Date ________________

Signature of physician ____________________________ Date ________________
Hydrogen Chloride (HCl)
CAS 7647-01-0; UN 1050 (anhydrous), UN 1789 (solution),
UN 2186 (refrigerated liquefied gas)

Synonyms for an aqueous solution of hydrogen chloride include chlorohydric acid, hydrochloric acid, and muriatic acid.

Persons exposed only to hydrogen chloride gas do not pose significant risks of secondary contamination. Persons whose clothing or skin is contaminated with hydrochloric acid can cause secondary contamination by direct contact or through off-gassing vapor.

Hydrogen chloride is a colorless, corrosive, nonflammable gas that fumes in air. It has a characteristic pungent odor. It is heavier than air and may accumulate in low-lying areas.

Hydrogen chloride is not absorbed through the skin, but when hydrogen chloride gas comes in contact with moisture, it forms hydrochloric acid, which is corrosive and can cause irritation and burns.

**Description**

At room temperature, hydrogen chloride is a colorless to slightly yellow gas with a pungent odor. On exposure to air, the gas forms dense white vapors due to condensation with atmospheric moisture. The vapor is corrosive, and air concentrations above 5 ppm can cause irritation.

Hydrogen chloride is available commercially as an anhydrous gas or as aqueous solutions (hydrochloric acid). Commercial concentrated hydrochloric acid contains 36% to 38% hydrogen chloride in water. Aqueous solutions generally are colorless but may be yellow due to traces of iron, chlorine, and organic impurities.

**Routes of Exposure**

**Inhalation**

Inhalation is an important route of exposure to hydrogen chloride. Its odor and highly irritating properties generally provide adequate warning for acute, high-level exposures. However, only 50% of exposed persons can perceive hydrogen chloride’s odor at the OSHA permissible exposure limit (5 ppm), and odor may not provide adequate warning in the workplace. Hydrogen chloride vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.
Children exposed to the same levels of hydrogen chloride as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of hydrogen chloride found nearer to the ground.

**Skin/Eye Contact**

Hydrogen chloride is not absorbed through the skin. Direct contact with aqueous solutions of hydrogen chloride or with concentrated vapor can cause severe chemical burns.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

**Ingestion**

Ingestion of concentrated hydrochloric acid can cause severe corrosive injury to the lips, mouth, throat, esophagus, and stomach.

**Sources/Uses**

Hydrogen chloride is produced commercially by any of the following reactions: heated hydrogen gas with calcium chloride, sulfuric acid with sodium chloride, sodium chloride with sulfur dioxide and steam, and hydrogen burned in chlorine. Hydrogen chloride can be formed during the combustion of many plastics. Hydrochloric acid (muriatic acid) is a component of commercial chemicals used to clean and disinfect swimming pools.

Hydrogen chloride is used for cleaning, pickling, and electroplating metals; in refining mineral ores; in petroleum well extraction; in leather tanning; and in the refining of fats, soaps, and edible oils. It is also used in producing polymers and plastics, rubber, fertilizers, dyes, dyestuffs, and pigments.

**Standards and Guidelines**

OSHA PEL (permissible exposure limit) = 5 ppm (ceiling)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

AIHA ERPG-2 (emergency response planning guideline) (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 individual’s ability to take protective action) = 20 ppm

**Physical Properties**

*Description:* Colorless-to-slightly yellow gas
Warning properties: Sharp, choking odor. Air odor threshold is 0.77 ppm, but only 50% of distracted exposed persons can perceive hydrogen chloride’s odor at 5 ppm.

Molecular weight: 36.5 daltons

Boiling point (760 mm Hg): = -121 °F (-85 °C)

Freezing point: -174 °F (-114 °C)

Vapor pressure: 30,780 mm Hg at 68 °F (20 °C)

Gas density: 1.3 (air = 1)

Water solubility: 67% at 68 °F (20 °C)

Flammability: Not flammable

Incompatibilities

Hydrogen chloride is highly corrosive to most metals. It also reacts with hydroxides, amines, and alkalies.
Health Effects

- Concentrated hydrogen chloride can be corrosive to the skin, eyes, nose, mucous membranes, and respiratory and gastrointestinal tracts.
- Inhalation of hydrogen chloride can lead to pulmonary edema. Ingestion can cause severe injury to the mouth, throat, esophagus, and stomach.
- Other effects of exposure include shock, circulatory collapse, metabolic acidosis, and respiratory depression.

Acute Exposure

Hydrogen chloride is a strong mineral acid; its corrosive and irritant properties are the primary concern in both acute and chronic exposures.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Hydrogen chloride gas is intensely irritating to the mucous membranes of the nose, throat, and respiratory tract. Brief exposure to 35 ppm causes throat irritation, and levels of 50 to 100 ppm are barely tolerable for 1 hour. The greatest impact is on the upper respiratory tract; exposure to high concentrations can rapidly lead to swelling and spasm of the throat and suffocation.

Most seriously exposed persons have immediate onset of rapid breathing, blue coloring of the skin, and narrowing of the bronchioles. Patients who have massive exposures may develop an accumulation of fluid in the lungs.

Exposure to hydrogen chloride can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic

A rare and unusual complication of ingestion of high levels of hydrogen chloride is an increase in the concentration of chloride ions in the blood, causing an acid-base imbalance.
Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

**Dermal**

Deep burns of the skin and mucous membranes are caused by contact with concentrated hydrochloric acid or hydrogen chloride gas; disfiguring scars may result. Contact with less concentrated acid or with vapor or mist can cause redness of the skin and mild inflammation.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

**Ocular**

Exposure of the eyes to concentrated hydrogen chloride vapor or hydrochloric acid can cause corneal cell death, cataracts, and glaucoma. Exposure to dilute solutions can cause stinging pain and injuries such as ulcers of the eye surface.

**Gastrointestinal**

Ingesting concentrated hydrochloric acid can cause pain, difficulty swallowing, nausea, and vomiting.

Ingestion of concentrated hydrochloric acid can also cause severe corrosive injury to the mouth, throat esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

**Cardiovascular**

Ingestion of concentrated hydrochloric acid or massive skin exposure to either hydrochloric acid or hydrogen chloride gas may cause low blood pressure as a result of gastrointestinal bleeding or fluid displacement. After acute exposure, pulmonary function generally returns to baseline in 7 to 14 days.

**Potential Sequelae**

Although complete recovery is usual, symptoms and prolonged pulmonary deficits can persist. Patients may develop Reactive Airways Dysfunction Syndrome (RADS).

Patients who have ingested hydrochloric acid may experience scarring of the esophagus or stomach, which can cause narrowing, difficulty swallowing, or gastric outlet obstruction.

**Chronic Exposure**

Chronic or prolonged exposure to hydrogen chloride gas (above the OSHA PEL) or to mist has been associated with changes in pulmonary function, chronic inflammation of the bronchi, nasal ulceration, and symptoms resembling acute viral infection of the upper respiratory tract as well as inflammation of the skin, discoloration and erosion of dental enamel, and inflammation of the eye membrane.
<table>
<thead>
<tr>
<th>Carcinogenicity</th>
<th>Hydrogen chloride has not been classified for carcinogenic effects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive and</td>
<td>The reproductive hazards of hydrogen chloride to humans are</td>
</tr>
<tr>
<td>Developmental Effects</td>
<td>unknown. Few studies have been directed at reproductive effects</td>
</tr>
<tr>
<td></td>
<td>in experimental animals exposed to hydrogen chloride. No data</td>
</tr>
<tr>
<td></td>
<td>were located pertaining to maternal transfer of hydrogen chloride through the placenta or in breast milk Hydrogen chloride is not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.</td>
</tr>
</tbody>
</table>
Prehospital Management

Victims exposed only to hydrogen chloride gas and whose skin and clothing appear dry do not pose risks of secondary contamination to rescuers. However, victims exposed to hydrochloric acid or hydrogen chloride whose clothing or skin is moist or wet can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

High concentrations of hydrogen chloride can cause corrosive injury to all exposed body tissues. When inhaled, it can result in upper respiratory tract irritation, leading to laryngeal edema, laryngeal spasm, and asphyxia. Concentrated hydrochloric acid causes similar corrosive injury to the skin and, if ingested, can cause severe corrosive injury to the mouth, throat, esophagus, and stomach.

There is no antidote for hydrogen chloride poisoning. Treatment consists of support of respiratory and cardiovascular functions.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Hydrogen chloride gas is a severe respiratory-tract and skin irritant that forms a strong acid (hydrochloric acid) on contact with water.

*Respiratory Protection:* Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen chloride.

*Skin Protection:* Chemical-protective clothing is recommended because hydrogen chloride can cause skin irritation and burns.

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.
Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**

Victrms exposed only to hydrogen chloride gas who have no skin or eye irritation do not need decontamination; they may be transferred immediately to the Support Zone. All others require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

Victims who are able may assist with their own decontamination. Remove contaminated clothing while flushing exposed skin and hair with water for 3 to 5 minutes, wash thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate. Double-bag contaminated clothing and personal belongings.

Flush exposed or irritated eyes with tepid plain water or saline for 15 minutes. Eye irrigation should be carried out simultaneously with other basic care and transport. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, do not induce emesis. Do not administer activated charcoal or attempt to neutralize stomach contents. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. (Children’s dose is 2 to 4 ounces.)

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.
Support Zone

Be certain that victims have been decontaminated properly (see \textit{Decontamination Zone} above). Victims who have undergone decontamination or who have been exposed only to gas and who have no symptoms of skin or eye irritation pose no serious risk of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

\textit{ABC Reminders}

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

\textit{Additional Decontamination}

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, \textbf{do not induce emesis}. \textbf{Do not administer activated charcoal or attempt to neutralize stomach contents}. Adult victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk, if it has not been given previously, to flush residual acid from the esophagus and to dilute stomach contents. Children should receive half of the adult dose.

\textit{Advanced Treatment}

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sympathomimetic bronchodilators generally will reverse bronchospasm in patients exposed to hydrogen chloride.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25\% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.
Hydrogen Chloride

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If hydrochloric acid has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure such as skin or eye irritation, pain, or breathing difficulties should be transported to a medical facility for evaluation. Others may be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see Patient Information Sheet below).
Patients exposed only to hydrogen chloride gas whose clothing and skin are dry do not pose a risk of secondary contamination. Hospital personnel can be secondarily contaminated by patients exposed to hydrochloric acid either by direct skin contact or through inhalation of vapor off-gassing from heavily soaked clothing or skin. Patients do not pose contamination risks after contaminated clothing is removed and the skin is washed.

High concentrations of hydrogen chloride causes corrosive injury to all exposed body tissues. When inhaled, it can result in upper respiratory tract irritation, leading to laryngeal edema, laryngeal spasm, and asphyxia. Concentrated hydrochloric acid causes similar corrosive injuries to exposed tissues and, if ingested, can cause severe corrosive injury to the mouth, throat, esophagus, and stomach.

There is no antidote for hydrogen chloride poisoning. Treatment consists of support of respiratory and cardiovascular functions.

### Decontamination Area

Previously decontaminated patients and patients exposed only to hydrogen chloride gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Hospital personnel should don rubber gloves, rubber aprons, and eye protection before treating patients who are wet with hydrochloric acid.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

### ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in
situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen chloride poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents. Sympathomimetic bronchodilators generally will reverse bronchospasm in patients exposed to hydrogen chloride.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

**Basic Decontamination**

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes (preferably under a shower). Wash thoroughly with soap and water, rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis. Do not administer activated charcoal or attempt to neutralize stomach contents.** If it has not been given previously, administer 4 to 8 ounces of water or milk to adults to flush residual acid from the esophagus and to dilute stomach contents. (Children’s dose is 2 to 4 ounces.)

**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see Decontamination Area above).
**ABC Reminders**

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

**Inhalation Exposure**

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sympathomimetic bronchodilators generally will reverse bronchospasm in patients exposed to hydrogen chloride.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients for at least 24 hours, repeating appropriate tests and chest examinations as needed. Follow-up as clinically indicated.

Some authorities recommend treatment with high doses of corticosteroids for patients who have high-dose exposures, but the value of this treatment is questionable and unsupported by clinical studies.

**Skin Exposure**

If the skin was in contact with concentrated hydrochloric acid or hydrogen chloride gas or mists, chemical burns may occur, treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.
<table>
<thead>
<tr>
<th><strong>Eye Exposure</strong></th>
<th>Continue irrigating for at least 15 minutes or until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ingestion Exposure</strong></td>
<td><strong>Do not induce emesis. Do not administer activated charcoal or attempt to neutralize stomach contents.</strong> Immediate dilution with 4 to 8 ounces of water or milk may be beneficial (pediatric dose 2 to 4 ounces) for alert patients who can swallow. Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient’s condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach. Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance. Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container). The use of corticosteroids to prevent acid-induced strictures is questionable and unsupported by clinical studies.</td>
</tr>
<tr>
<td><strong>Antidotes and Other Treatments</strong></td>
<td>There is no antidote for hydrogen chloride poisoning.</td>
</tr>
<tr>
<td><strong>Laboratory Tests</strong></td>
<td>The diagnosis of acute hydrogen chloride toxicity is primarily clinical, based on symptoms of the corrosive action of the gas or acid. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Monitor acid-base status in patients who have ingested hydrochloric acid. If respiratory-tract irritation is present, monitor with chest radiography and pulse oximetry (or ABG measurements).</td>
</tr>
</tbody>
</table>
There is no biologic test specific for systemically absorbed hydrogen chloride.

**Disposition and Follow-up**

Patients who develop serious signs or symptoms of hydrogen chloride exposure should be hospitalized and observed closely for 4 to 6 hours or until asymptomatic.

**Delayed Effects**

Delayed effects are unlikely in patients who have minor symptoms that resolve quickly. However, symptoms can be delayed for 1 to 2 days.

**Patient Release**

Patients who have had minor exposure and who are asymptomatic 4 to 6 hours after exposure may be discharged and advised to seek medical care promptly if symptoms develop (see the Hydrogen Chloride—Patient Information Sheet below).

**Follow-up**

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Patients who have inhaled significant amounts of hydrogen chloride should be monitored with pulmonary function tests. Patients should also be monitored for the development of Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma. About 2 to 4 weeks after an ingestion, consider follow-up esophagoscopy and an upper gastrointestinal tract series to evaluate secondary scarring or stricture formation.

Patients who have skin or corneal injury should be re-examined within 24 hours.

**Reporting**

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Hydrogen Chloride
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen chloride gas or hydrochloric acid solution.

What are hydrogen chloride and hydrochloric acid?
Hydrogen chloride is a colorless to slightly yellow gas with a sharp, irritating odor. It forms a dense white vapor when it comes in contact with air. When hydrogen chloride dissolves in water, it forms hydrochloric acid also known as muriatic acid. Both hydrogen chloride and hydrochloric acid are corrosive and may cause burns on contact. Hydrogen chloride is not flammable.

What immediate health effects can be caused by exposure to these chemicals?
Hydrogen chloride gas can irritate the lungs, causing a cough and shortness of breath. Breathing high levels of the gas or vapor can lead to a build-up of fluid in the lungs, which may cause death. Because hydrochloric acid is corrosive, it can cause eye damage, even blindness, if splashed in the eyes. Skin contact can cause severe burns. Ingestion of concentrated hydrochloric acid can cause severe injury to the mouth, throat, esophagus and stomach. Generally, the more serious the exposure, the more severe the symptoms.

Can hydrogen chloride or hydrochloric acid overexposure be treated?
There is no antidote for poisoning due to these substances, but their effects can be treated and most exposed persons get well. People who have had serious exposures may need to be hospitalized.

Are any future health effects likely to occur?
A single, small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. Patients who breath a large amount of hydrogen chloride may develop permanent lung injury. If hydrochloric acid was swallowed, a patient may permanently have trouble swallowing.

What tests can be done if a person has been exposed to hydrogen chloride?
Specific tests for the presence of hydrogen chloride in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs or stomach has been injured. Testing is not needed in every case.

Where can more information about hydrogen chloride and hydrochloric acid be found?
More information about hydrogen chloride and hydrochloric acid can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
  • coughing or wheezing
  • difficulty breathing, shortness of breath, or chest pain
  • stomach pain or vomiting
  • increased pain or a discharge from exposed eyes
  • increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. __________________________ in the practice of __________________________.
When you call for your appointment, please say that you were treated in the Emergency Department at __________________________ Hospital by __________________________ and were advised to be seen again in ________ days.

[ ] Return to the Emergency Department/ __________________________ Clinic on (date) _____________ at ___ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for ________ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: __________________________
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __________________________
[ ] Other instructions: __________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: __________________________
  ________ or __________________________, or by checking out the following Internet Web sites: __________________________; __________________________.

Signature of patient __________________________ Date __________________________

Signature of physician __________________________ Date __________________________
Persons exposed only to methyl bromide gas do not pose substantial risks of secondary contamination; however, some methyl bromide may permeate clothing. Persons whose clothing or skin is contaminated with liquid methyl bromide (temperatures less than 38.5 °F) can secondarily contaminate others by direct contact or through off-gassing vapor.

A gas at room temperature, methyl bromide readily penetrates skin, cloth, and other protective materials such as rubber and leather. It is nonflammable and toxic at low concentrations.

Methyl bromide is odorless and odor provides no warning of hazardous concentrations. However, because methyl bromide is odorless and nonirritating, a lacrimator (an agent that irritates the eyes and causes tearing), most commonly chloropicrin, is often added as a warning agent.

• Methyl bromide is absorbed well by the lungs and to some degree through intact skin. Oral exposure is rare because methyl bromide is a gas at room temperature, but it may be absorbed by the gastrointestinal tract. Exposure by any route can cause systemic effects.

Description

Methyl bromide is a colorless gas at room temperature and a liquid below 38.5 °F (3.6 °C) or when compressed. It is usually shipped as a liquefied, compressed gas. It is odorless and nonirritating at low concentrations and has a musty or fruity odor at high concentrations (greater than 1,000 ppm). Because methyl bromide lacks adequate physiologic warning properties, up to 2% chloropicrin, a lacrimator, is often added to prevent significant exposure.

Routes of Exposure

Inhalation

Most exposures occur by inhalation and by absorption through the skin. **Odor is not an adequate indicator of the presence of pure methyl bromide and does not provide reliable warning of hazardous concentrations.** Because pure methyl bromide lacks adequate warning properties, significant exposure can occur before symptoms are evident.

Methyl bromide is 3 times heavier than air and can accumulate in poorly ventilated or low-lying areas. Under adverse conditions, it can remain in the air for days after application as

Synonyms include bromomethane, monobromomethane, isobrome, and methyl fume.
Methyl Bromide

a fumigant. Fatalities have occurred among pesticide applicators and building occupants who were exposed during the application process or who prematurely reentered fumigated buildings.

Children exposed to the same levels of methyl bromide as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of methyl bromide found nearer to the ground.

**Skin/Eye Contact**

Methyl bromide gas easily penetrates most protective clothing (e.g., cloth, rubber, and leather) and skin. Prolonged retention in clothing and rubber boots may lead to chemical dermatitis and severe burns. Skin absorption may contribute to systemic toxicity.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

**Ingestion**

Ingestion of methyl bromide is unlikely because it is a gas at room temperature.

**Sources/Uses**

Methyl bromide is produced by adding sulfuric acid to a mixture of sodium bromide and methyl alcohol. Methyl bromide is used primarily as a pesticide to fumigate soil, spaces, structures, and commodities. It is also used as a methylating agent, low-boiling solvent, and oil extractant in chemical syntheses. Less toxic chemicals have replaced it as a refrigerant and fire-extinguisher constituent.

**Standards and Guidelines**

OSHA ceiling limit = 20 ppm (skin)

NIOSH IDLH (immediately dangerous to life or health) = 250 ppm

AIHA ERPG-2 (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 individual’s ability to take protective action) = 50 ppm

**Physical Properties**

*Description*: Colorless; gas at room temperature and liquid below 38.5 °F (3.6 °C)
Warning properties: **Inadequate**; musty or fruity odor at greater than 1,000 ppm; eye and throat irritation at greater than 500 ppm.

*Molecular weight:* 95.0 daltons

*Boiling point* (760 mm Hg): 38.5 °F (3.6 °C)

*Freezing point:* -137 °F (-94 °C)

*Vapor pressure:* 1420 mm Hg at 68 °F (20 °C)

*Gas density:* 3.4 (air = 1)

*Water solubility:* Water soluble (0.09% at 68 °F) (20 °C)

*Flammability:* Flammable, but only in the presence of a high-energy ignition source.

*Flammable range:* 13.5% to 14.5% (concentration in air)

**Incompatibilities**

Methyl bromide reacts with strong oxidizers, magnesium, aluminum, tin, zinc, and alloys. It attacks aluminum to form aluminum trimethyl, which is spontaneously flammable.
Health Effects

Methyl bromide is a neurotoxic gas that can cause convulsions, coma, and long-term neuromuscular and cognitive deficits.

Exposure to high concentrations of pure methyl bromide may cause inflammation of the bronchi or lungs, an accumulation of fluid in the lung, and irritation of the eyes and nose. Tearing agents added to methyl bromide to provide warning of its presence can also cause these symptoms, even at very low concentrations.

Skin contact with high vapor concentrations or with liquid methyl bromide can cause systemic toxicity and may cause stinging pain and blisters.

Acute Exposure

Methyl bromide methylates the sulfhydryl groups of enzymes, causing cellular disruption and reduced glutathione levels. Cellular disruption, primarily in the CNS, results in progressive dysfunction. In sublethal poisoning, a latency period of 2 to 48 hours can occur between exposure and onset of symptoms. Methanol, a metabolite of methyl bromide, may also contribute to the neurologic and visual effects, but this is only likely to be significant at high levels of exposure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

The most serious effects of acute inhalation exposure involve the CNS. Depending on the concentration and duration of exposure, initial neurologic effects may be delayed for 2 or more hours after exposure and may include headache, nausea, vomiting, dizziness, malaise, and visual disturbances. Examination may reveal involuntary movements of the eyes, dilated pupils, slurred speech, trembling of the extremities during movement, impaired gait, impaired sensation of touch, brain damage (i.e., cerebellar abnormalities), motor deficits, and decreased reflexes.

Neuropsychiatric abnormalities often occur after acute exposure, although onset may be delayed for days to weeks. In some cases, mental disturbances may predominate with only mild neurologic signs and no seizures; in others, severe and prolonged seizures may occur. Motor and cognitive deficits may persist indefinitely.
### Peripheral Neurologic
Peripheral neuropathy may develop after acute exposure to methyl bromide and may persist indefinitely.

### Respiratory
Respiratory symptoms are the most likely nonneurologic effects of acute methyl bromide inhalation. Throat irritation, chest pain, and shortness of breath are common. Severe exposures may cause inflammation of the bronchi or lungs and an accumulation of fluid in the lungs, which may be delayed 24 hours or longer after exposure. Death may result from respiratory or cardiovascular failure.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

### Cardiovascular
Acute inhalation of high concentrations can cause rapid, ineffective beating of the heart.

### Renal
Protein and blood in the urine, scant urine production, absence of urine production, and accumulation of urea and other nitrogen wastes in the blood due to death of kidney cells have been described. Complete recovery is usual.

### Hepatic
Elevated liver enzymes in serum and jaundice occur occasionally after acute exposure.

### Ocular
Eye exposure to liquid methyl bromide or to high concentrations of vapor may cause corneal irritation and burns.

### Dermal
Contact with either liquid or high vapor concentrations can cause stinging pain, redness of the skin, and blisters characteristic of second-degree burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

### Potential Sequelae
Peripheral nerve damage, speech difficulty, and neuropsychiatric sequelae such as impaired gait, involuntary movements of the eyes, tremors, involuntary muscle jerks, seizures, decline in mental abilities, and severe mental disorders (i.e., psychoses) may develop weeks after exposure.
Chronic Exposure

Repeated exposures have been associated with peripheral neuropathies, especially sensory neuropathy, impaired gait, behavioral changes, and mild liver and kidney dysfunction. Visual impairment secondary to atrophy of the optic nerve has been reported. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The International Agency for Research on Cancer has determined that methyl bromide is not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects

Methyl bromide is not considered a reproductive or developmental toxicant. No human data are available; one study of experimental animals (rats and rabbits) did not find teratogenic effects at levels below those causing maternal death. Methyl bromide is not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.
Prehospital Management

Victims exposed only to methyl bromide gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone; however, some methyl bromide may permeate clothing. Victims whose clothing or skin is contaminated with liquid methyl bromide (i.e., ambient temperature less than 38.5°F) can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Methyl bromide is a neurotoxic gas that may cause headaches, dizziness, visual disturbances, ventricular fibrillation, pulmonary edema, ataxia, convulsions, coma, and death.

Exposures to high concentrations of methyl bromide can cause eye, skin, and respiratory tract irritation, as well as chemical pneumonitis. Dermal absorption may contribute to systemic toxicity.

There is no antidote for methyl bromide. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Methyl bromide is a highly toxic systemic poison that is absorbed well by inhalation and through the skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) with a full facepiece is recommended in response situations that involve exposure to potentially unsafe levels of methyl bromide vapor.

Skin Protection: Chemical-protective clothing (including boots and gloves) is recommended because methyl bromide vapor or liquid can be absorbed through the skin and may contribute to systemic toxicity. Contact with liquid methyl bromide can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.
**Victim Removal**  
If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**  
Remove clothing, including footwear, from all victims because methyl bromide gas persists in cloth, leather, and rubber. After clothing has been removed, patients exposed only to the gas who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination (see Basic Decontamination below).

**Rescuer Protection**  
If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (see Rescuer Protection, above).

**ABC Reminders**  
Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**  
Victims who are able may assist with their own decontamination. Remove all contaminated clothing including footwear. Methyl bromide can persist in cloth, leather, and rubber, and these materials may contribute to severe chemical burns after prolonged skin contact. Double-bag contaminated clothing and personal belongings. **Leave these items in the Hot Zone.**

Flush exposed skin and hair with water for at least 15 minutes, then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.
Oral exposure to methyl bromide is rare (it is a gas at temperatures above 38.5 °F); however, if ingestion occurs, **do not induce emesis**. If the victim is alert and able to swallow, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Persons who have undergone decontamination pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

**ABC Reminders**

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

**Additional Decontamination**

Continue irrigating exposed skin and eyes, as appropriate.

**Advanced Treatment**

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine...
solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer’s solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

**Multi-Casualty Triage**

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims. Because systemic symptoms may be delayed for several hours after exposure, all exposed patients should be transported to a medical facility for evaluation. Symptomatic patients should receive priority in transport.
Methyl bromide is a neurotoxic gas that may cause headaches, dizziness, visual disturbances, ventricular fibrillation, pulmonary edema, ataxia, convulsions, coma, and death.

Exposures to high concentrations of methyl bromide can cause eye, skin, and respiratory tract irritation, as well as chemical pneumonitis. Dermal absorption can contribute to systemic toxicity.

There is no antidote for methyl bromide. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Patients who have been decontaminated previously may be transferred immediately to the Critical Care Area. Other patients require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of
cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

**Basic Decontamination**

Patients who are able may assist with their own decontamination. Remove and double-bag all clothing, including footwear, because methyl bromide penetrates many materials and can remain trapped in them. If clothing is to be reused, it must undergo thorough decontamination. Some contaminated clothing may not be safe for reuse (e.g., leather articles).

Flush exposed skin and hair with water for at least 15 minutes, then wash **twice** with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

Oral exposure to methyl bromide is rare (it is a gas at temperatures above 38.5 °F); however, if ingestion occurs, **do not induce emesis.** If the victim is alert and able to swallow, and if not already done, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see Decontamination Area, above).
**Methyl Bromide**

**ABC Reminders**
Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

**Inhalation Exposure**
Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe these patients for 24 hours using repeated chest examinations and other appropriate tests. Follow-up as clinically indicated.

**Skin Exposure**
If the skin was in contact with concentrated methyl bromide vapor or liquid, chemical burns may result; treat as thermal burns. Burns may be delayed in onset.

**Eye Exposure**
Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

**Ingestion**
Oral exposure to methyl bromide is rare (it is a gas at temperatures above 38.5 °F); however, if ingestion occurs, **do not induce emesis**. If the victim is alert and able to swallow, and if not already done, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

**Antidotes and Other Treatments**
There is no proven antidote for methyl bromide poisoning. Dimercaprol (BAL) or acetylcysteine (Mucomyst) have been
suggested as antidotes based on the postulated mechanism of methyl bromide’s toxicity. However, no adequate studies have tested the efficacy of these therapies, and they are not recommended for routine use.

**Laboratory Tests**

Serum bromide levels can be used to document that exposure did occur. However, bromide levels do not accurately predict the clinical course. Routine laboratory studies include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to methyl bromide include liver-function tests and renal-function tests. In cases of inhalation exposure, chest radiography and pulse oximetry (or ABG measurements) may be helpful.

**Disposition and Follow-up**

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results. The probable delay in onset of serious effects from methyl bromide exposure should be considered.

**Delayed Effects**

Because the onset of pulmonary edema may be delayed for up to several days, patients who have severe exposure should be monitored with serial examinations before absence of toxic effects can be assured. If pulmonary edema is suspected, admit patients to an intensive care unit. Neurological symptoms also may not develop for several days or weeks.

**Patient Release**

Patients who have no evidence of neuropsychiatric or pulmonary effects 24 hours after exposure may be discharged with instructions to return to the ED if symptoms develop or recur (see the *Methyl Bromide—Patient Information Sheet*).

**Follow-up**

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Patients exposed to methyl bromide should be monitored for late neuropsychiatric sequelae.

Patients who have corneal injuries should be reexamined within 24 hours.

**Reporting**

Methyl bromide is a pesticide. If a pesticide or work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future
incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Methyl Bromide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to methyl bromide.

What is methyl bromide?
Methyl bromide is a colorless gas or liquid that is odorless at low concentrations. At very high concentrations, it has a sweet, fruity odor. Tear gas is often mixed with it so that a person exposed to methyl bromide will be warned of its presence. Methyl bromide is used to kill insects in the soil and to rid soils and buildings of termites. Typically, the field or home is covered (“tented”) by a large tarp and the methyl bromide is pumped in. Methyl bromide is also used in industry to make other chemicals.

What immediate health effects can be caused by exposure to methyl bromide?
Breathing methyl bromide can cause injury to the brain, nerves, lungs, and throat. High doses can also injure the kidneys and liver. Contact with the skin and eyes can lead to irritation and burns. Generally, the more serious the exposure, the more severe the symptoms.

Can methyl bromide poisoning be treated?
There is no antidote for methyl bromide poisoning, but its effects can be treated and most persons recover. Persons who have experienced serious symptoms may need to be hospitalized and may need follow-up examinations or treatment later on.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure that causes lung or nervous system-related problems, permanent brain or nerve damage can result.

What tests can be done if a person has been exposed to methyl bromide?
Specific tests for the presence of bromide in blood may provide some useful information to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, brain, nerves, liver, or kidneys have been damaged. Testing is not needed in every case.

Where can more information about methyl bromide be found?
More information about methyl bromide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
  • coughing or wheezing
  • difficulty in breathing, shortness of breath, or chest pain
  • difficulty in walking
  • numbness of hands or feet
  • confusion, dizziness, or fainting
  • increased pain or a discharge from exposed eyes
  • increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. ______________________ in the practice of ______________________.
  When you call for your appointment, please say that you were treated in the Emergency Department at ______________________ Hospital by ______________________ and were advised to be seen again in _______ days.

[ ] Return to the Emergency Department/ ______________________ Clinic on (date) _________ at ______________________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: ______________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ______________________

[ ] Other instructions: ______________________

  • Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
  • You or your physician can get more information on the chemical by contacting: ______________________ or ______________________, or by checking out the following Internet Web sites: ______________________; ______________________.

Signature of patient ______________________ Date ______________________

Signature of physician ______________________ Date ______________________
Methyl Isocyanate (C\textsubscript{2}H\textsubscript{3}NO)
CAS 624-83-9; UN 2480

Synonyms include isocyanomethane, isocyanatomethane, methylcarbylamine, and MIC.

- Persons exposed only to methyl isocyanate gas pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid methyl isocyanate can secondarily contaminate rescuers by direct contact or through off-gassing of vapor.

- At temperatures below 39 °C (102 °F), methyl isocyanate is a very flammable colorless liquid that readily evaporates when exposed to air. Gaseous methyl isocyanate is slightly heavier than air.

- Although methyl isocyanate has a pungent odor, adverse health effects have been reported at or below the human odor threshold; therefore, odor detection is not a reliable indicator of exposure.

- Methyl isocyanate is readily absorbed through the upper respiratory tract. Methyl isocyanate can also be absorbed through the digestive tract or skin.

**Description**

At temperatures below 39 °C (102 °F), methyl isocyanate is a very flammable liquid that readily evaporates when exposed to air. Gaseous methyl isocyanate is approximately 1.4 times heavier than air. Methyl isocyanate liquid is colorless with a pungent odor. Most people can smell methyl isocyanate vapors at levels as low as 2 to 5 ppm. Methyl isocyanate is handled and transported as a very flammable and explosive liquid.

**Routes of Exposure**

**Inhalation**

Inhalation is the major route of exposure to methyl isocyanate. The vapors are readily absorbed through the lungs. The odor threshold is approximately 100 to 250 times higher than the OSHA PEL-TWA (0.02 ppm). Significant exposures to methyl isocyanate occur primarily in occupational settings. Acute exposure to methyl isocyanate vapors below the odor threshold can be irritating to the eye and respiratory epithelium. Acute exposure to higher vapor concentrations may cause severe pulmonary edema and injury to the alveolar walls of the lung and death. Survivors of acute exposures may exhibit long-term respiratory effects. **Odors of methyl isocyanate may not provide adequate warning of hazardous concentrations** because the Immediately Dangerous to Life or
Health (IDLH) limit is only 3 ppm and the threshold for detection of methyl isocyanate vapors ranges from 2 to 5 ppm in humans. Significant exposure to methyl isocyanate vapors would most likely be the result of accidental release of methyl isocyanate to the air such as occurred in Bhopal, India in 1984, where the primary effect was pulmonary edema with some alveolar wall destruction. Methyl isocyanate is heavier than air; therefore, exposure in poorly ventilated, enclosed, or low-lying areas could result in asphyxiation.

Children exposed to the same levels of methyl isocyanate as adults may receive larger doses because they have relatively greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of methyl isocyanate found nearer to the ground. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways.

**Skin/Eye Contact**

Direct contact with liquid or concentrated vapors of methyl isocyanate may cause irritation of the skin or eyes and severe ocular damage. Direct skin contact may result in dermal absorption. Significant dermal exposure to methyl isocyanate would not likely occur outside an occupational environment in which methyl isocyanate is stored or used.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

**Ingestion**

Although unlikely, ingestion of liquid methyl isocyanate could produce severe gastrointestinal irritation.

**Sources/Uses**

Methyl isocyanate is made by reacting methylamine with phosgene. The primary use of methyl isocyanate is as a chemical intermediate in the production of pesticides. It is also used to produce polyurethane foams and plastics.

**Standards and Guidelines**

OSHA PEL (permissible exposure limit) = 0.02 ppm (averaged over an 8-hour workshift) with a skin notation

NIOSH IDLH (immediately dangerous to life or health) = 3 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious
health effects or symptoms that could impair their abilities to take protective action) = 0.5 ppm

**Physical Properties**

*Description:* Colorless liquid at room temperature; volatile, flammable, explosive in air

*Warning properties:* Pungent odor of methyl isocyanate may not be adequate to warn of acute exposure. Most people can detect methyl isocyanate at levels of 2 to 5 ppm (1 ppm is equivalent to 2.35 mg/m³)

*Molecular weight:* 57.05 daltons

*Boiling point* (760 mm Hg): 102 °F (39.1 °C)

*Freezing point:* -49 °F (-45 °C)

*Vapor pressure:* 348 mm Hg at 68 °F (20 °C)

*Vapor density:* 1.42 (air = 1.00)

*Water solubility:* 6.7% at 68 °F (20 °C)

*Flammability:* highly flammable

*Flammable Range:* 5.3 % to 26 % (concentration in air)

**Incompatibilities**

Methyl isocyanate reacts violently with water. Methyl isocyanate is incompatible with oxidizers, acids, alkalis, amines, iron, tin, and copper.
Health Effects

- Methyl isocyanate is irritating and corrosive to the eyes, respiratory tract, and skin. Acute exposure to high vapor concentrations may cause severe pulmonary edema and injury to the alveolar walls of the lung, severe corneal damage, and death. Survivors of acute exposures may exhibit long-term respiratory and ocular effects. Methyl isocyanate may be a dermal and respiratory sensitizer.

- Mechanisms of methyl isocyanate-induced toxicity are not known. Persistent respiratory and ocular effects may reflect methyl isocyanate-induced immunologic effects. Methyl isocyanate may cross the placenta and enter a developing fetus. Individuals especially susceptible to the toxic effects of methyl isocyanate include those with existing disorders of the respiratory system or eyes.

Acute Exposure

Mechanisms of toxicity have not been clearly elucidated for methyl isocyanate; however, carbamylation of globin and blood proteins may play a role. Persistent respiratory and ocular effects may reflect methyl isocyanate-induced immunologic effects since antibodies specific to methyl isocyanate have been demonstrated in the blood of exposed patients. Methyl isocyanate is highly reactive; therefore, it is not metabolized in the classical sense. The onset of respiratory effects following acute exposure to methyl isocyanate can be immediate in some cases. In others, respiratory injury can evolve over periods of hours or days. Exposure-related deaths sometimes can occur as late as 30 or more days post-exposure, due in part to the development of pneumonia.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Methyl isocyanate vapors are severely irritating and corrosive to the respiratory tract. Symptoms may include cough, chest pain, dyspnea, coma, and death. Irritative respiratory symptoms such as pulmonary edema and bronchial spasms may occur in immediate response to exposure. Methyl isocyanate-induced pulmonary edema may progress to effects such as alveolar wall destruction and pneumonia, which may ultimately lead to respiratory failure and death. Some respiratory effects may progress in severity over a period of hours to days post-exposure. Asthmatic reactions and long-term respiratory effects have been reported.
Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children also may be more vulnerable to gas exposure because of relatively higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Ocular/Ophthalmic**
Severe eye irritation can result from exposure to methyl isocyanate vapors or direct contact with the liquid. Symptoms may include immediate eye pain, lacrimation, photophobia, profuse lid edema, and corneal ulcerations. Ocular exposure may result in long-term or permanent eye damage.

**Dermal**
Methyl isocyanate is a skin irritant and may cause chemical burns upon dermal contact at high exposure levels.

Because of their relatively larger surface area: body weight ratio, children are more vulnerable to toxicants that affect the skin.

**Gastrointestinal**
Nausea, vomiting, abdominal pain, and defecation have been reported after acute exposure to methyl isocyanate vapors.

**Potential Sequelae**
Initial irritative symptoms of the respiratory tract may progress to more serious respiratory injury over a period of hours to days following exposure to methyl isocyanate vapors. Compromised lung tissue may be susceptible to bacterial pneumonias. Exposure may result in permanent eye damage. Methyl isocyanate may also be a respiratory and dermal sensitizer. Renal tubular necrosis, reduced liver function, and miscarriage were associated with methyl isocyanate exposure in the Bhopal, India incident.

**Chronic Exposure**
Chronic exposure to methyl isocyanate may result in chronic obstructive lung disease.

**Carcinogenicity Reproductive and Developmental Effects**
Methyl isocyanate has not been classified for carcinogenicity.

Methyl isocyanate is not included in the list of *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Increased rates of spontaneous abortions and neonatal deaths among victims of the Bhopal accident were observed for months following exposure. However, the precise role of methyl isocyanate in developmental toxicity is difficult to determine. Poor oxygenation resulting from compromised lung...
function may not be involved. Animal studies indicate that inhalation exposure during gestation may result in decreased numbers of live births and decreased survival during lactation. There was no evidence of a dominant lethal effect in exposed male mice. Genotoxicity testing in animals indicates that methyl isocyanate may have the capacity to affect chromosome structure, but it apparently does not induce gene mutations.
Prehospital Management

- Persons exposed only to methyl isocyanate gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid methyl isocyanate can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.

- Methyl isocyanate is irritating to the eyes, respiratory tract, and skin. Early symptoms may include eye irritation, coughing, and shortness of breath. In cases of severe exposure, later symptoms may include vomiting and diarrhea. Acute exposure to high vapor concentrations may cause relatively rapid and severe pulmonary edema, alveolar wall injury, and corneal damage. Initial signs of irritation may progress to vomiting, diarrhea, and death. Survivors of acute exposures may exhibit long-term respiratory and ocular effects. Methyl isocyanate may be a dermal and respiratory sensitizer.

- There is no antidote for methyl isocyanate. Treatment consists of removal of the victim from the contaminated area and support of respiratory and cardiovascular functions.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional hazardous materials (HAZMAT) team or other properly equipped response organization.

**Rescuer Protection**

Inhaled methyl isocyanate is a severe respiratory tract irritant. Contamination of the skin can cause irritation or chemical burns. Contamination of the eyes can cause irritation and serious or long-term damage. Methyl isocyanate is absorbed through the skin.

*Respiratory protection:* Positive-pressure, self-contained breathing apparatus (SCBA) with a full facepiece and operated in a positive pressure mode is recommended in response to situations that involve exposure to potentially unsafe levels of methyl isocyanate gas.

*Skin protection:* Chemical protective clothing is recommended because methyl isocyanate can cause skin irritation and burns. Protective eye equipment is recommended to prevent eye contact.

**ABC Reminders**

Quickly establish a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar.
and a backboard when feasible. Apply direct pressure to stop any heavy bleeding.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

**Decontamination Zone**

Patients exposed only to methyl isocyanate gas who have no eye or skin irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

**ABC Reminders**

Quickly establish a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control any heavy bleeding.

**Basic Decontamination**

**Rapid skin decontamination is critical.** Victims who are able may assist with their own decontamination. Remove contaminated clothing and personal belongings and place them in double plastic bags.

Wash exposed skin thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed eyes with copious amounts of tepid water for at least **15 minutes**. Remove contact lenses if they are easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.
In cases of ingestion, **do not induce emesis**. If the victim is not symptomatic, consider administering activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

If the victim is conscious and able to swallow, consider giving 4 to 8 ounces of water.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to methyl isocyanate gas pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

**ABC Reminders**

Quickly establish a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

**Additional Decontamination**

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is not symptomatic, consider administering charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

If the victim is conscious and able to swallow, consider giving 4 to 8 ounces of water if it has not been given previously.
**Methyl Isocyanate**

**Advanced Treatment**

Treat cases of respiratory compromise with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with oxygen, aerosolized bronchodilators such as albuterol, and/or steroids according to established protocol.

In cases of non-cardiogenic pulmonary edema, which may be delayed in onset, maintain adequate ventilation and oxygenation. Early use of mechanical ventilation and positive-end-expiratory pressure (PEEP) may be required. To minimize barotrauma and other complications, use the lowest amount of PEEP possible while maintaining adequate oxygenation. Consider drug therapy for pulmonary edema.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults with systolic pressure less than 80 mmHg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer’s solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Consider vasopressors if patient is hypotensive with a normal fluid volume.

**Transport to Medical Facility**

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

If methyl isocyanate has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.
Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or evidence suggesting significant exposure (e.g., altered behavior, respiratory distress, or chemical burns) should be transported to a medical facility for evaluation. Patients who have a history of chronic pulmonary disease should be clinically evaluated for airflow obstruction.

Patients who have mild symptoms of respiratory or eye irritation should be clinically evaluated because onset of pulmonary edema may be delayed for up to 72 hours post-exposure and eye injury may need to be treated topically for inflammation or secondary infection. Patients who have symptoms of transient skin, nose, or eye irritation may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to rest and to seek medical care promptly if symptoms develop or recur (see Patient Information Sheet below).
Emergency Department Management

- Persons exposed only to methyl isocyanate gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid methyl isocyanate can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.

- Methyl isocyanate is irritating to the eyes, respiratory tract, and skin. Acute exposure to high vapor concentrations may cause severe pulmonary edema and injury to the alveolar walls of the lung, severe corneal damage, and death. Survivors of acute exposures may exhibit long-term respiratory and ocular effects. Methyl isocyanate may be a dermal and respiratory sensitizer.

- There is no antidote for methyl isocyanate. Treatment consists of removal of the victim from the contaminated area and support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and those exposed only to methyl isocyanate gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxins absorbed through the skin. Also emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. Treat cases of respiratory compromise with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with oxygen, aerosolized bronchodilators such as albuterol, and/or steroids according to established protocol.
Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

In cases of non-cardiogenic pulmonary edema, which may be delayed in onset, maintain adequate ventilation and oxygenation. Mechanical ventilation and positive-end-expiratory pressure (PEEP) may be required. To minimize barotrauma and other complications, use the lowest amount of PEEP possible while maintaining adequate oxygenation. Consider drug therapy for pulmonary edema. Keep in mind that the use of steroids to prevent or treat chemical pneumonitis and pulmonary edema is controversial.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

**Basic Decontamination**

Patients who are able may assist with their own decontamination.

Because methyl isocyanate can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient’s clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove contaminated clothing while gently washing the skin with soap and water. Double-bag the contaminated clothing and personal belongings. Handle burned skin with caution.

Wash exposed skin thoroughly with soap and water. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with copious amounts of tepid water for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.
In cases of ingestion, **do not induce emesis.** If the victim is not symptomatic, consider administering activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

If the victim is conscious and able to swallow, consider giving 4 to 8 ounces of water.

**Critical Care Area**

Be certain that appropriate decontamination has been carried out.

**ABC Reminders**

Evaluate and support the airways, breathing, and circulation as in **ABC Reminders** above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

**Inhalation Exposure**

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators such as albuterol and/or steroids.

In cases of non-cardiogenic pulmonary edema, which may be delayed in onset, maintain adequate ventilation and oxygenation. Monitor arterial blood gases and/or pulse oximetry. If a high FIO$_2$ is required to maintain adequate oxygenation, mechanical ventilation and positive-end-expiratory pressure (PEEP) may be required. To minimize barotrauma and other complications, use the lowest amount of PEEP possible while maintaining adequate oxygenation. Consider drug therapy for pulmonary edema. Keep in mind that the use of steroids to prevent or treat chemical pneumonitis and pulmonary edema is controversial. Antibiotics should be used as indicated to control infection. Damaged lower respiratory tissue might be more susceptible to infection.

**Skin Exposure**

If concentrated methyl isocyanate is in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin.

**Eye Exposure**

Continue irrigation for at least **15 minutes.** Test visual acuity. Examine the eyes for corneal damage and treat appropriately.
Immediately consult an ophthalmologist for patients who have suspected severe corneal injuries.

**Ingestion**

**Do not induce emesis.** Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyrotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric (NG) tube if: (1) a large dose has been ingested; (2) the patient’s condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

If the victim is not symptomatic, consider administering activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

Consider giving 4 to 8 ounces of water to alert patients who can swallow, if not done previously.

**Antidotes and Other Treatments**

There is no antidote for methyl isocyanate. Treatment is supportive of respiratory and cardiac functions.

**Laboratory Tests**

Routine laboratory studies include chest radiography and pulse oximetry (or ABG measurements).

**Disposition and Follow-up**

Consider hospitalizing symptomatic patients who have evidence of respiratory or cardiac distress or significant chemical burns.

**Delayed Effects**

Acute exposure to high concentrations of methyl isocyanate may result in delayed onset of pulmonary edema and risk of secondary infection of the lungs or eyes.
Patient Release

Patients who become totally asymptomatic in terms of pulmonary complaints in a 72-hour observation period are not likely to develop complications. They may be released and advised to rest and to seek medical care promptly if symptoms develop (see the Methyl Isocyanate—Patient Information Sheet below). Cigarette smoking can exacerbate pulmonary injury and should be discouraged for 72 hours after exposure.

Follow-up

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Follow-up evaluation of respiratory function should be arranged for severely exposed patients. Patients who have skin or corneal lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department.

Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). See Appendix III for a list of agencies that may be of assistance.
Methyl Isocyanate (C₃H₃NO)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to methyl isocyanate.

What is methyl isocyanate?
Methyl isocyanate is a very flammable liquid that readily evaporates when exposed to air. Methyl isocyanate liquid is colorless with a pungent odor. The primary use of methyl isocyanate is as a chemical intermediate in the production of pesticides. It is also used to produce polyurethane foams and plastics. It is shipped and handled as a flammable and explosive liquid in a special container.

What immediate health effects can be caused by exposure to methyl isocyanate?
Methyl isocyanate vapors are severely irritating and corrosive to the respiratory tract and eyes. Symptoms may include cough, chest pain, shortness of breath, watery eyes, eye pain (particularly when exposed to light), profuse lid edema, and corneal ulcerations. Respiratory symptoms such as pulmonary edema and bronchial spasms may occur in immediate response to exposure or develop and progress in severity over a period of hours to days post-exposure. Acute exposure to very high concentrations may be quickly fatal due to respiratory failure. Methyl isocyanate is a skin irritant and may cause chemical burns upon dermal contact.

Can methyl isocyanate poisoning be treated?
There is no antidote for methyl isocyanate, but its effects can be treated. Persons who have inhaled large amounts of methyl isocyanate would most likely need to be hospitalized. Persons who have come into direct skin or eye contact with methyl isocyanate liquid or vapors may need to be treated for chemical burns or serious eye injury.

Are any future health effects likely to occur?
A single exposure from which a person recovers quickly may not result in long-term health effects. However, some respiratory and eye damage may persist for a long time after exposure to methyl isocyanate. The chemical may also be a dermal and respiratory sensitizer, causing reactive responses upon subsequent exposures.

What tests can be done if a person has been exposed to methyl isocyanate?
Specific tests for the presence of methyl isocyanate in blood or urine are not generally useful. If a severe exposure has occurred, blood analyses, x-rays, and breathing tests might show whether the lungs have been injured.

Where can more information about methyl isocyanate be found?
More information about methyl isocyanate can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you might be required to contact your employer and the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
  ∘ eye, nose, throat irritation
  ∘ coughing or wheezing
  ∘ difficulty breathing or shortness of breath
  ∘ chest pain or tightness
  ∘ nausea, vomiting, diarrhea, or stomach pain

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. __________________________ in the practice of __________________________.
  When you call for your appointment, please say that you were treated in the Emergency Department at ___________ Hospital by __________________________ and were advised to be seen again in ________ days.

[ ] Return to the Emergency Department/ __________________________ Clinic on (date) __________ at ________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for ______ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: __________________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __________________________

[ ] Other instructions: __________________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: __________________________
  __________________________ or __________________________, or by checking out the following Internet Web sites: __________________________: __________________________.

Signature of patient __________________________ Date __________

Signature of physician __________________________ Date __________
Phosgene (COCl₂)
CAS 75-44-5; UN 1076

Synonyms include carbonic acid dichloride, carbonic dichloride, carbon oxychloride, carbonyl chloride, and chloroformyl chloride.

Persons exposed only to phosgene gas do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid phosgene (ambient temperature below 47 °F) can secondarily contaminate response personnel through direct contact or off-gassing vapor.

At room temperature, phosgene is a colorless, nonflammable gas with a suffocating odor like new mown hay. However, odor provides insufficient warning of hazardous concentrations. At high concentrations it is mildly irritating.

Below 47 °F, it is a colorless, fuming liquid; contact with the liquid can cause frostbite. In the presence of water (sweat, saliva, tears), the liquid or gas slowly hydrolyzes to hydrochloric acid, which can irritate and damage cells.

Phosgene is absorbed to some extent by the lungs, but not by intact skin. Systemic damage is usually a secondary result of anoxia caused by loss of lung function. It is corrosive to the lungs and intact skin.

**Description**

Phosgene is a colorless, fuming liquid below 47 °F (8.2 °C) and a colorless, nonflammable gas above 47 °F. At low concentrations, its odor is similar to that of green corn or new mown hay; at high concentrations, its odor can be sharp and suffocating. Phosgene is slightly soluble in water and is hydrolyzed slowly by moisture to form hydrochloric acid. It is soluble in most liquid hydrocarbons. It is shipped as a liquefied, compressed gas. Large quantities of phosgene should be stored in a dry, cool, well-ventilated, and fireproof room. Phosgene is a combustion product of many household products that contain volatile organochlorine compounds. Therefore, it may contribute to the hazards of smoke inhalation in fire victims and firefighters.

**Routes of Exposure**

**Inhalation**

Inhalation is the major route of phosgene exposure. The odor threshold for phosgene is 5 times higher than the OSHA PEL. Thus, odor provides insufficient warning of hazardous concentrations. Phosgene’s irritating quality can be mild and delayed, which may result in a lack of avoidance leading to exposure for prolonged periods. Phosgene is heavier than air and may cause asphyxiation in poorly ventilated, low-lying, or enclosed spaces.
Children exposed to the same levels of phosgene gas as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of phosgene gas found nearer to the ground.

**Skin/Eye Contact**

When phosgene gas contacts moist or wet skin, it may cause irritation and erythema. High airborne concentrations can also cause corneal inflammation and opacification. Direct contact with liquid phosgene under pressure can cause frostbite as well as severe irritation and corrosive effects.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

**Ingestion**

Ingestion of phosgene is unlikely because it is a gas at room temperature.

**Sources/Uses**

Phosgene is produced commercially by chlorinating carbon monoxide. It is a combustion or decomposition by-product of most volatile chlorinated compounds; therefore, household substances such as certain solvents, paint removers, and dry-cleaning fluids can produce phosgene when exposed to heat or fire. Phosgene may also be produced during the welding of metal parts that have been cleaned with chlorinated hydrocarbons. Phosgene is used as an intermediate in the manufacture of many chemicals including isocyanates, polyurethane, polycarbonates, dyes, pesticides, and pharmaceuticals.

**Standards and Guidelines**

OSHA PEL (permissible exposure limit) = 0.1 ppm (averaged over a 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 2 ppm

AIHA ERPG-2 (emergency response planning guideline) (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 individual’s ability to take protective action) = 0.2 ppm

**Physical Properties**

*Description:* Colorless gas with musty odor at room temperature; a fuming liquid below 47 °F (8 °C).
Phosgene

Warning properties: Detectable odor following brief emergency releases; odor threshold 0.4 to 1.5 ppm; slightly irritating in high concentration. Odor provides inadequate warning of harmful concentrations.

Molecular weight: 98.9 daltons

Boiling point: (760 mm Hg): 47 °F (8 °C)

Freezing point: -198 °F (-127 °C)

Specific gravity: 1.43 (liquid at 32 °F)

Vapor pressure: 1,215 mm Hg at 68 °F (20 °C)

Gas density: 3.48 (air = 1)

Water solubility: Slight

Flammability: Nonflammable gas

Incompatibilities
Phosgene reacts with moisture (water or alcohols). In water, it slowly decomposes to hydrochloric acid and carbon dioxide. When heated to decomposition, it will produce toxic and corrosive fumes. Phosgene reacts violently with various chemicals (e.g., alkalis, ammonia, amines, copper, aluminum); it attacks many metals in the presence of water and can also attack plastic and rubber.
**Health Effects**

Phosgene is an irritant to the skin, eyes, and respiratory tract; there may be minimal irritation immediately after exposure, but delayed damage may be severe.

Common initial symptoms include mild irritation of the eyes and throat, with some coughing, choking, feeling of tightness in the chest, nausea and occasional vomiting, headache, and lacrimation.

Phosgene poisoning may cause respiratory and cardiovascular failure, which results from low plasma volume, increased hemoglobin concentration, low blood pressure, and an accumulation of fluid in the lungs. Secondary systemic damage is the result of anoxia.

**Acute Exposure**

Phosgene directly reacts with amine, sulphydryl, and alcohol groups in cells, thereby adversely affecting cell macromolecules and cell metabolism. Direct toxicity to the cells leads to an increase in capillary permeability, resulting in large shifts of body fluid, decreasing plasma volume. In addition, when phosgene hydrolyzes, it forms hydrochloric acid, which can also damage surface cells and cause cell death in the alveoli and bronchioles. Hydrochloric acid release into the mucosa triggers a systemic inflammatory response. Phosgene stimulates the synthesis of lipoxygenase-derived leukotrienes, which attract neutrophils and causes their massive accumulation in the lungs; this contributes to the development of pulmonary edema. Following phosgene exposure, a patient may be free of symptoms for 30 minutes to 48 hours before respiratory damage becomes evident; the more severe the exposure, the shorter the latency. If the initial concentration of phosgene was high, rapid onset of direct cytotoxicity and enzymatic poisoning may ensue. Because phosgene is not very water soluble and hydrolysis tends to be slow, victims inhaling low concentrations of the gas may experience no irritation or only mild irritation of the upper airway. Lack of irritation allows victims to inhale the gas more deeply into the lungs and for prolonged periods.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

**Respiratory**

Inhaling low concentrations of phosgene may cause no signs or symptoms initially, or symptoms may be due only to mild irritation of the airways; these symptoms (dryness and burning of the throat and cough) may cease when the patient is removed from exposure.
However, after an asymptomatic interval of 30 minutes to 48 hours, in those developing severe pulmonary damage, progressive pulmonary edema develops rapidly with shallow rapid respiration, cyanosis, and a painful paroxysmal cough producing large amounts of frothy white or yellowish liquid. Inadequate, labored respiration, during which abnormal chest sounds are evident, may be accompanied by increased distress and apprehension. Insufficient oxygenation of arterial blood, and massive accumulation of fluid in the lungs may be accompanied by cardiovascular and hematological signs.

Exposure to phosgene has been reported to result in Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Cardiovascular**

Cardiovascular collapse may occur if the patient is severely hypovolemic and hypoxemic from accumulation of fluid in the lungs. Destruction of red blood cells in the pulmonary circulation can cause capillary plugging that leads to strain on the right side of the heart and death.

**Dermal**

If the skin is wet or moist, contact with phosgene vapor can cause irritation and redness of the skin. Contact with liquid phosgene under pressure can result in frostbite.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

**Ocular**

High vapor concentrations cause tearing and increased presence of blood in the eye. Contact with liquid phosgene may result in clouding of the cornea and delayed perforation.

**Hematologic**

In severe cases, phosgene may cause hemolysis that results in the plugging of pulmonary capillaries.

Most hematologic changes (e.g., hemolysis, methemoglobinemia, bone marrow suppression, and anemia) can be detected by standard blood tests.
### Hepatic
In cases of high exposures, phosgene may be directly cytotoxic to the liver, causing necrosis and loss of function.

### Renal
In cases of high exposures, phosgene may be directly cytotoxic to the kidneys, causing necrosis and loss of function.

### Gastrointestinal
Nausea and vomiting may occur following exposure to phosgene.

### Potential Sequelae
If the patient survives the initial 48 hours after exposure, recovery is likely. Sensitivity to irritants may persist, causing bronchospasm and chronic inflammation of the bronchioles. Pulmonary tissue destruction and scarring may lead to chronic dilation of the bronchi, lobular emphysema, regions of atelectasis, and increased susceptibility to infection.

Exposure to phosgene has been reported to result in Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

### Chronic Exposure
A group of workers who were exposed daily to high levels of phosgene showed an increase in mortality and morbidity from inflammation of the lungs, chronic inflammation of the bronchioles, destruction of alveoli, and impaired pulmonary function. Chronic exposures to low levels of phosgene may lead to chronic pneumonitis, which may resolve or lead to pulmonary edema.

Chronic exposure may be more serious for children because of their potential longer latency period.

### Carcinogenicity
Phosgene has not been classified for carcinogenic effects.

### Reproductive and Developmental Effects
No information was found pertaining to reproductive or developmental hazards caused by phosgene exposure. Phosgene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.
Prehospital Management

Victims exposed only to phosgene gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid phosgene (ambient temperature below 47 °F) can secondarily contaminate response personnel through direct contact or off-gassing vapor.

Rescue personnel should use breathing apparatus and chemical protective clothing if there is a possibility of exposure to unsafe levels of phosgene.

Phosgene is a severe pulmonary irritant. However, serious pulmonary effects may be delayed up to 48 hours.

Systemic effects are largely a secondary effect of anoxia resulting from pulmonary injury. Phosgene is also irritating to the eyes and skin.

There is no antidote for phosgene. Treatment consists of support of respiratory and cardiovascular functions.

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Phosgene is a severe respiratory tract irritant and skin irritant; contact with the liquid will cause frostbite.

**Respiratory Protection:** Positive-pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of phosgene.

**Skin Protection:** Chemical-protective clothing is recommended because phosgene gas can cause skin irritation and burns. NIOSH recommends protective suites made from Responder™ (Kappler Co.), Tychem 10000™ (DuPont Co.), or Teflon™ (DuPont Co.).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be
removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Victims should be kept warm and quiet; any activity subsequent to exposure may increase the likelihood of death.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**

Victims exposed only to phosgene gas who have no evidence of skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

Victims should be kept warm and quiet; any activity subsequent to exposure may increase the likelihood of death.

Victims who are able may assist with their own decontamination. If the exposure involved liquid phosgene (ambient temperature below 47 °F [8 °C]) and if clothing is contaminated, remove and double-bag the clothing.

Flush exposed skin and hair with plain water for 3 to 5 minutes. Wash thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.
### Transfer to Support Zone
As soon as basic decontamination is complete, move the victim to the Support Zone.

### Support Zone
Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to phosgene gas generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

### ABC Reminders
Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

### Additional Decontamination
Continue irrigating exposed skin and eyes, as appropriate.

### Advanced Treatment
In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Phosgene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.
Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Phosgene has relatively little odor or irritating effects at moderately toxic air concentrations; serious health effects may occur without warning or symptoms. Because serious complications may be delayed up to 48 hours after exposure, all patients who have suspected phosgene exposure should be transported to a medical facility for evaluation.
Phosgene

Emergency Department Management

Patients exposed only to phosgene gas do not pose significant risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid phosgene (ambient temperature below 47°F) can secondarily contaminate hospital personnel by direct contact or through off-gassing vapor.

Rescue personnel should use breathing apparatus and chemical protective clothing if there is a possibility of exposure to unsafe levels of phosgene.

Phosgene is a severe pulmonary irritant. However, serious pulmonary effects may be delayed up to 48 hours.

Systemic effects are largely a secondary effect of anoxia resulting from pulmonary injury. Phosgene is also irritating to the eyes and skin.

There is no antidote for phosgene. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with phosgene liquid and all victims with skin or eye irritation require decontamination as described below. Because contact with liquid phosgene may cause burns, don butyl rubber gloves and apron and eye protection before treating patients. All other patients may be transferred immediately to the Critical Care Area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

Victims should be kept warm and quiet; any activity subsequent to exposure may increase the likelihood of death.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.
Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Phosgene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias or renal failure should be treated in the conventional manner.

**Basic Decontamination**

Victims who are able may assist with their own decontamination. If the exposure involved liquid phosgene (ambient temperature below 47°F [8 °C]) and if clothing is contaminated, remove and double-bag the clothing.

Flush exposed skin and hair with plain water for 3 to 5 minutes. Wash thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue eye irrigation while transferring the patient to the Critical Care Area.

An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

**Critical Care Area**

Be certain that appropriate decontamination has been carried out (see Decontamination Area above).

**ABC Reminders**

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive...
agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

**Inhalation Exposure**

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Phosgene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients who are in respiratory distress for up to 48 hours and periodically reexamine their chests and order other appropriate studies. Follow up as clinically indicated.

Corticosteroids are suggested for intense inflammation, especially inflammation of the respiratory epithelium. If the patient experienced severe exposure, consider initiating intravenous steroid therapy while the patient is asymptomatic.

Prophylactic antibiotics are not routinely recommended but may be used based on the results of sputum cultures. Pneumonia can complicate severe pulmonary edema and may cause death up to 48 hours after onset of pulmonary edema.

Diuretics are contraindicated. Pulmonary edema due to phosgene inhalation is not hypervolemic in origin; patients tend to be hypovolemic and hypotensive. Dopamine may be required for treatment of hypotension, bradycardia, or renal failure. Initiate fluid resuscitation as needed.

**Skin Exposure**

If phosgene was in contact with the skin, chemical burns may result; treat as thermal burns.
Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

**Eye Exposure**

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

**Antidotes and Other Treatments**

There is no antidote for phosgene. Treatment is supportive.

**Laboratory Tests**

The diagnosis of acute phosgene toxicity is primarily clinical, based on symptoms of irritation and breathing difficulty. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. ECG monitoring is useful for patients exposed to phosgene. Chest radiography and pulse oximetry (or ABG measurements) are also recommended for severe inhalation exposure. Evidence of pulmonary edema—hilar enlargement, and ill-defined, central-patch infiltrates on chest radiography—is a late finding that may occur 6 to 8 hours after exposure.

Plasma phosgene levels are not clinically useful.

**Disposition and Follow-up**

Consider hospitalizing all patients who have suspected phosgene exposure. Patients who have respiratory compromise should be admitted to an intensive care unit.

**Delayed Effects**

Because pulmonary edema may not occur for up to 48 hours after exposure, patients who have known exposure should be observed and reexamined periodically before confirming the absence of toxic effects. Patients who have bronchospasm or pulmonary edema should be watched carefully for signs of impending respiratory failure and should be managed accordingly. Patients who survive for 48 hours usually recover.

**Patient Release**

Asymptomatic patients who have normal initial examinations and no signs of toxicity after observation for 48 hours may be discharged with instructions to seek medical care promptly if symptoms develop (see the Phosgene—Patient Information Sheet below).

**Follow-up**

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

Patients may have long term damage to the lungs and increased susceptibility to infection. Sensitivity to irritants may persist, causing bronchospasm, chronic inflammation of the bronchioles and
Phosgene

Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Patients who have corneal injuries should be reexamined in 24 hours.

**Reporting**

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Phosgene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phosgene.

What is phosgene?
At room temperature, phosgene is a colorless gas. At high concentrations, it has a suffocating odor; at low concentrations, it smells like green corn or new mown hay. It is not flammable. Phosgene is used in the manufacture of many chemicals. It is also produced when chlorine-containing chemicals burn or break down.

What immediate health effects can result from exposure to phosgene?
Most exposures to phosgene occur from breathing the gas. Exposure to small amounts usually causes eye, nose, and throat irritation. However, the irritating effects can be so mild at first that the person does not leave the area of exposure. Generally, the higher the exposure, the more severe the symptoms. Extended exposure can cause severe breathing difficulty, which may lead to chemical pneumonia and death. Severe breathing problems may not develop for as long as 48 hours after exposure.

Can phosgene poisoning be treated?
There is no antidote for phosgene, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, some symptoms may take a few days to develop. Some persons who have had serious exposures have developed permanent breathing difficulty and tend to develop lung infections easily.

What tests can be done if a person has been exposed to phosgene?
Specific tests for the presence of phosgene in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, chest x-rays, blood and urine analyses and other tests may show whether the lungs or other organs have been injured. Because effects may take several days to develop, immediate and follow-up testing of lung function should be done in all cases of suspected exposure to phosgene.

Where can more information about phosgene be found?
More information about phosgene can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

coughing or wheezing
difficulty breathing or shortness of breath
increased pain or a discharge from exposed skin or eyes
chest pain or tightness

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. ____________________ in the practice of ____________________.

When you call for your appointment, please say that you were treated in the Emergency Department at __________________ Hospital by __________________________ and were advised to be seen again in _______ days.

[ ] Return to the Emergency Department/ __________________ Clinic on (date) __________ at __________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for ______ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications:

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you:

[ ] Other instructions:

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ___________________________, __________________________, or by checking out the following Internet Web sites: __________________________; __________________________.

Signature of patient __________________________ Date __________________________

Signature of physician __________________________ Date __________________________
Phosphine (PH₃)
CAS 7803-51-2; UN 2199
Also: Aluminum Phosphide (CAS 20859-73-B; UN 1397) and Zinc Phosphide (CAS 1314-84-7; UN 1714)

Synonyms of phosphine include hydrogen phosphide, phosphorus hydride, phosphorus trihydride, and phosphoretted hydrogen.

Persons exposed only to phosphine gas do not pose substantial risks of secondary contamination; however, persons exposed to solid phosphides may present such risks. Metallic phosphides on clothes, skin, or hair can react with water or moisture to generate phosphine gas. Vomitus containing phosphides can also off-gas phosphine.

Phosphine is extremely flammable and explosive; it may ignite spontaneously on contact, with air. Phosphine has a fish- or garlic-like odor, but may not provide adequate warning of hazardous concentrations. When phosphine burns it produces a dense white cloud of phosphorus pentoxide, P₂O₅ fume. This fume is a severe respiratory tract irritant due to the rapid formation of orthophosphoric acid, H₃PO₄, on contact with water.

- Phosphine is a respiratory tract irritant that attacks primarily the cardiovascular and respiratory systems causing peripheral vascular collapse, cardiac arrest and failure, and pulmonary edema.

Most phosphine exposures occur by inhalation of the gas or ingestion of metallic phosphides, but dermal exposure to phosphides can also cause systemic effects.

**Description**

Phosphine is a colorless, flammable, and toxic gas with an odor of garlic or decaying fish. It can ignite spontaneously on contact with air. The gas is shipped as a liquefied, compressed gas.

Aluminum phosphide (Celphos, Phostoxin, Quick Phos) and zinc phosphide are solids used as grain fumigants and as a rodenticide, respectively. Zinc phosphide is often mixed with bait food such as cornmeal, which can be a danger to pets and children. When phosphides are ingested or exposed to moisture, they release phosphine gas. Phosphine gas may also be released when acetylene is made by the action of water on calcium carbide which is contaminated with calcium phosphide as is commonly the case.
**Routes of Exposure**

*Inhalation*

Inhalation is the major route of phosphine toxicity. **Odor is not an adequate indicator of phosphine’s presence and may not provide reliable warning of hazardous concentrations.** The OSHA PEL of 0.3 ppm is within the range of reported odor thresholds. Phosphine is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of phosphine as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of phosphine found nearer to the ground.

*Skin/Eye Contact*

Phosphides may be absorbed dermally, especially through broken skin, and can cause systemic toxicity by this route. Phosphine gas produces no adverse effects on the skin or eyes, and contact does not result in systemic toxicity. Contact with liquefied or compressed phosphine gas may cause frostbite.

*Ingestion*

Ingestion of phosphine is unlikely because it is a gas at room temperature. Ingestion of metallic phosphides can produce phosphine intoxication when the solid phosphide contacts gastric acid.

*Sources/Uses*

Phosphine is produced when metallic phosphides (e.g., aluminum, calcium, or zinc phosphides) react with water or acid. Both aluminum and zinc phosphides are used as rodenticides. Phosphine may be produced during the generation of acetylene gas. Phosphine is used in the semiconductor industry to introduce phosphorus into silicon crystals as an intentional impurity. Phosphine is also used as a fumigant and a polymerization initiator.

*Standards and Guidelines*

OSHA PEL (permissible exposure limit) = 0.3 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

ERPG-2 (Emergency Response Planning Guideline) (maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious adverse health effects or symptoms that could impair an individual’s ability to take protective action) = 0.5 ppm
### Physical Properties

*Description:* Colorless gas; odor of garlic or decaying fish

*Warning properties:* Inadequate; nonirritating and garlic-like or fishy odor at 1 to 3 ppm.

*Molecular weight:* 34.0 daltons

*Melting point:* -209 °F (-134 °C)

*Boiling point (760 mm Hg):* = -126 °F (-87.7 °C)

*Vapor pressure:* >760 mm Hg at 68 °F (20 °C)

*Gas density:* 1.17 (air = 1)

*Water solubility:* Slightly water soluble (0.3% at 68 °F (20 °C)

*Flammability:* Extremely flammable and explosive; may ignite spontaneously on contact with air.

### Incompatibilities

Phosphine reacts with air, oxidizers, chlorine, acids, moisture, halogenated hydrocarbons, and copper.
Health Effects

Symptoms of phosphine intoxication are primarily related to the cardiovascular and pulmonary systems and may include restlessness, irritability, drowsiness, tremors, vertigo, diplopia, ataxia, cough, dyspnea, retrosternal discomfort, abdominal pain, and vomiting.

The same symptoms may occur after ingestion of phosphide salts. Multiple signs may be seen representing various stages of cardiovascular collapse.

Phosphine interferes with enzymes and protein synthesis, primarily in the mitochondria of heart and lung cells. As a result, effects may include hypotension, reduction in cardiac output, tachycardia, oliguria, anuria, cyanosis, pulmonary edema, tachypnea, jaundice, hepatosplenomegaly, ileus, seizures, and diminished reflexes.

Acute Exposure

Phosphine interferes with enzymes and protein synthesis, primarily in the mitochondria of heart and lung cells. Metabolic changes in heart muscle cause cation disturbances that alter transmembrane potentials. Ultimately, cardiac arrest, peripheral vascular collapse and pulmonary edema can occur. Pulmonary edema and pneumonitis are believed to result from direct cytotoxicity to the pulmonary cells. In fatal cases, centrlobular necrosis of the liver has also been reported.

Most deaths occur within the first 12 to 24 hours after exposure and are cardiovascular in origin. If the patient survives the initial 24 hours, the ECG typically returns to normal, indicating that heart damage is reversible. Deaths after 24 hours are usually due to liver failure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Phosphine is a CNS depressant. Initial effects may include headache, restlessness, dizziness, loss of feeling, impaired gait, trembling of the extremities during movement, and double vision. Severe exposure can cause seizures and coma.

Respiratory

Toxicity that occurs after inhalation is characterized by chest tightness, cough, and shortness of breath. Severe exposure can cause accumulation of fluid in the lungs, which may have a delayed onset of 72 hours or more after exposure. Pulmonary symptoms can
also result from ingestion of metallic phosphides (e.g., aluminum or zinc phosphide).

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Cardiovascular**

Cardiovascular manifestations include hypotension, reduction in cardiac output, tachycardia, irregular heart beat, or cardiac arrest. Laboratory tests may reveal abnormal myocardial enzymes. Phosphine affects the small peripheral vessels, causing a profound decrease in systemic vascular resistance. Vascular changes may lead to marked low blood pressure that does not respond well to pressor agents.

**Gastrointestinal**

Gastrointestinal symptoms are usually the first to occur after exposure. Symptoms may include nausea, vomiting, abdominal pain, and diarrhea.

**Hepatic**

Typically, liver injury does not become evident until 48 to 72 hours after exposure. Findings may include jaundice, enlarged liver, elevated serum transaminases, and increased bilirubin in the blood.

**Renal**

Blood and protein in the urine, and acute kidney failure can occur.

**Electrolyte**

Analysis of blood gases may reveal combined respiratory and metabolic acidosis. Also, there have been reports of significant hypomagnesemia and hypermagnesemia associated with massive focal myocardial damage.

**Potential Sequelae**

Although most survivors of acute phosphine exposure show no permanent disabilities, damage due to insufficient blood supply to the heart and brain have been reported. Subacute poisoning resulting from exposure for a few days may cause reactive airways dysfunction syndrome (RADS) months later.

**Chronic Exposure**

Chronic exposure to very low concentrations may result in anemia, bronchitis, gastrointestinal disturbances, and visual, speech, and motor disturbances. Chronic exposure may be more serious for children because of their potential longer latency period.

**Carcinogenicity**

The EPA has determined that phosphine is not classifiable as to its human carcinogenicity.
Reproductive and Developmental Effects

Phosphine is not contained in the TERIS or Reprotext databases, nor is it mentioned in Shepards Catalog of Teratogenic Agents. Phosphine is not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

No teratogenic effects from acute exposure are known.
Victims exposed only to phosphine gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims exposed to solid phosphides, which react with moisture to produce phosphine, can pose such risks if phosphides are on clothes, skin, or hair. Protect personnel through the use of rubber gloves and aprons.

Phosphine is a multisystem toxicant that can cause pulmonary irritation, CNS depression, and cardiovascular collapse.

There is no antidote for phosphine poisoning. Treatment consists of support of respiratory and cardiovascular functions.

**Prehospital Management**

**Hot Zone**

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

**Rescuer Protection**

Phosphine is a highly toxic systemic poison and a severe respiratory tract irritant.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of phosphine.

Skin Protection: Chemical-protective clothing is not generally required because phosphine gas is not absorbed through the skin, and skin irritation is unlikely. Use rubber gloves and aprons with victims exposed to phosphides.

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Brush powder from the skin, hair, and clothes of victims before leaving the Hot Zone.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.
Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

**Decontamination Zone**

Victims exposed only to phosphine gas do not need decontamination. They may be transferred immediately to the Support Zone. Victims exposed to metallic phosphides will require decontamination as described below.

**Rescuer Protection**

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

**ABC Reminders**

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

**Basic Decontamination**

Victims who are able may assist with their own decontamination. Brush all visible particles from clothes, skin, and hair. Remove and double-bag contaminated clothing and personal belongings.

Thoroughly flush exposed skin and hair with water for 3 to 5 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

If phosphides have been ingested, **do not induce emesis**. Phosphides will release phosphine in the stomach; therefore, watch for signs similar to those produced by phosphine inhalation. Administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

Be certain that victims exposed to metallic phosphides have been decontaminated properly (see Decontamination Zone above). Victims who have been exposed only to phosphine gas or who have
undergone decontamination pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

**ABC Reminders**

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

**Additional Decontamination**

Continue irrigating exposed skin and eyes, as appropriate.

If phosphides have been ingested, **do not induce emesis**. If it has not been given previously and the patient is alert and able to swallow, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. Phosphides will release phosphine in the stomach; therefore, watch for signs similar to those produced by phosphine inhalation.

**Advanced Treatment**

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer’s solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.
Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If metallic phosphides have been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for further advice regarding triage of multiple victims.

Because it is difficult to determine at the scene which patients have had the most serious inhalation exposure, and because some systemic symptoms may be delayed for up to 72 hours after exposure, all patients who have potentially significant exposures should be transported to a medical facility for evaluation. Those who have had massive exposures and those who have experienced a garlic- or fish-like odor should be transported first.

All patients who have ingested phosphides should be transported to a medical facility without delay.
Victims exposed only to phosphine gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. However, solid phosphides, which react with moisture to produce phosphine, may present secondary contamination risks on clothes, skin, or hair.

Phosphine is a multisystem toxicant that causes acute pulmonary irritation, CNS depression, and cardiovascular collapse. Fatal outcomes after the initial 24 hours are usually due to hepatic or renal failure.

There is no antidote for phosphine poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to phosphine gas may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts. Rubber gloves and aprons should be used with non-decontaminated victims exposed to phosphides.

Emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.
Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Correct acidosis in the patient who has coma, seizures or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by ABG measurements.

**Basic Decontamination**

Patients who are able may assist with their own decontamination. If the patient has been exposed to solid phosphides, brush the powder from skin, hair, and clothes. Remove and double-bag the patient’s clothing and personal belongings. Flush the skin and hair with water (preferably under a shower). Remove contact lenses if easily removable without additional trauma to the eye. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

In cases of phosphide ingestion, **do not induce emesis**. If activated charcoal has not been given previously, administer a slurry of it at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). Phosphides will release phosphine in the stomach; therefore, watch for signs similar to those produced by phosphine inhalation. (More information is provided in *Ingestion Exposure* under *Critical Care Area* below).

**Critical Care Area**

Be certain that patients who have ingested solid phosphides have been decontaminated as described above. Decontamination is not necessary for patients exposed only to phosphine gas.

**ABC Reminders**

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Watch for signs of airway compromise. Monitor cardiac rhythm.

Hypotension may develop and may respond poorly to pressor agents.

Patients who are comatose or have seizures should be treated in the conventional manner. Correct acidosis in the patient who has coma, seizures or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg).

**Inhalation Exposure**

Symptomatic patients should receive supplemental oxygen for dyspnea and should be observed for at least 72 hours with repeated
chest examinations and other appropriate studies. Follow-up as clinically indicated.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

**Ingestion Exposure**

Remove phosphides from the stomach as soon as possible because most phosphides release phosphine gas on contact with water or acids. Administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been given previously. A mineral oil cathartic (100 mL) is recommended rather than a saline cathartic. Watch for signs and symptoms similar to those produced by inhalation exposure; treat accordingly.

Gastric lavage with a potassium permanganate solution (1:10,000) is recommended if ingestion occurred. Permanganate oxidizes phosphine in the stomach to form phosphate, thus reducing the available phosphine.

**Antidotes and Other Treatments**

There is no antidote for phosphine poisoning. Treatment consists of supportive measures. Hemodialysis is recommended only if renal failure develops. The effectiveness of exchange transfusions is questionable. The value of steroids for phosphine-exposed patients who develop acute pulmonary symptoms has not been proven.

**Laboratory Tests**

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to phosphine include ECG monitoring, renal function tests, and liver-function tests. Chest radiography, pulse oximetry (or ABG measurements), and PFl3 are recommended to establish baseline for pulmonary status. Serial myocardial enzyme levels may also be helpful.

Phosphine is metabolized to phosphite and hypophosphite, which are excreted in the urine. Although analysis for these metabolites is not clinically useful in an emergency setting, urine samples can be collected and frozen for future analysis, particularly if questions on the nature or extent of exposure are likely.
**Disposition and Follow-up**

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results.

**Delayed Effects**

Because onset of pulmonary edema and liver damage may be delayed for 72 hours or more after exposure, all patients who have significant exposure should be admitted and observed carefully.

**Patient Release**

Asymptomatic patients who have normal initial examinations, minimal exposure, and no signs of toxicity after observation for 4 to 6 hours may be discharged with instructions to return to the ED if symptoms develop (see the Phosphine—Patient Information Sheet below).

**Follow-up**

Obtain the name of the patient’s primary care physician so the hospital can send a copy of the ED visit to the patient’s doctor.

Patients exposed to phosphine should be monitored for pulmonary dysfunction.

**Reporting**

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Phosphine
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phosphine or phosphides.

What is phosphine? How are phosphides related?
Phosphine is a toxic gas that has no color and smells like garlic or fish. A serious exposure to phosphine could occur, however, even if a person does not smell it. Phosphine is used widely in the semiconductor industry. Phosphine may be encountered in grain storage silos where it has been used as a fumigant, or zinc phosphide has been put down as a rat poison.

Certain pesticides containing zinc phosphide or aluminum phosphide can release phosphine when they come in contact with water or acid. The phosphine formed in the stomach when these solid phosphides are swallowed can result in phosphine poisoning.

What immediate health effects can be caused by exposure to phosphine?
Exposure to even small amounts of phosphine can cause headache, dizziness, nausea, vomiting, diarrhea, drowsiness, cough, and chest tightness. More serious exposure can cause shock, convulsions, coma, irregular heartbeat, and liver and kidney damage. Generally, the more serious the exposure, the more severe the symptoms.

Can phosphine poisoning be treated?
There is no antidote for phosphine, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, symptoms usually begin immediately but might not appear for 72 hours or more.

Some severely exposed persons have experienced long-term brain, heart, lung, and liver injury.

What tests can be done if a person has been exposed to phosphine?
There are no specific blood or urine tests for phosphine itself. Breakdown products of phosphine can be measured in urine, but the result of this test is generally not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may also show whether the brain, lungs, heart, liver, or kidneys have been damaged. Testing is not needed in every case.

Where can more information about phosphine be found?
More information about phosphine and phosphides can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
- coughing or wheezing
- difficulty breathing or shortness of breath
- chest pain or tightness
- headache, dizziness, tremor, or double vision
- difficulty walking
- nausea, vomiting, diarrhea, or stomach pain

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. ________________ in the practice of ________________.
When you call for your appointment, please say that you were treated in the Emergency Department at ________________ Hospital by ________________ and were advised to be seen again in ________ days.
[ ] Return to the Emergency Department/______________ Clinic on (date) __________ at ________________ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for ______ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: ________________________________
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ________________________________

[ ] Other instructions: ________________________________________________________________

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
- You or your physician can get more information on the chemical by contacting: ________________________________ or ________________________________, or by checking out the following Internet Web sites: ________________________________, ________________________________.

Signature of patient ________________________________ Date ____________________
Signature of physician ________________________________ Date ____________________
Nerve Agents
Tabun (GA) CAS 77-81-6; Sarin (GB) CAS 107-44-8; Soman (GD) CAS 96-64-0; and VX CAS 5078269-9

Synonyms:
GA: ethyl dimethylamidocyanophosphate; ethyl N,N-dimethylphosphoramidocyanidate; ethyl dimethyl-phosphoramidecyanidate; dimethylaminoethoxy-cyanophosphine oxide; dimethylamidoethoxy-phosphoryl cyanide; EA1205; dimethylphosphoramidocyanidic acid ethyl ester
GB: isopropyl methylphosphonofluoridate; isopropoxymethylphosphoryl fluoride; trilone; MFI; TL1 618; isopropylmethanefluorophosphonate; T144; T2106; fluoro(isopropoxy)methylphosphine oxide; methylisopropoxyfluorophosphine oxide; zarin
GD: pinacolyl methylphosphonofluoridate; 1,2,2-trimethylpropyl methylphosphonofluoridate; methyl-pinacolyloxyfluorophosphine oxide; pinacolyloxymethylphosphonyl fluoride; pinacolymethylfluorophosphonate; 1,2,2-trimethylpropoxyfluoro(methyl)phosphine oxide; pinacolyl methyl-phosphonyl fluoride
VX: O-ethyl S-(2-diisopropylaminoethyl) methylphosphonothiolate; methylphosphonothioic acid; S-2-(diisopropylamino)ethyl O-ethyl methylphosphonothioate; O-ethyl S-(2-diisopropylaminoethyl)methylphosphonothioate; O-ethyl S-(2-diisopropyldiaminoethyl) methylthiol-phosphonoate; O-ethyl S-diisopropylaminoethyl methylphosphonothiolate

- Persons whose skin or clothing is contaminated with nerve agent can contaminate rescuers by direct contact or through off-gassing vapor. Persons whose skin is exposed only to nerve agent vapor pose no risk of secondary contamination; however, clothing can trap vapor.
- G-type nerve agents (GA, GB, and GD) are clear, colorless liquids that are volatile at ambient temperatures. VX is an amber-colored, oily liquid with low volatility unless temperatures are high.
- Nerve agents are readily absorbed by inhalation, ingestion, and dermal contact. Rapidly fatal systemic effects may occur.

Description
Nerve agents are the most toxic of the known chemical warfare agents. They are chemically similar to organophosphate pesticides and exert their biological effects by inhibiting acetylcholinesterase enzymes. G-type agents are clear,
Nerve Agents

colorless, and tasteless liquids that are miscible in water and most organic solvents. GB is odorless and is the most volatile nerve agent; however, it evaporates at about the same rate as water. GA has a slightly fruity odor, and GD has a slight camphor-like odor. VX is a clear, amber-colored, odorless, oily liquid. It is miscible with water and soluble in all solvents. It is the least volatile nerve agent. Table 1 lists selected physical properties for each of the nerve agents.

Routes of Exposure

Inhalation

Nerve agents are readily absorbed from the respiratory tract. Rhinorrhea and tightness in the throat or chest begin within seconds to minutes after exposure. Nerve agent vapors are heavier than air. Odor does not provide adequate warning of detection. The estimated LC₅₀ (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) ranges from 10 mg-min/m³ for VX to 400 mg-min/m³ for GA.

Skin/Eye Contact

Nerve agent liquids are readily absorbed from the skin and eyes. Vapors are not absorbed through the skin except at very high concentrations. Ocular effects may result from both direct contact and systemic absorption. The nature and timing of symptoms following dermal contact with liquid nerve agents depend on exposure dose; effects may be delayed for several hours. As little as one drop of VX on the skin can be fatal and 1 to 10 mL of GA, GB, or GD can be fatal.

Ingestion

Ingestion of nerve agents is expected to be relatively rare compared to inhalation exposure or skin contact; however, they are readily absorbed from the GI tract and are highly toxic.

Sources/Uses

Most of the nerve agents were originally synthesized in a search for insecticides, but because of their toxicity, they were evaluated for military use. GA was synthesized in 1936 by a German scientist who synthesized GB 2 years later. During World War II, Germany developed chemical weapons using both GA and GB but never used them. GD was synthesized in 1944 by a German chemist, and VX was synthesized in the early 1950s by a British scientist. Although related organophosphate chemicals are used in medicine, pharmacology, and agriculture, these are not as toxic as the nerve agents. Nerve agents were used by Iraq against Iran and have been used by terrorists. They are known to be included in military stockpiles of several nations, including the United States.

Standards and
Guidelines

Workplace time-weighted average: GA and GB, 0.0001 mg/m³; GD, 0.00003 mg/m³; VX, 0.00001 mg/m³

General population limits: 0.000003 mg/m³ (all) over an 8-hour workshift

Physical Properties

Table 1. Physical Properties of Nerve Agents

<table>
<thead>
<tr>
<th>Property</th>
<th>Tabun (GA)</th>
<th>Sarin (GB)</th>
<th>Soman (GD)</th>
<th>VX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>clear, colorless, and tasteless liquid</td>
<td>clear, colorless, tasteless, and odorless liquid</td>
<td>pure liquid is clear, colorless, and tasteless; discolors with aging to dark brown</td>
<td>amber colored, tasteless, and odorless oily liquid</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>162.3 daltons</td>
<td>140.1 daltons</td>
<td>182.2 daltons</td>
<td>267.4 daltons</td>
</tr>
<tr>
<td>Boiling point</td>
<td>(760 mm Hg) = 428 to 475 °F (220 to 246 °C)</td>
<td>(760 mm Hg) = 316 °F (158 °C)</td>
<td>(760 mm Hg) = 332.6 to 392 °F (167 to 200 °C)</td>
<td>(760 mm Hg) = 568.4 °F (298 °C)</td>
</tr>
<tr>
<td>Freezing point</td>
<td>-58 °F (-50 °C)</td>
<td>-68.8 °F (-56 °C)</td>
<td>-43.6 °F (-42 °C)</td>
<td>-59.8 °F (-51 °C)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.073 g/mL (water = 1.0)</td>
<td>1.089 (water = 1.0)</td>
<td>1.022 (water = 1.0)</td>
<td>1.008 (water = 1.0)</td>
</tr>
<tr>
<td>Vapor pressure</td>
<td>0.037 mm Hg at 68 °F (20 °C); 0.057 mm Hg at 77 °F (25 °C)</td>
<td>2.1 mm Hg at 68 °F (20 °C); 2.9 mm Hg at 77 °F (25 °C)</td>
<td>0.4 mm Hg at 77 °F (25 °C)</td>
<td>0.0007 mm Hg at 77 °F (25 °C)</td>
</tr>
<tr>
<td>Vapor density</td>
<td>5.6 (air = 1.0)</td>
<td>4.9 (air = 1.0)</td>
<td>6.33 (air = 1.0)</td>
<td>9.2 (air = 1.0)</td>
</tr>
<tr>
<td>Liquid density</td>
<td>1.08 g/mL at 77 °F (25 °C)</td>
<td>1.10 g/mL at 68 °F (20 °C)</td>
<td>1.02 g/mL at 77 °F (25 °C)</td>
<td>1.008 g/mL at 68 °F (20 °C)</td>
</tr>
<tr>
<td>Flash point</td>
<td>172.4 °F (78 °C)</td>
<td>nonflammable</td>
<td>249.8 °F (121 °C)</td>
<td>318.2 °F (159 °C)</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>9.8 g/100 g at 77 °F (25 °C)</td>
<td>miscible</td>
<td>2.1 g/100g at 68 °F (20 °C)</td>
<td>3 g/100 g (miscible below 48.9 °F 9.4 °C)</td>
</tr>
<tr>
<td>Volatility</td>
<td>490 mg/m³ at 77 °F (25 °C)</td>
<td>22,000 mg/m³ at 77 °F (25 °C)</td>
<td>3,900 mg/m³ at 77 °F (25 °C)</td>
<td>10.5 mg/m³ at 77 °F (25 °C)</td>
</tr>
<tr>
<td>NAERG#</td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>
### Incompatibilities

Decomposition of GA may produce HCN, oxides of nitrogen, oxides of phosphorus, carbon monoxide, and hydrogen cyanide. Under acid conditions GB and GD hydrolyze to form HF. GB decomposes tin, magnesium, cadmium plated steel, and aluminum. Hydrolysis of VX produces a class B poison.
Health Effects

Manifestations of nerve agent exposure include rhinorrhea, chest tightness, pinpoint pupils, shortness of breath, excessive salivation and sweating, nausea, vomiting, abdominal cramps, involuntary defecation and urination, muscle twitching, confusion, seizures, flaccid paralysis, coma, respiratory failure, and death.

- Nerve agents are potent acetylcholinesterase inhibitors causing the same signs and symptoms regardless of the exposure route. However, the initial effects depend on the dose and route of exposure.

Acute Exposure

Nerve agents alter cholinergic synaptic transmission at neuroeffector junctions (muscarinic effects), at skeletal myoneural junctions and autonomic ganglia (nicotinic effects), and in the CNS. Initial symptoms depend on the dose and route of exposure.

Muscarinic effects include pinpoint pupils; blurred or dim vision; conjunctivitis; eye and head pain; hypersecretion by salivary, lacrimal, sweat, and bronchial glands; narrowing of the bronchi; nausea, vomiting, diarrhea, and crampy abdominal pains; urinary and fecal incontinence; and slow heart rate.

Nicotinic effects include skeletal muscle twitching, cramping, and weakness. Nicotinic stimulation can obscure certain muscarinic effects and produce rapid heart rate and high blood pressure.

Relatively small to moderate vapor exposure causes pinpoint pupils, rhinorrhea, bronchoconstriction, excessive bronchial secretions, and slight to moderate dyspnea. Mild to moderate dermal exposure results in sweating and muscular fasciculations at the site of contact, nausea, vomiting, diarrhea, and weakness. The onset of these mild to moderate signs and symptoms following dermal exposure may be delayed for as long as 18 hours. Higher exposures (any route) cause loss of consciousness, seizures, muscle fasciculations, flaccid paralysis, copious secretions, apnea, and death.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Nerve agents cause behavioral and psychological changes in humans. CNS effects include irritability, nervousness, fatigue, insomnia, memory loss, impaired judgment, slurred speech, and depression. High exposures may produce loss of consciousness, seizures, and apnea.
### Respiratory
Inhalation of nerve agent vapors causes respiratory tract effects within seconds to minutes. Symptoms include excessive rhinorrhea and bronchial secretions, chest tightness, and difficulty breathing due to constriction of bronchial muscles and mucous secretions. Respiratory failure may occur due to CNS depression.

### Cardiovascular
Vagal stimulation may produce bradycardia, but pulse rate may be increased due to ganglionic stimulation, and the effects of hypoxia. Bradyarrhythmias and hypertension may occur.

### Gastrointestinal
Abdominal pain, nausea and vomiting are common manifestations of exposure by any route but may be the first systemic effects from liquid exposure on skin. If these symptoms occur within an hour of dermal exposure, severe intoxication is indicated. Diarrhea and fecal incontinence may also occur.

### Skeletal muscles
Nerve agents stimulate skeletal muscle producing fasciculations and twitching leading to fatigue and flaccid paralysis. Muscle twitching/fasciculations are clinical identifiers that indicate possible nerve agent exposure.

### Metabolic
Profuse sweating may occur.

### Ocular
Symptoms may occur from local effects of vapor exposure and from systemic absorption. Pinpoint pupils and spasm of the muscle of visual accommodation (i.e., ciliary muscle) leading to blurred and dim vision, aching pain in the eye, and conjunctivitis are typical effects.

### Potential Sequelae
CNS effects such as fatigue, irritability, nervousness and impairment of memory may persist for as long as 6 weeks after recovery from acute effects. Although exposure to some organophosphate compounds may cause a delayed mixed sensory-motor peripheral neuropathy, there are no reports of this condition among humans exposed to nerve agents.

### Chronic Exposure
Very little information is available regarding prolonged exposures to low levels of nerve agents.

### Carcinogenicity
No information is available regarding the potential carcinogenicity of nerve agents in humans. Limited animal data indicate that nerve agents are not likely to be carcinogenic.
Nerve Agents

*Developmental Effects*  
The limited data available indicate that nerve agents are not reproductive or developmental toxicants.
### Prehospital Management

Victims whose skin or clothing is contaminated with liquid nerve agent can contaminate rescuers by direct contact or through off-gassing vapor.

Nerve agents are extremely toxic and can cause loss of consciousness and convulsions within seconds and death from respiratory failure within minutes of exposure.

Atropine and pralidoxime chloride (2-PAM Cl) are antidotes for nerve agent toxicity; however, pralidoxime must be administered within minutes to a few hours following exposure (depending on the specific agent) to be effective. Treatment consists of supportive measures and repeated administration of antidotes.

| Hot Zone | Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center. SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer. |
| Rescuer Protection | Nerve agent vapor is readily absorbed by inhalation and ocular contact and produces rapid local and systemic effects. The liquid is readily absorbed through the skin; however, effects may be delayed for several minutes to up to 18 hours. |

**Respiratory protection:** Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any nerve agent vapor or liquid.

**Skin protection:** Chemical-protective clothing and butyl rubber gloves are recommended when skin contact is possible because nerve agent liquid is rapidly absorbed through the skin and may cause systemic toxicity.

**ABC Reminders** Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely
casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4). Clinical signs and effects of nerve agents associated with each of these categories are presented in Table 2.

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advice concerning management of multiple casualties.

<table>
<thead>
<tr>
<th>General principles of triage for chemical exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Check triage tag/card for any previous treatment or triage.</td>
</tr>
<tr>
<td>2. Survey for evidence of associated traumatic/blast injuries.</td>
</tr>
<tr>
<td>3. Observe for sweating, labored breathing, coughing/vomiting, secretions.</td>
</tr>
<tr>
<td>4. Severe casualty triaged as immediate if assisted breathing is required.</td>
</tr>
<tr>
<td>5. Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.</td>
</tr>
<tr>
<td>6. Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.</td>
</tr>
<tr>
<td>7. If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms.</td>
</tr>
<tr>
<td>8. Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.</td>
</tr>
</tbody>
</table>

1. **Immediate**: casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. **Delayed**: casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. **Minimal**: casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. **Expectant**: casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be retriaged to a higher category.
Table 2. Triage for Nerve Agent Casualties

<table>
<thead>
<tr>
<th>Category (Priority)</th>
<th>Effects</th>
<th>Clinical Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate (1)</td>
<td>Unconscious, talking but not walking, or moderate to severe effects in two or more systems (e.g., respiratory, GI, muscular, CNS)</td>
<td>Seizing or post-ictal, severe respiratory distress or apneic. Recent cardiac arrest.</td>
</tr>
<tr>
<td>Delayed (2)</td>
<td>Recovering from agent exposure or antidote</td>
<td>Diminished secretions, improving respiration.</td>
</tr>
<tr>
<td>Minimal (3)</td>
<td>Walking and talking</td>
<td>Miosis, rhinorrhea, mild to moderate dyspnea.</td>
</tr>
<tr>
<td>Expectant (4)</td>
<td>Unconscious</td>
<td>Cardiac/respiratory arrest of long duration.</td>
</tr>
</tbody>
</table>

**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a decontaminable cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

**Antidotes**

Administration of antidotes is a critical step in managing a nerve agent victim; however, this may be difficult to achieve in the Hot Zone, because the antidotes may not be readily available, and procedures or policies for their administration while in the Hot Zone may be lacking. If the military Mark I kits containing autoinjectors are available, they provide the best way to administer the antidotes. One autoinjector automatically delivers 2 mg atropine and the other automatically delivers 600 mg 2-PAM Cl. Otherwise, administer antidotes as described in Table 3.

**Victim Removal**

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Dependant upon available resources, triage of remaining victims should be performed. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety. Should there be a large number of casualties, and if decontamination resources permit, separate decontamination corridors should be established for ambulatory and non-ambulatory victims.
### Table 3. Recommendations for Nerve Agent Therapy — Prehospital Management.

<table>
<thead>
<tr>
<th>Patient Age</th>
<th>Antidotes(^1)</th>
<th>Other Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mild/Moderate Symptoms(^2)</td>
<td>Severe Symptoms(^3)</td>
</tr>
<tr>
<td>Infant (0 - 2 yrs)</td>
<td>Atropine: 0.05 mg/kg IM; 2-PAM Cl: 15 mg/kg IM</td>
<td>Atropine: 0.1 mg/kg IM; 2-PAM Cl: 25 mg/kg IM</td>
</tr>
<tr>
<td>Child (2 - 10 yrs)</td>
<td>Atropine: 1 mg IM; 2-PAM Cl: 15 mg/kg IM</td>
<td>Atropine: 2 mg IM; 2-PAM Cl: 25 mg/kg IM</td>
</tr>
<tr>
<td>Adolescent (&gt;10 yrs)</td>
<td>Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IM</td>
<td>Atropine: 4 mg IM; 2-PAM Cl: 25 mg/kg IM</td>
</tr>
<tr>
<td>Adult</td>
<td>Atropine: 2 to 4 mg IM; 2-PAM Cl: 600 mg IM</td>
<td>Atropine: 6 mg IM; 2-PAM Cl: 1800 mg IM</td>
</tr>
<tr>
<td>Elderly, frail</td>
<td>Atropine: 1 mg IM; 2-PAM Cl: 10 mg/kg IM</td>
<td>Atropine: 2 to 4 mg IM; 2-PAM Cl: 25 mg/kg IM</td>
</tr>
</tbody>
</table>

1. 2-PAMCl solution needs to be prepared from the ampule containing 1 gram of desiccated 2-PAMCl: inject 3 ml of saline, 5% distilled or sterile water into ampule and shake well. Resulting solution is 3.3 ml of 300 mg/ml.
2. Mild/Moderate symptoms include localized sweating, muscle fasciculations, nausea, vomiting, weakness, dyspnea.
3. Severe symptoms include unconsciousness, convulsions, apnea, flaccid paralysis.

### Decontamination Zone

Rapid decontamination is critical to prevent further absorption by the patient and to prevent exposure to others. Decontaminable gurneys and back boards should be used if possible when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The Chemical Resuscitation Device is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

### Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see Rescuer Protection under Hot Zone, above).
**ABC Reminders**

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Antidote administration may be required to allow ventilation. Suction oral and bronchial secretions. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control heavy bleeding, if present.

**Antidotes**

Administer antidotes if they have not been administered. If possible, a system should be employed to track antidotes administered. If atropine was previously administered and signs and symptoms have not diminished within 5 to 10 minutes, give a second dose of atropine (2 mg for adults or 0.05 to 0.1 mg/kg for children) (see Antidotes under Hot Zone, Table 3).

**Basic Decontamination**

The eyes must be decontaminated within minutes of exposure to liquid nerve agent to limit injury. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. There is no need to flush the eyes following exposure to nerve agent vapor. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, a thorough shower with soap and water should be used. However, if water supplies are limited, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution, or absorbent powders such as flour, talcum powder, or Fuller’s earth. If exposure to vapor only is certain, remove outer clothing and wash exposed skin with soap and water or 0.5% sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, do not induce emesis. If the victim is alert and able to swallow, immediately administer a slurry of activated charcoal.

**Transfer to Support Zone**

As soon as basic decontamination is complete, move the victim to the Support Zone.

**Support Zone**

All victims must be decontaminated properly before entering the Support Zone (see Decontamination Zone, above).
**ABC Reminders**

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. **In a severely exposed casualty (unconscious, gasping, or not breathing), the antidotes will be required to allow ventilation.** Suction oral and bronchial secretions. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.

**Antidotes**

Administer antidotes if they have not been administered (see *Antidotes* under Hot Zone, Table 3). Administer atropine (2 mg for adults and 0.05 to 0.1 mg/kg for children) every 5 to 10 minutes until dyspnea, resistance to ventilation, and secretions are minimized.

**Additional Decontamination**

In cases of ingestion, **do not induce emesis.** If the victim is alert and able to swallow, immediately administer a slurry of activated charcoal if not given previously.

**Advanced Treatment**

Intubate the trachea in cases of coma or respiratory compromise, or to facilitate removal of excessive pulmonary secretions. When the patient’s condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so. Frequent suctioning of the airways will be necessary to remove mucous secretions. When possible, atropine and 2-PAM Cl should be given under medical supervision to symptomatic patients who have known or strongly suspected nerve agent toxicity (see *Antidote* sections, above).

Patients who are comatose, hypotensive, or seizing or have cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols. Diazepam (5 to 10 mg in adults and 0.2 to 0.5 mg/kg in children) should be used to control convulsions. Lorazepam or other benzodiazepines may be used but barbiturates, phenytoin, and other anticonvulsants are not effective.

**Transport to Medical Facility**

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.
Nerve Agents

Emergency Department Management

Patients whose skin or clothing is contaminated with liquid nerve agent can contaminate rescuers by direct contact or through off-gassing vapor.

Nerve agents are extremely toxic and can cause death within minutes to hours after exposure from respiratory failure.

Atropine and pralidoxime (2-PAM Cl) are antidotes for nerve agent toxicity; however, pralidoxime must be administered within minutes to a few hours following exposure (depending on the specific agent) to be effective. Treatment consists of supportive measures and repeated administration of antidotes.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

**ABC Reminders**

Evaluate and support the airway, breathing, and circulation. If the patient is apneic, give antidotes immediately (see Antidote section below). Intubate the trachea in cases of respiratory compromise. Suctioning may be required for excessive bronchial secretions. If the patient's condition precludes intubation, surgically create an airway. Antidote administration may be required to allow ventilation.

**Personal Protection**

If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can only take place inside the hospital if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see Rescuer Protection under Hot Zone, above).

**Basic Decontamination**

Patients who are able and cooperative may assist with their own decontamination. Remove and double bag contaminated clothing and all personal belongings.

For patients exposed to nerve agent vapor only, remove outer clothing and wash exposed areas including the head and hair with soap and water. For patients exposed to liquid agent, remove all clothing and wash entire body and hair with soap and water or 0.5% hypochlorite followed by a water rinse.
Irrigate exposed eyes with plain water or saline for about 5 to 10 minutes (see Basic Decontamination under Decontamination Zone, above). Remove contact lenses if present and easily removable without additional trauma to the eye.

In cases of ingestion, do not induce emesis. If the patient is able to swallow, immediately administer a slurry of activated charcoal if not given previously. (More information is provided in Ingestion Exposure above.)

**Treatment Area**
All patients should undergo decontamination before entering the treatment area (see Decontamination Area, above).

**ABC Reminders**
Evaluate and support the airway, breathing, and circulation (as in ABC Reminders, above). Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

**Triage**
Patients who are conscious and have full muscular control will need minimal care. Patients who may have been exposed to liquid must be kept under observation for at least 18 hours.

Patients with a history of possible exposure to vapor only (with no possibility of liquid exposure) who have no signs of exposure by the time they reach the medical facility have not been exposed (because these effects occur within seconds to minutes after exposure). They can be discharged.

**Antidotes and Other Treatments**
Patients exposed to vapor who have miosis and rhinorrhea will need no care unless (a) they have eye or head pain or nausea and vomiting; under these circumstances topical atropine or homatropine in the eye should relieve the symptoms and the patient can be discharged within an hour or so; or (b) the rhinorrhea is very severe; under these circumstances, atropine IM (2 mg in adults and 0.05 mg/kg in children) should relieve this and the patient can be discharged in an hour or so. Topical atropine and homatropine should not be used routinely for miosis because they cause visual impairment for about 24 hours. See Table 4 for other antidote and treatment recommendations.
Table 4. Recommendations for Nerve Agent Therapy – Emergency Department Management.

<table>
<thead>
<tr>
<th>Patient Age</th>
<th>Antidotes</th>
<th>Other Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mild/Moderate Symptoms¹</td>
<td>Severe Symptoms²</td>
</tr>
<tr>
<td>Infant (0 - 2 yrs)</td>
<td>Atropine: 0.05 mg/kg IM or 0.02 mg/kg IV; 2-PAM Cl: 15 mg/kg IV slowly</td>
<td>Atropine: 0.1 mg/kg IM or 0.02 mg/kg IV; 2-PAM Cl: 15 mg/kg IV slowly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assisted ventilation as needed.</td>
</tr>
<tr>
<td></td>
<td>(Repeat atropine (2 mg IM or 1 mg IM for infants) at 5 - 10 minute intervals until secretions have diminished and breathing is comfortable or airway resistance has returned to near normal.)</td>
<td></td>
</tr>
<tr>
<td>Child (2 - 10 yrs)</td>
<td>Atropine: 1 mg IM; 2-PAM Cl: 15 mg/kg IV slowly</td>
<td>Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IV slowly</td>
</tr>
<tr>
<td>Adolescent (&gt;10 yrs)</td>
<td>Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IV slowly</td>
<td>Atropine: 4 mg IM; 2-PAM Cl: 15 mg/kg IV slowly</td>
</tr>
<tr>
<td>Adult</td>
<td>Atropine: 2 to 4 mg IM; 2-PAM Cl: 15 mg/kg (1 g) IV slowly</td>
<td>Atropine: 6 mg IM; 2-PAM Cl: 15 mg/kg (1 g) IV slowly</td>
</tr>
<tr>
<td>Elderly, frail</td>
<td>Atropine: 1 mg IM; 2-PAM Cl: 5 to 10 mg/kg IV slowly</td>
<td>Atropine: 2 mg IM; 2-PAM Cl: 5 to 10 mg/kg IV slowly</td>
</tr>
</tbody>
</table>

1. **Mild/Moderate symptoms** include localized sweating, muscle fasciculations, nausea, vomiting, weakness, dyspnea.
2. **Severe symptoms** include unconsciousness, convulsions, apnea, flaccid paralysis.

**Inhalation Exposure**

Ventilatory support is essential. Following low-dose exposure, administration of antidotes and supplemental oxygen may be adequate. Suction secretions from the nose, mouth, and
Nerve Agents

respiratory tract. Marked resistance to ventilation is expected due to bronchial constriction and spasm. Resistance lessens after administration of atropine.

**Skin Exposure**

Skin must be decontaminated within minutes following exposure to nerve agent. Because of the high toxicity, rapid absorption, and volatility, it is unlikely that a patient brought to a medical facility will have nerve agent on the skin. However, some nerve agent may remain in the hair or clothing and should be decontaminated if not previously done (see Basic Decontamination, above).

**Eye Exposure**

Severity of miosis cannot be used as an indicator of the amount of exposure or effectiveness of the antidotes. Maximum miosis may not occur until an hour or more after exposure. If severe eye pain or nausea and vomiting occur, protect eyes from bright light and consider topical administration of atropine or homatropine. Test visual acuity.

**Ingestion Exposure**

*Do not induce emesis* because of the risk of pulmonary aspiration of gastric contents which may result from abrupt respiratory arrest, seizures, or vomiting. If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal. If the patient’s condition is evaluated within 30 minutes after ingestion, consider gastric lavage. (Gastric contents should be considered potentially hazardous by skin contact or inhalation and should be quickly isolated.)

**Laboratory Tests**

Routine laboratory studies for all admitted patients include CBC, glucose, and serum electrolyte determinations. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for severe exposures. Symptomatic and asymptomatic patients suspected of significant exposure should have determinations of red blood cell (RBC) cholinesterase activity, the most useful test for nerve agent poisoning. Severe symptoms of toxicity are usually present when more than 70% of RBC cholinesterase is inhibited. However, there is no correlation between cholinesterase activity and severity of topical signs and symptoms (e.g., miosis, rhinorrhea, dyspnea). If this test is not available, plasma cholinesterase can be measured.

**Disposition and Follow-up**

Patients exposed to nerve agent vapor who have only miosis and/or mild rhinorrhea when they reach the medical facility do not need to be admitted. All other patients who have had exposure to nerve agent should be hospitalized and observed closely.
## Delayed Effects

Effects from skin exposure to liquid nerve agent may not develop for up to 18 hours following exposure. Patients who have inhalation exposure and who complain of chest pain, chest tightness, or cough should be observed and examined periodically for 6 to 12 hours to detect delayed-onset bronchitis, pneumonia, pulmonary edema, or respiratory failure.

Formaldehyde poisoning can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, headache, and sensory and perceptual changes.

## Follow-up

Patients who have severe exposure should be evaluated for persistent CNS sequelae. Patients should be advised to avoid organophosphate insecticide exposure until sequential RBC cholinesterase activity (measured at weekly to monthly intervals) has stabilized in the normal range, a process that may take 3 to 4 months after severe poisoning (see *Follow-up Instructions*, included with the *Nerve Agent Patient Information Sheet* below).

## Reporting

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.
Nerve Agents
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to nerve agents.

What are nerve agents?
Nerve agents are chemical warfare agents, similar to but much more potent than organophosphate insecticides. They are colorless to amber-colored, tasteless liquids that may evaporate to create a gas. GB and VX are odorless, while GA has a slight fruity odor, and GD has a slight camphor odor.

What immediate health effects can result from exposure to nerve agents?
Nerve agents are extremely toxic chemicals that attack the nervous system. As little as one drop to a few milliliters of nerve agent contacting the skin can cause death within 15 minutes. Nerve agent exposure can cause runny nose, sweating, blurred vision, headache, difficulty breathing, drooling, nausea, vomiting, muscle cramps and twitching, confusion, convulsions, paralysis, and coma. Symptoms occur immediately if you inhale nerve agent vapor but may be delayed for several hours if you get nerve agent liquid on your skin.

Can nerve agent poisoning be treated?
There are antidotes for nerve agent poisoning but they must be administered quickly after exposure. Immediate decontamination is critical and hospitalization may be needed.

Are any future health effects likely to occur?
Complete recovery may take several months. After a severe exposure with prolonged seizures, permanent damage to the central nervous system is possible.

What tests can be done if a person has been exposed to nerve agents?
Activity of a blood enzyme called acetylcholinesterase can be measured to assess exposure and recovery.

Where can more information about nerve agents be found?
More information about nerve agents can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
  dizziness, loss of coordination, loss of memory
  coughing, wheezing, or shortness of breath
  nausea, vomiting, cramps, or diarrhea
  muscle weakness or twitching
  blurred vision

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. ________________ in the practice of ________________.
  When you call for your appointment, please say that you were treated in the Emergency Department at ________________ Hospital by ________________ and were advised to be seen again in ________ days.
[ ] Return to the Emergency Department/ ________________ Clinic on (date) ____________ at ________________ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for ________ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: ________________
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ________________

[ ] Other instructions: ________________
  ________________
  ________________

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: ________________ or ________________, or by checking out the following Internet Web sites: ________________.

Signature of patient __________________________ Date __________

Signature of physician __________________________ Date __________
Ethylene Glycol
CAS 107-21-1

Synonyms include 1,2-dihydroxyethane, 1,2-ethanediol, 2-hydroxyethanol, ethylene alcohol, glycol, glycol alcohol, monoethylene glycol, and ethylene dihydrate. Ethylene glycol is sold under a variety of brand names as automobile radiator antifreeze. It should not be confused with ethylene glycol ethers, which are a different group of chemicals.

- Persons exposed to ethylene glycol do not pose a significant risk of secondary contamination to response personnel outside the Hot Zone.
- Ethylene glycol is a clear, odorless, slightly viscous liquid. It is combustible and has a low vapor pressure. Odor does not provide any warning of hazardous concentrations.
- Ingestion is the most important exposure route. Dermal absorption is negligible and does not contribute significantly to systemic toxicity.
- Significant inhalation exposure does not occur at room temperature, but respiratory tract irritation is possible when the liquid is heated, agitated, or sprayed.

Description
Ethylene glycol is a clear, odorless, slightly viscous liquid with a sweet taste. It is combustible and has a low vapor pressure. Ethylene glycol is a very useful industrial compound because of its low freezing point and high boiling point. It is widely available as automotive antifreeze; in that application, it is often mixed with a yellow-green fluorescent.

Routes of Exposure

Inhalation
Toxic inhalation of ethylene glycol is unlikely at room temperature because of the chemical’s low volatility, but can occur when the liquid is heated, agitated, or sprayed. Ethylene glycol is odorless and thus, odor does not provide any warning of hazardous concentrations. Ethylene glycol vapor is lighter than air.

Children exposed to the same levels of ethylene glycol as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios.

Skin/Eye Contact
Ethylene glycol is only mildly irritating to mucous membranes or skin and is slowly and poorly absorbed through the skin.
**Ingestion**
Ethylene glycol is rapidly absorbed following ingestion, which is the predominant route of exposure. Ingestion of ethylene glycol leads to systemic toxicity beginning with CNS effects, followed by cardiopulmonary effects, and finally renal failure.

**Sources/ Uses**
Ethylene glycol is produced commercially in large amounts and widely used as an antifreeze and de-icer. It is also used in chemical synthesis, including synthesis of plastics, films, and solvents. Ethylene glycol can be found in many consumer products, including automotive antifreeze, hydraulic brake fluids, inks used in some stamp pads, ballpoint pens, solvents, paints, plastics, and solar energy systems.

**Standards and Guidelines**
ACGIH ceiling limit = 100 mg/m³ (39 ppm)

**Physical Properties**
*Description:* odorless, colorless, slightly viscous, sweet-tasting liquid. Many antifreeze products also contain yellow-green fluorescent dyes and a bitter taste to reduce the chances of accidental ingestion.

*Warning properties:* **odor is inadequate to protect against acute inhalation exposure**

*Molecular weight:* 62.07 daltons

*Boiling point:* (760 mm HG): 387 °F (198 °C)

*Freezing point:* 8.6 °F (-13 °C)

*Specific gravity:* 1.11 at 68 °F (20 °C) (water = 1)

*Vapor pressure:* 0.06 mm Hg at 68 °F (20 °C)

*Gas density:* 0.092 (air = 1)

*Water solubility:* miscible with water; can absorb twice its weight of water

*Flammability:* 232 °F (111 °C)

*Flammable range:* 3.2% to 21.6% (concentration in air)

**Incompatibilities**
Ethylene glycol reacts with strong oxidizers and acids, including chromium trioxide, potassium permanganate, sodium peroxide, potassium dichromate, chlorosulfonic acid, sulfuric acid, perchloric acid, and diphosphorous pentasulfide.
Health Effects

- Ethylene glycol is only mildly irritating to skin and mucous membranes and is not absorbed well through the skin or by inhalation.
- Ingestion of ethylene glycol produces CNS depression which may be accompanied by nausea, vomiting, and abdominal cramps.
- Metabolites of ethylene glycol produce severe metabolic acidosis and damage to the brain, heart, and kidneys.
- Severe poisoning is potentially fatal if treatment is inadequate or delayed.

Acute Exposure

Ethylene glycol is a dehydrating agent and is mildly irritating to the skin and mucous membranes after prolonged contact.

Upon ingestion, it is rapidly absorbed (within 1 to 4 hours). Less than 20% is excreted unmetabolized; most is successively metabolized to very toxic compounds. A characteristic progression of toxic effects can be roughly divided into three stages, although overlap is possible:

**Stage 1:** From 30 minutes to 12 hours after exposure, unmetabolized ethylene glycol produces CNS depression, intoxication, and hyperosmolarity similar to that produced by ethanol.

**Stage 2:** From 12 to 48 hours, metabolites produce severe acidosis with compensatory hyperventilation. The acidosis is primarily the result of an increase in glycolic acid, although glyoxylic, oxalic, and lactic acids also contribute in small part. Calcium oxalate crystals are deposited in the brain, lungs, kidneys, and heart.

**Stage 3:** From 24 to 72 hours, the direct toxic effects of ethylene glycol metabolites in the kidneys can cause acute renal failure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Unmetabolized ethylene glycol can produce an ethanol-like intoxication. Symptoms include dizziness, ataxia, disorientation, irritation, restlessness, nystagmus, headache, slurred speech, and somnolence. Severe poisoning can lead to coma and death.
Cerebral edema and deposits of calcium oxalate crystals in the walls of small blood vessels contribute to the CNS toxicity.

**Renal**
Kidney toxicity is a major consequence of ethylene glycol absorption. Acute cell death (i.e., tubular necrosis) and kidney failure can occur within 24 to 28 hours as a result of the direct cytotoxic action of oxalic, glyoxylic, and glycolic acids or due to precipitation of calcium oxalate crystals in the renal tubules. Focal tubular degeneration, atrophy, and tubular interstitial inflammation have also been observed. Renal damage, if untreated, can lead to acute oliguric renal failure and can necessitate long-term hemodialysis. The resulting hyperkalemia can cause life-threatening cardiac dysrhythmias.

**Metabolic**
An osmolar gap can be present early after ingestion; this represents unmetabolized ethylene glycol. It will resolve as metabolism proceeds. A severe metabolic acidosis with elevated anion gap develops as metabolism to glycolic, glyoxylic, and oxalic acids occurs. Large quantities of sodium bicarbonate can be administered without affecting the acidosis because of the ongoing generation of acid metabolites. However, overzealous alkanization could cause ionized calcium deficits. Hypocalcemia and tetany can occur as a result of calcium oxalate deposition.

**Respiratory**
Very high levels of inhaled ethylene glycol vapors can irritate the upper respiratory tract. Levels higher than 80 ppm produce intolerable respiratory discomfort and cough. Ethylene glycol’s CNS effects can cause respiratory depression, and metabolic acidosis can result in hyperventilation and respiratory alkalosis. Aspiration of ethylene glycol following ingestion can result in pulmonary edema.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

**Cardiovascular**
Cardiovascular effects include tachycardia, dysrhythmias, congestive heart failure, hypertension or hypotension, and circulatory collapse. Hyperkalemia resulting from kidney toxicity can cause life-threatening cardiac dysrhythmias.

**Gastrointestinal**
Nausea and vomiting can be present in the initial stage of intoxication.

**Dermal**
Ethylene glycol is a minor skin irritant, although a few cases of allergic contact dermatitis have been reported.
Ethylene Glycol

**Ocular**
Mild ocular irritation may occur after contact with ethylene glycol.

**Potential Sequelae**
Renal failure can occur 24 to 72 hours after an acute ingestion and can necessitate hemodialysis. Some loss of renal function can be permanent. There are infrequent reports of cranial nerve palsies (e.g., facial palsy, hearing loss, visual disturbances) or peripheral neuropathy one or more weeks after an acute poisoning.

**Chronic Exposure**
There are only a few reports on the adverse health effects in humans of chronic exposure to ethylene glycol. Irritation of the throat, mild headache, low backache, loss of consciousness, and nystagmus have been reported. These symptoms were resolved when the exposure ceased.

**Carcinogenicity**
The U.S. Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC) and EPA have not classified ethylene glycol in terms of its carcinogenic potential. Studies in humans and animals have not yielded any associations between ethylene glycol exposure and the incidence of any cancer.

**Reproductive and Developmental Effects**
Ethylene glycol is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Some experimental animal studies of exposure to glycols have shown teratogenicity, specifically craniofacial and neural tube closure defects and skeletal dysplasia. Human effects are not known or documented.
### Prehospital Management

- Persons exposed to ethylene glycol liquid or vapor do not pose significant risks of secondary contamination to rescuers.

- Ethylene glycol is a CNS depressant, similar to ethanol. Its metabolites are toxic and cause profound metabolic acidosis, cerebral edema, cardiovascular collapse, acute renal failure, and possibly death.

- Timely treatment is effective and consists of supportive care, hemodialysis, and administration of a specific antidote.

<table>
<thead>
<tr>
<th>Hot Zone</th>
<th>Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rescuer Protection</td>
<td>Ethylene glycol is a mild respiratory tract irritant. It is not well absorbed through the lungs or skin.</td>
</tr>
<tr>
<td></td>
<td>Respiratory protection: Respirable concentrations of ethylene glycol are significant only when the liquid is heated (e.g., during a fire) or aerosolized. Positive-pressure, self-contained breathing apparatus (SCBA) is recommended under these circumstances.</td>
</tr>
<tr>
<td></td>
<td>Skin protection: Chemical-protective clothing is generally not required because ethylene glycol (whether vapor or liquid) is only a minor skin irritant and is absorbed poorly and slowly through the skin.</td>
</tr>
<tr>
<td>ABC Reminders</td>
<td>Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.</td>
</tr>
<tr>
<td>Victim Removal</td>
<td>If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.</td>
</tr>
<tr>
<td></td>
<td>Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.</td>
</tr>
</tbody>
</table>
### Decontamination Zone

Victims exposed only to ethylene glycol vapor who have no skin or eye irritation do not need to undergo decontamination. These individuals may be transferred immediately to the Support Zone. Others can undergo decontamination, but even severely exposed victims need only external decontamination (see Basic Decontamination below) because ingestion is the major toxic exposure route.

### Rescuer Protection

Ethylene glycol acts as a systemic toxicant only when ingested. Rescuers need not take any special precautions.

### ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

### Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of recent ingestion (less than one hour), in an alert, awake patient, emesis may be induced with ipecac. For other patients, perform gastric lavage. **Early treatment is important to reduce absorption of ethylene glycol and subsequent production of highly toxic metabolites.** Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of multiple chemical ingestion. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.
### Transfer to Support Zone
As soon as basic decontamination is complete, move the victim to the Support Zone.

### Support Zone
Victims pose no serious risk of secondary contamination to rescuers. Therefore, Support Zone personnel require no specialized protective gear.

### ABC Reminders
Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

### Additional Decontamination
Continue irrigating exposed skin and eyes, as appropriate.

In cases of recent ingestion (less than one hour), in an alert, awake patient, emesis may be induced with ipecac. For other patients, perform gastric lavage (if the patient has not already undergone gastric lavage in the Decontamination Zone). **Early treatment is important to reduce absorption of ethylene glycol and subsequent production of highly toxic metabolites.** Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of multiple chemical ingestion. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

### Advanced Treatment
In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

A pH of less than 7.0 and a serum bicarbonate of less than 7 mmol/L are common with severe ethylene glycol intoxication. Treatment of this metabolic acidosis may be difficult. Liberal use of sodium bicarbonate solution is appropriate to correct the acidemia.

### Transport to Medical Facility
Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.
Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Vomit containing ethylene glycol requires no chemical safety precautions since there is little exposure potential or risk of secondary contamination.

**Multi-Casualty Triage**

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence suggesting ingestion of ethylene glycol should be rapidly transported to a medical facility for evaluation. All patients who have ingested more than a taste or sip of ethylene glycol, even if asymptomatic, should be evaluated in a hospital where appropriate laboratory studies can be carried out. Delays in treatment can result in more severe toxicity and potentially irreversible damage to major organ systems.

Patients with a history suggesting insignificant exposure and who have no symptoms of ethylene glycol toxicity may be discharged from the scene after their names, addresses, and telephone numbers have been recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).
Emergency Department Management

- Patients exposed to ethylene glycol liquid or vapor pose no risk of secondary contamination to hospital personnel.

- Ethylene glycol is only mildly irritating to skin and mucous membranes and is not absorbed well through the skin or by inhalation.

- Ingestion of ethylene glycol causes CNS depression. If the patient is not treated, ethylene glycol’s metabolites can cause acidosis, hyperventilation, and renal failure requiring hemodialysis.

- Timely treatment is effective and consists of supportive care, hemodialysis, and administration of a metabolic antidote such as ethanol or 4-methylpyrazole (fomepizole).

Decontamination Area

Patients exposed to ethylene glycol do not require extensive decontamination. Remove contaminated clothing and personal belongings.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Emergency room personnel should examine children’s mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

A pH of less than 7.0 and a serum bicarbonate of less than 7 mmol/L are common with severe ethylene glycol intoxication. Treatment of this metabolic acidosis may be difficult. Liberal use of sodium bicarbonate solution is appropriate to correct the acidemia.
**Ethylene Glycol**

**Basic Decontamination**

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of substantial recent ingestion (less than 1 hour), where the patient is alert and awake, emesis can be induced with ipecac. In unconscious or symptomatic patients, consider gastric lavage if it can be administered within 1 hour of ingestion. Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of ingestion of multiple chemicals. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). Ethylene glycol is rapidly absorbed and little benefit is expected from these procedures if more than an hour has elapsed. Early antidotal treatment with ethanol or 4-methylpyrazole to prevent formation of toxic metabolites is the most effective intervention. (More information is provided in Antidotes and Other Treatments under Critical Care Area below)

**Critical Care Area**

**ABC Reminders**

Evaluate and support the airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

A pH of less than 7.0 and a serum bicarbonate of less than 7 mL/dL are common with severe ethylene glycol intoxication. Treatment of this metabolic acidosis may be difficult. Liberal use of sodium bicarbonate solution is appropriate to correct the acidemia.
Inhalation Exposure
Administer supplemental oxygen by mask to patients who have respiratory complaints.

Skin Exposure
In most cases, no further treatment is needed after washing. If irritation or allergic contact dermatitis occurs, treatment with emollient creams, antihistamines, or topical steroids might be indicated.

Eye Exposure
Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients with suspected severe corneal injuries.

Ingestion Exposure
In cases of substantial recent ingestion where the patient is alert and awake, emesis can be induced with ipecac. In unconscious or symptomatic patients, consider gastric lavage if it can be administered within 1 hour of ingestion. Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of ingestion of multiple chemicals. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g)

Antidotes and Other Treatments
Contact a medical toxicologist or a regional poison control center for assistance in evaluating the anion and osmolar gaps, and to decide whether antidotal therapy, intravenous sodium bicarbonate, or hemodialysis is needed.

In severe poisoning by ingestion, prompt administration of ethanol or another blocking agent (e.g., 4-methylpyrazole) prevents further metabolism of ethylene glycol. Rapid treatment with a blocking agent is very important; do not wait for symptoms to appear before treatment. Time elapsed between ingestion and treatment and the dose ingested are major factors of fatality.

Administration of thiamine and pyridoxine may aid metabolism of ethylene glycol to nontoxic products, but these compounds are less effective than ethanol or 4-methylpyrazole. Hemodialysis is indicated in cases of severe acidosis and/or renal dysfunction.

By competing with ethylene glycol as a substrate for alcohol dehydrogenase, ethanol inhibits the formation of toxic ethylene glycol metabolites. A medical toxicologist or the poison control center should be contacted to determine the proper dosage, which depends on many factors (e.g., age, degree of alcohol use by the victim, and effect on blood sugar). In general, the optimal
blood ethanol level is 100 to 150 mg/dL; this level should be attained quickly by administering 10% ethanol intravenously over 30 to 60 minutes.

Alternatively, ethanol can be administered orally with a 20% ethanol solution until a blood ethanol level of 100 to 150 mg/dL is reached. Patients previously treated with ipecac/charcoal cannot tolerate oral loading. The dosage must be adjusted if the patient is undergoing hemodialysis. Repeatedly monitor blood ethanol and glucose levels, as under dosing and overdosing of ethanol regularly occur; this can lead to hypoglycemia, especially in children.

An alternative to ethanol that also inhibits the action of alcohol dehydrogenase on ethylene glycol has recently become available in the United States. This drug, 4-methylpyrazole, has low toxicity and is easier to administer than ethanol. It is available as fomepizole (Antizol) in packages of 1.5 mL vials (concentration = 1 g/1 mL). Each vial is diluted to 100 mL with sodium chloride. Treatment consists of a 15-mg/kg loading dose followed in 12 hours by 10 mg/kg every 12 hours for four doses, then 15 mg/kg every 12 hours as long as indicated. Although fomepizole has been less widely used than ethanol, its use is rapidly increasing because of advantages over ethanol in terms of its predictable pharmacokinetics, ease of administration and lack of adverse effects.

**Laboratory Tests**

In all patients with known or suspected ethylene glycol poisoning, blood tests should be performed to measure blood glucose, serum electrolyte, calcium, BUN, creatinine, ethylene glycol, and ethanol levels. ABG levels and osmolarity should also be measured. These tests should be repeated as necessary to closely monitor the progression of toxic effects. Expected values depend on the time elapsed since the ingestion of ethylene glycol, so this must be considered in interpreting laboratory results.

Methanol levels should be measured in patients with elevated anion and osmolar gaps. Other conditions that can elevate anion and osmolar gaps include methanol poisoning and diabetic ketoacidosis.

Traditionally, a serum ethylene glycol level greater than 50 mg/dL has been associated with significant toxicity. Nevertheless, although the toxicokinetics are not well known, if enough time has passed for metabolism to toxic metabolites to
Ethylene Glycol

occur, significant poisoning can be present when serum ethylene glycol levels are less than 50 mg/dL.

Chest radiography and pulse oximetry (or ABG measurements) are recommended for patients with respiratory complaints.

A cardiac monitor should be placed to look for QT prolongation, an indication of hypocalcemia.

Calcium oxalate crystals can be seen on microscopic examination of the urine, but their absence does not preclude ethylene glycol poisoning. A Woods (UV) lamp test of the urine detects the fluorescent compound, fluorescein, which is commonly added as a coloring agent to automotive antifreezes. Urine fluorescence cannot be relied upon to diagnose the presence or absence of ethylene glycol ingestion. If present, it supports the diagnosis.

Disposition and Follow-up

All patients with ethylene glycol poisoning should be evaluated and treated without delay. Even patients with no or mild symptoms should undergo appropriate blood and urine tests if they have a history of significant ingestion. Patients requiring ethanol infusions, 4-methylpyrazole, or hemodialysis should be admitted to an intensive care unit.

Delayed Effects

Renal effects typically take 24 to 72 hours to develop. Hemodialysis to treat acute renal failure is essential.

Patient Release

Patients who have no history suggestive of significant exposure and who have no symptoms or laboratory findings of ethylene glycol poisoning may be discharged with instructions to seek medical care promptly if symptoms develop (see the Ethylene Glycol—Patient Information Sheet below).

Follow-up

Obtain the name of the patient’s primary care physician so that the hospital can send a copy of the ED visit to the patient’s doctor.

In cases of severe exposure, follow-up laboratory evaluation of renal function should be arranged and neurologic examination for post-hypoxic or oxalate crystal injury is recommended.

Patients who have corneal lesions should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.
Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.
Ethylene Glycol (C₂H₆O₂)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to ethylene glycol.

What is ethylene glycol?
Ethylene glycol is a colorless, syrupy liquid used in antifreeze solutions and as a solvent in making certain chemicals. When used in antifreeze solutions, it is usually mixed with a fluorescent yellow dye to create a bright yellow color. Ethylene glycol is odorless and can have a sweet taste.

What immediate health effects can be caused by exposure to ethylene glycol?
Drinking even small amounts (from 1 to 3 ounces) of ethylene glycol can result in damage to the kidneys if the poisoning is not treated. Consumption of larger quantities can be fatal. Skin contact with liquid ethylene glycol or breathing low levels of vapors in the air is generally not harmful or causes only minor irritation. Very few individuals develop an allergic rash when the liquid is on their skin.

Can ethylene glycol poisoning be treated?
Persons who have swallowed large amounts of ethylene glycol should be hospitalized. In severe exposures, special antidotes and hemodialysis might be needed. Treatment is generally successful if begun within 3 hours of swallowing, and most people recover completely after treatment.

Are any future health effects likely to occur?
Kidney damage is the most common effect if severe exposure by ingestion is not treated.

What tests can be done if a person has been exposed to ethylene glycol?
Ethylene glycol and its breakdown products can be measured in blood and urine. After significant exposure, diagnostic tests are needed to measure kidney function and the levels of the toxicant in the blood.

Where can more information about ethylene glycol be found?
More information about ethylene glycol can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow only the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- headache, dizziness, or a feeling of intoxication
- nausea, vomiting, or abdominal cramps.

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. ___________ in the practice of ___________.

When you call for your appointment, please say that you were treated in the Emergency Department at ___________ Hospital by ___________ and were advised to be seen again in _______ days.

[ ] Return to the Emergency Department/ ___________ Clinic on (date) ___________ at ___________ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: ______________________________

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ______________________________

[ ] Other instructions: ______________________________

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: ________________ or ________________, or by checking out the following Internet Web sites: ________________; ________________.

Signature of patient ______________________________ Date ____________

Signature of physician ______________________________ Date ____________