The general population is primarily exposed to nitrogen oxides by breathing in air. People who live near combustion sources such as coal burning power plants or areas with heavy motor vehicle use may be exposed to higher levels of nitrogen oxides.
ouseholds that burn a lot of wood or use kerosene heaters and gas stoves tend to have higher levels of nitrogen oxides in them when compared to houses without these appliances.
Nitric oxide and nitrogen dioxide are found in tobacco smoke, so people who smoke or breathe in second-hand smoke may be exposed to nitrogen oxides.
Workers employed in facilities that produce nitric acid or certain explosives like dynamite and trinitrotoluene (TNT), as well as workers involved in the welding of metals may breath in nitrogen oxides during their work.

How can nitrogen oxides affect my health?

Low levels of nitrogen oxides in the air can irritate your eyes, nose, throat, and lungs, possibly causing you to cough and experience shortness of breath, tiredness, and nausea. Exposure to low levels can also result in fluid build-up in the lungs 1 or 2 days after exposure. Breathing high levels of nitrogen oxides can cause rapid burning, spasms, and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of body tissues, a build-up of fluid in your lungs, and death.

If you were to come into skin or eye contact with high concentrations of nitrogen oxide gases or nitrogen dioxide liquid, you would likely experience serious burns.

We do not know if exposure to nitrogen oxides will result in reproductive effects in humans.

How likely are nitrogen oxides to cause cancer?

The Department of Health and Human Services (DHHS), the International Agency for Research on ancer (IARC), and the EPA have not classified nitrogen oxides for potential carcinogenicity.

How does nitrogen oxides affect children?

Children would probably be affected by exposure to nitrogen oxides in the same ways as adults. But we do not know whether children differ from adults in their susceptibility to nitrogen oxides.

Exposure of pregnant animals to nitrogen oxides has resulted in toxic effects in developing fetuses. Nitrogen oxides have also caused changes in the genetic material of animal cells. But we do not know if exposure to nitrogen oxides might cause developmental effects in humans.

How can families reduce the risk of exposure to nitrogen oxides?

Families with indoor gas stoves, space heaters, or indoor cigarette smoke can minimize indoor exposure to nitrogen oxides by periodically allowing fresh outdoor air into the home. Farm families should not allow children to play near silos that contain silage.

Is there a medical test to show whether I've been exposed to nitrogen oxides?

Specific tests for the presence of nitrogen oxides in blood or urine are not generally useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether damage has been done to your respiratory airways. Some of these tests may be done at the doctor's office, others may require a clinic or hospital that have specialized equipment.

Has the federal government made recommendations to protect human health?

The EPA has established that the average concentration of nitrogen dioxide in ambient air in a calendar year should not exceed 0.053 parts of nitrogen dioxide per million parts of air (0.053 ppm).

The Occupational Safety and Health Administration (OSHA) has set a limit of 25 ppm of nitric oxide in workplace air during an 8-hour workday, 40-hour work week. OSHA has also set a 15-minute exposure limit of 5 ppm for nitrogen dioxide in workplace air.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2002. Managing Hazardous Materials Incidents. Volume III – Medical Management Guidelines for Acute Chemical Exposures: Nitrogen Oxides (/MMG/MMG.asp?id=394&tid=69) . Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE, Mailstop F-62
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)
Fax: 1-770-488-4178
Email: cdcinfo@cdc.gov (mailto:cdcinfo@cdc.gov)

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

Information line and technical assistance:

Phone: 888-422-8737
FAX: (770)-488-4178

To order toxicological profiles, contact:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

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Contact CDC: 800-232-4636 / TTY: 888-232-6348

Agency for Toxic Substances & Disease Registry

Medical Management Guidelines for Hydrogen Chloride

(HCl)

CAS# 7647-01-0
UN# 1050 (anhydrous), 1789 (solution), 2186 (refrigerated liquefied gas)

(/MHMI/mmg173.pdf) **PDF Version, 66 KB** (/MHMI/mmg173.pdf)

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.

General Information

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.

Carcinogenicity

Hydrogen chloride has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

The reproductive hazards of hydrogen chloride to humans are unknown. Few studies have been directed at reproductive effects in experimental animals exposed to hydrogen chloride. No data 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.

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

Victims 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.)

onsider 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 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.

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 ingestion, **do not induce emesis. 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.

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.

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).

Emergency Department Management

- 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.

Eye Exposure

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.

Ingestion Exposure

Do not induce emesis. Do not administer activated charcoal or attempt to neutralize stomach contents. 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.

Antidotes and Other Treatments

There is no antidote for hydrogen chloride poisoning.

Laboratory Tests

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).

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.

Patient Information Sheet

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

Print this handout only. (/MHMI/mmg173-handout.pdf#page=1) 19k

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 hydrogen chloride and hydrochloric acid?

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 and hydrochloric acid poisoning 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 and hydrochloric acid?

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.

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[ ] 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 _____

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE, Mailstop F-62
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)

Fax: 1-770-488-4178
Email: cdcinfo@cdc.gov (mailto:cdcinfo@cdc.gov)

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

Information line and technical assistance:
Phone: 888-422-8737
FAX: (770)-488-4178

To order toxicological profiles, contact:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

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Agency for Toxic Substances and Disease Registry, 4770 Buford Hwy NE, Atlanta, GA 30341
Contact CDC: 800-232-4636 / TTY: 888-232-6348

ATSDR Agency for Toxic Substances & Disease Registry

Medical Management Guidelines
for
Sulfur Dioxide
(SO_2)

(/MHMI/mmg116.pdf) **PDF Version, 54 KB** (/MHMI/mmg116.pdf)

CAS#: 7446-09-5
UN#: 1079

Synonyms include sulfur oxide, sulfurous acid anhydride, sulfurous anhydride, and sulfurous oxide.

- Persons exposed only to sulfur dioxide gas pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate rescuers by direct contact or through off-gassing of vapor.
- At room temperature, sulfur dioxide is a nonflammable, colorless gas that is heavier than air. Its strong, pungent odor and irritating properties usually provide adequate warning of its presence.
- Sulfur dioxide is readily absorbed through the upper respiratory tract; no data were located regarding dermal absorption. Sulfur dioxide is present in some foods; therefore, oral ingestion, although insignificant, is possible.

General Information

Description

At room temperature, sulfur dioxide is a nonflammable, colorless gas with a very strong, pungent odor. Most people can smell sulfur dioxide at levels of 0.3 to 1 ppm. It is handled and transported as a liquefied compressed gas. It easily dissolves in water. The liquid is heavier than water. Although sulfur dioxide does not burn in air, cylinders of compressed liquid can explode in the heat of a fire.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure to sulfur dioxide. The odor threshold is 5 times lower than the OSHA PEL (5 ppm). Most exposures are due to air pollution, and this has both short-term and chronic health consequences for people with lung disease. Inhaled sulfur dioxide readily reacts with the moisture of mucous membranes to form sulfurous acid (H_2SO_3), which is a severe irritant. People with asthma can experience increased airway resistance with sulfur dioxide concentrations of less than 0.1 ppm when exercising. Healthy adults experience increased airway resistance at 5 ppm, sneezing and coughing at 10 ppm, and bronchospasm at 20 ppm. Respiratory protection is required for exposures at or above 20 ppm. Exposures of 50 to 100 ppm may be tolerated for more than 30 to 60 minutes, but higher or longer exposures can cause death from airway obstruction. Sulfur dioxide is heavier than air; thus, exposure in poorly ventilated, enclosed, or low-lying areas can result in asphyxiation.

Children exposed to the same levels of sulfur dioxide 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 tature and the higher levels of sulfur dioxide found nearer to the ground and because they are slow to leave the site of an exposure.

Skin/Eye Contact

Exposures of 10 to 20 ppm cause irritation to mucous membranes. Direct contact with escaping compressed gas or liquid sulfur dioxide can produce severe corneal damage and frostbite injury to the skin. No data were located regarding dermal absorption.

Ingestion

Ingestion of sulfur dioxide is unlikely because it is a gas at room temperature. Sulfur dioxide is used in small amounts as a food and wine preservative. Highly sensitive asthmatic individuals can develop bronchospasm after eating foods or drinking wine preserved with sulfur dioxide or other sulfur preservatives.

Sources/Uses

Sulfur dioxide gas is released primarily from the combustion of fossil fuels (75% to 85% of the industrial sources), the smelting of sulfide ores, volcanic emissions, and several other natural sources. It is a U.S. Environmental Protection Agency (EPA) priority air pollutant, but has many industrial and agricultural uses. It is sometimes added as a warning marker and fire retardant to liquid grain fumigants. Approximately 300,000 tons are used each year to manufacture hydrosulfites and other sulfur-containing chemicals (40%); to bleach wood pulp and paper (20%); to process, disinfect, and bleach food (16%); for waste and water treatment (10%); in metal and ore refining (6%); and in oil refining (4%). Toxic amounts of sulfur dioxide can be released from the preservative chemical metabisulfite in the presence of water and acid.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 5 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 100 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: colorless gas at room temperature, colorless liquid when pressurized or cooled.

Warning properties: pungent odor is usually adequate to warn of acute exposure. Most people can detect sulfur dioxide at levels of 1 to 3 ppm (1 ppm is equivalent to 2.62 mg/m^3).

Molecular weight: 64.06 daltons

Boiling point (760 mm Hg): 14.0°F (-10.0°C)

Freezing point: -99.4°F (-72.7°C)

Vapor pressure: 2,538 mm Hg at 70.0EF (21.1°C)

Vapor density: 1.43 g/mL (water = 1.00)

Water solubility: soluble in water (11.3 g/100 mL at 68°F [20°C])

Flammability: nonflammable

Incompatibilities

Sulfur dioxide dissolves in water or steam to form sulfurous acid. Liquid sulfur dioxide corrodes iron,

brass, copper, and some forms of plastic and rubber. Many metals, including zinc, aluminum, cesium, and iron, incandesce and/or ignite in unheated sulfur dioxide. Sulfur dioxide reacts explosively when it comes in contact with sodium hydride. Sulfur dioxide ignites when it is mixed with lithium acetylene carbide diamino or lithium acetylide ammonia.

Health Effects

- Sulfur dioxide is severely irritating to the eyes, mucous membranes, skin, and respiratory tract. Bronchospasm, pulmonary edema, pneumonitis, and acute airway obstruction can occur.
- Inhalation exposure to very low concentrations of sulfur dioxide can aggravate chronic pulmonary diseases, such as asthma and emphysema. Certain highly sensitive asthmatics may develop bronchospasm when exposed to sulfur dioxide or sulfite-preserved foods.
- Sulfur dioxide reacts with water in the upper airway to form hydrogen, bisulfite, and sulfite, all of which induce irritation. As a result, reflex bronchoconstriction increases airway resistance.

Acute Exposure

Sulfur dioxide dissolves in the moisture on skin, eyes, and mucous membranes to form sulfurous acid, an irritant and inhibitor of mucociliary transport. Most of the inhaled sulfur dioxide is detoxified by the liver to sulfates and excreted in the urine. The bisulfite ion produced when sulfur dioxide reacts with water is likely to be the main initiator of sulphur dioxide-induced bronchoconstriction.

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

Respiratory

Sulfur dioxide respiratory irritation induces symptoms such as sneezing, sore throat, wheezing, shortness of breath, chest tightness, and a feeling of suffocation. Reflex laryngeal spasm and edema can cause acute airway obstruction. Bronchospasm, pneumonitis, and pulmonary edema can occur.

Some individuals are very susceptible to the presence of sulfur dioxide and overreact to concentrations which, in most people, elicit a much milder response. This hyperreactive response occurs the first time the individual is exposed and is therefore not an acquired immune or "hypersensitivity" response.

Acclimatization (a physiological adjustment of the individual to environmental changes) may also occur in up to 80% of exposed individuals. This is not necessarily beneficial although exposure may become less subjectively objectionable upon continuous or repeated exposure.

Asthmatics who are sensitive to sulfites in food can develop bronchospasm or an anaphylactoid reaction. Sulfur dioxide, along with other components of air pollution, can exacerbate chronic cardiopulmonary disease.

Exposure to high concentrations of sulfur dioxide 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 also may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Sulfur dioxide is a severe skin irritant causing stinging pain, redness, and blisters, especially on mucous membranes. Skin contact with escaping compressed gas or liquid sulfur dioxide can cause

frostbite and irritation injury.

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

Ocular

Exposure to low vapor concentrations of ethylene oxide can result in nausea and vomiting, which is often delayed.

Dermal

Skin contact with concentrated vapor or aqueous solutions of ethylene oxide may cause inflammation with redness of the skin, blisters, and crusted ulcerations. Initially, lesions are painless, but later can become painful and itchy. Skin reactions may be delayed 5 hours or more after exposure. Exposure to liquefied ethylene oxide can cause frostbite due to rapid evaporation and consequent cooling.

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

Ocular

Conjunctivitis and corneal burns can result from the irritant effect of sulfur dioxide vapor or escaping compressed gas, and from direct exposure to the liquid.

Gastrointestinal

Nausea, vomiting, and abdominal pain have been reported after inhalation exposure to moderate to high doses of sulfur dioxide.

Potential Sequelae

High-level acute exposures have resulted in pulmonary fibrosis, chronic bronchitis, and chemical bronchopneumonia with bronchiolitis obliterans. Bronchospasm can be triggered in individuals who have underlying lung disease, especially those who have asthma and emphysema. Rarely, new onset airway hyperreactivity, known as reactive airways dysfunction syndrome (RADS), develops in patients without prior bronchospasm.

Chronic Exposure

Chronic exposure can result in an altered sense of smell (including increased tolerance to low levels of sulfur dioxide), increased susceptibility to respiratory infections, symptoms of chronic bronchitis, and accelerated decline in pulmonary function. Chronic exposure may be more serious for children because of their potential longer life span.

Carcinogenicity

The International Agency for Research on Cancer (IARC) assigned sulfur dioxide to Group 3, not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects

Sulfur dioxide 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. There are no known reproductive or developmental effects of sulfur dioxide alone by any route of exposure. There is no conclusive evidence that sulfur dioxide is a genotoxin in humans.

Prehospital Management

- Persons exposed only to sulfur dioxide gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.
- Sulfur dioxide is severely irritating to the eyes, mucous membranes, skin, and respiratory tract. Exposure to high levels can cause pulmonary edema, bronchial inflammation and laryngeal spasm and edema with possible airway obstruction.
- There is no antidote for sulfur dioxide. 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 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 sulfur dioxide vapor is readily absorbed and is a potent respiratory tract irritant, causing mild irritation even at low doses. Escaping compressed gas or liquid sulfur dioxide on the skin or eyes can cause frostbite injury and irritation. Dermal absorption is negligible.

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

Skin Protection: Fully encapsulated chemical-protective clothing is recommended because sulfur dioxide can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization 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 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 sulfur dioxide 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 access for a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization 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.

Gently wash exposed skin and hair with copious amounts of water (preferably under a shower). 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 **5 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.

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). Victims who have undergone decontamination or have been exposed only to sulfur dioxide gas pose no serious risk 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.

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). Sulfur dioxide 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 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 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.

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., severe or persistent cough or dyspnea, 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 symptoms of mild or 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 sulfur dioxide gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.
- Sulfur dioxide is a severe irritant to the respiratory tract, eyes, mucous membranes, and skin. Exposure to high doses can cause pulmonary edema, bronchial inflammation, and laryngeal spasm and edema with possible airway obstruction.
- There is no antidote for sulfur dioxide. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and those exposed only to sulfur dioxide 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 fear in children, resulting in decreased compliance with further management efforts.

Emergency room personnel should examine children's mouth because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Provide supplemental oxygen if cardiopulmonary compromise is suspected. 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). Sulfur dioxide 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

Patients who are able may assist with their own decontamination.

Because sulfur dioxide 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 water (preferably under a shower). Double-bag the contaminated clothing and personal belongings. Sulfur dioxide reacts with body moisture to form sulfurous and sulfuric acids; therefore, chemical burns are likely. Handle burned skin with caution.

Flush exposed or irritated eyes with plain water or saline for at least **5 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, might be necessary to alleviate blepharospasm, and lid retractors might 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 the airways, 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. 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. 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). Sulfur dioxide 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.

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

Escaping compressed gas or liquid sulfur dioxide can cause frostbite. If frostbite is present, treat affected areas by rewarming in a water bath at a temperature of 104 to 107.6°F (40 to 42°C) for 20 to 30 minutes and continue until a flush has returned to the affected area. If chemical burns are present, 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 or until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have suspected severe corneal injuries.

Antidotes and Other Treatments

There is no antidote for sulfur dioxide. Treatment is supportive of respiratory function.

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 distress or significant skin burns.

Pulmonary injury might continue to evolve over 18 to 24 hours. Patients exposed by inhalation who are initially symptomatic should be observed carefully and reexamined periodically. Patients who develop pulmonary edema should be admitted to an intensive care unit.

Delayed Effects

Reactive airways dysfunction syndrome (RADS) is a non-immune-mediated asthma-like syndrome

that can develop after exposure to sulfur dioxide. Once established, this non-specific bronchial hyperreactivity might diminish over a few weeks or persist for years. Bronchospasm might be triggered in people who have chronic pulmonary diseases, such as asthma and emphysema.

atient Release

Patients who become totally asymptomatic in terms of pulmonary complaints in a 6- to 8-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 *Sulfur Dioxide-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).

Patient Information Sheet

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

Print this handout only. (/MHMI/mmg116-handout.pdf#page=1) 27k

What is ethylene oxide?

Sulfur dioxide is a colorless gas that has a strong, stinging odor. It has many industrial and agricultural uses. Most sulfur dioxide comes from burning fossil fuels containing sulfur and is a major part of air pollution. It is shipped and handled as a compressed gas in a special container. Some foods and wines are preserved with small amounts of sulfur dioxide that are safe for most people.

What immediate health effects can result from ethylene oxide exposure?

Inhaling sulfur dioxide causes irritation to the nose, eyes, throat, and lungs. Typical symptoms include sore throat, runny nose, burning eyes, and cough. Inhaling high levels can cause swollen lungs and difficulty breathing. Skin contact with sulfur dioxide vapor can cause irritation or burns. Liquid sulfur dioxide is very cold and can severely injure the eyes or cause frostbite if it touches the skin. Some people with asthma who are sensitive to sulfites might have an asthma attack if they eat foods preserved with sulfur dioxide or other sulfur-containing chemicals.

Can ethylene oxide poisoning be treated?

There is no antidote for sulfur dioxide, but its effects can be treated and most exposed persons recover completely. Persons who have inhaled large amounts of sulfur dioxide might 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, damage to the lungs can occur, causing asthma, pneumonia, and bronchitis. Permanent damage to the lungs is possible.

What tests can be done if a person has been exposed to ethylene oxide?
Specific tests for the presence of sulfur dioxide 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. Testing is not needed in every case.

Where can more information about ethylene oxide be found?
If the exposure happened at work, you might be required to contact your employer and the Occupational Safety and Health Administration (OSHA).

Employees may request a Health Hazard Evaluation from the National Institute for Occupational Safety and health (NIOSH).

More information about sulfur dioxide 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. 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.

Print instructions only. (/MHMI/mmg116-handout.pdf#page=2) 27k

[ ] 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 _____

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE, Mailstop F-62
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)
Fax: 1-770-488-4178
Email: cdcinfo@cdc.gov (mailto:cdcinfo@cdc.gov)

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

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Agency for Toxic Substances and Disease Registry, 4770 Buford Hwy NE, Atlanta, GA 30341
Contact CDC: 800-232-4636 / TTY: 888-232-6348

Agency for Toxic Substances & Disease Registry

Medical Management Guidelines for Nitrogen Oxides

(NO, NO_2, and others)

CAS# 10102-43-9, 10102-44-0
UN# 1660 (NO), 1067 (NO_2), 1975 (Mixture)

(/MHMI/mmg175.pdf) **PDF Version, 30 KB** (/MHMI/mmg175.pdf)

Synonyms for nitric oxide (NO) include mononitrogen monoxide and nitrogen monoxide. Synonyms for nitrogen dioxide (NO_2) include dinitrogen tetroxide, nitrogen peroxide, nitrogen tetroxide, and NTO. Synonyms for mixtures of nitrogen oxides include nitrogen fumes and nitrous fumes.

- Persons exposed only to nitrogen oxide gases do not pose substantial secondary contamination risks. Persons whose clothing is contaminated with liquid nitrogen oxides can secondarily contaminate others by direct contact or through off-gassing vapors.
- Nitric oxide and nitrogen dioxide are nonflammable liquids or gases; however, they will accelerate the burning of combustible materials. Odor generally provides an adequate warning of acute exposure providing the higher oxides (NO_2, N_2O_4 and N_2O_5) are present. Nitric oxide (NO) is odorless and nitrous oxide (N_2O) has only a very faint odor.
- The primary route of exposure to nitrogen oxides is by inhalation, but exposure by any route can cause systemic effects. Nitrogen oxides are irritating to the eyes, skin, mucous membranes, and respiratory tract. On contact with moisture, nitrogen dioxide forms a mixture of nitric and nitrous acids.

General Information

Description

Nitrogen oxides represent a mixture of gases designated by the formula NO_x. The mixture includes nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen trioxide (N_2O_3), nitrogen tetroxide (N_2O_4), and nitrogen pentoxide (N_2O_5). The toxicity of nitrous oxide (N_2O) or laughing gas, which is used as an anesthetic, is different from that of the other nitrogen oxides and is not discussed in this protocol.

The most hazardous of the nitrogen oxides are nitric oxide and nitrogen dioxide; the latter exists in equilibrium with its dimer, nitrogen tetroxide. Nitric oxide is a colorless gas at room temperature, very sparingly soluble in water. Nitrogen dioxide is a colorless to brown liquid at room temperature and a reddish-brown gas above 70°F poorly soluble in water. Nitric oxide is rapidly oxidized in air at high concentrations to form nitrogen dioxide.

Routes of Exposure

Inhalation

Nitrogen oxides (NO_2, N_2O_4, N_2O_3 and N2O5) are irritating to the upper respiratory tract and

lungs even at low concentrations. Only one or two breaths of a very high concentration can cause severe toxicity. Odor is generally an adequate warning property for acute exposures. Nitrogen dioxide is heavier than air, such that exposure in poorly ventilated, enclosed, or low-lying areas can result in asphyxiation.

Children exposed to the same levels of nitrogen oxides 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 of nitrogen dioxide than adults in the same location because of their short stature and the higher levels of nitrogen dioxide found nearer to the ground.

Skin/Eye Contact

Exposure to relatively high air concentrations can produce eye irritation and inflammation.

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

Ingestion

Both nitrogen dioxide and nitric oxide are gases at room temperature. However, nitrogen dioxide exists as a liquid below 21°C and, if ingested, will cause gastrointestinal irritation or burns.

Sources/Uses

Nitrogen oxides form naturally during the oxidation of nitrogen-containing compounds such as coal, diesel fuel, and silage. Nitrogen oxides are also formed during arc welding, electroplating, engraving, dynamite blasting, as components of rocket fuel, and nitration reactions such as in the production of nitro-explosives, including gun-cotton, dynamite and TNT. They are produced commercially, usually as the first step in the production of nitric acid, either by the direct oxidation of atmospheric nitrogen in the electric arc (Birkeland-Eyder Process) or by the catalytic oxidation of anhydrous ammonia (Oswald Process). Trace metal impurities most likely cause nitrogen oxides to form in nitric acid and its solutions. Nitrogen oxides are intermediates in the production of lacquers, dyes, and other chemicals and are important components of photo-oxidant smog.

Standards and Guidelines

Nitric Oxide: OSHA PEL (permissible exposure limit) = 25 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm
Nitrogen Dioxide: OSHA PEL (permissible exposure limit) = 5 ppm (Ceiling)

NIOSH IDLH (immediately dangerous to life or health) = 20 ppm

Physical Properties

Nitric Oxide

Description: Colorless gas Yellow-brown liquid or red-brown gas

Warning properties: Non-irritating, odorless and colorless gas; no adequate 1-5 ppm; warning for acute exposure unless accompanied by NO_2 or another higher oxide as is usual.

Molecular weight: 30.0 daltons

Boiling point (760 mm Hg): -241°F (-152°C)

Freezing point: -263°F (-164°C)

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

Gas density: 1.0 (air = 1)

Water solubility: Water soluble

Flammability: Not flammable, but will accelerate burning of combustible materials

Nitrogen Dioxide

Description: Yellow-brown liquid or red-brown gas

Warning properties: Irritating, sharp odor at adequate warning for acute exposure; inadequate warning for chronic exposure.

Molecular weight: 46.0 daltons

Boiling point (760 mm Hg): 70°F (21°C)

Freezing point: 12°F (-11°C)

Vapor pressure: 720 mm Hg at 68°F (20°C)

Gas density: 1.5 (air = 1)

Water solubility: Highly soluble, but reacts with water to form a mixture of nitric and nitrous acids.

Flammability: Not flammable, but will accelerate burning of combustible materials

Incompatibilities

Nitrogen dioxide and nitric acid react with combustible materials, chlorinated hydrocarbons, carbon disulfide, and ammonia. May react violently with cyclohexane, fluorine, formaldehyde and alcohol, nitrobenzene, petroleum, and toluene.

Health Effects

- Most of the higher oxides of nitrogen are eye, skin, and respiratory tract irritants. Nitrogen dioxide is a corrosive substance that forms nitric and nitrous acids upon contact with water; it is more acutely toxic than nitric oxide, except at lethal concentrations when nitric oxide may kill more rapidly.Nitric oxide is a potent and rapid inducer of methemoglobinemia.
- Exposure to nitrogen oxides may result in changes of the pulmonary system including pulmonary edema, pneumonitis, bronchitis, bronchiolitis, emphysema, and possibly methemoglobinemia. Cough, hyperpnea, and dyspnea may be seen after some delay.
- Damage to, and subsequent scarring of, the bronchioles may result in a life-threatening episode several weeks following exposure involving cough, rapid, shallow breathing, rapid heartbeat, and inadequate oxygenation of the tissues.
- Populations that may be particularly sensitive to nitrogen oxides include asthmatics and those with chronic obstructive pulmonary disease or heart disease.

Acute Exposure

Nitrogen dioxide is thought to damage lungs in three ways: (1) it is converted to nitric and nitrous acids in the distal airways, which directly damages certain structural and functional lung cells; (2) it initiates free radical generation, which results in protein oxidation, lipid peroxidation, and cell membrane damage; and (3) it reduces resistance to infection by altering macrophage and immune function. There may be an immediate response to exposure to nitrogen oxide vapors that may include coughing, fatigue, nausea, choking, headache, abdominal pain, and difficulty breathing. A symptom-free period of 3 to 30 hours may then be followed by the onset of pulmonary edema with anxiety, mental confusion, lethargy, and loss of consciousness. If survived, this episode may be followed by bronchiolitis obliterans (fibrous obstruction of the bronchioles) several weeks later. Any of these phases can be fatal.

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

Respiratory

The higher nitrogen oxides are respiratory irritants. The primary site of toxicity is the lower respiratory tract. Low concentrations initially may cause mild shortness of breath and cough; then, after a period of hours to days, victims may suffer bronchospasm and pulmonary edema. Inhalation of very high concentrations can rapidly cause burns, spasms, swelling of tissues in the throat, upper airway obstruction, and death.

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 to corrosive agents than adults because of the relatively smaller diameter of their airways. Children also may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Absorption of nitrogen oxides can lead to a weak rapid pulse, dilated heart, chest congestion, and circulatory collapse.

Hematologic

High-dose exposure may convert Fe^{+2} in hemoglobin to Fe^{+3}, by virtue of the presence of nitric oxide (NO), causing methemoglobinemia and impaired oxygen transport.

Dermal

Higher nitrogen oxides are skin irritants and corrosives. Skin moisture in contact with liquid nitrogen dioxide or high concentrations of its vapor can result in nitric acid formation, which may lead to second-and third-degree skin burns. Nitric acid may also cause yellowing of the skin and erosion of dental enamel.

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

Ocular

Liquid nitrogen oxides cause severe eye burns after brief contact. High concentrations of the gas cause irritation and, after prolonged exposure, may cause clouding of the eye surface and blindness.

Potential Sequelae

Obstruction of the bronchioles may develop days to weeks after severe exposure. Patients suffer malaise, weakness, fever, chills, progressive shortness of breath, cough, hemorrhage of the lungs or bronchioles, blue or purple coloring of the skin, and respiratory failure. This condition may be confused with the adult respiratory distress syndrome secondary to infectious diseases such as miliary tuberculosis.

Victims of inhalation exposure may suffer reactive airways dysfunction syndrome (RADS) after a single acute, high-dose exposure.

Chronic Exposure

Chronic exposure to nitrogen oxides is associated with increased risk of respiratory infections in children. Permanent restrictive and obstructive lung disease from bronchiolar damage may occur.

Carcinogenicity

Nitrogen oxides have not been classified for carcinogenic effects.

Reproductive and Developmental Effects

Nitric oxide and nitrogen dioxide are 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. Methemoglobin inducers are considered harmful to the fetus and nitrogen dioxide has been shown to be fetotoxic in rats and has affected behavior and growth statistics in newborn mice. Nitrogen dioxide also causes DNA damage, mutations, sister chromatid exchanges, and other DNA aberrations.

Special consideration regarding the exposure of pregnant women may be warranted, since nitrogen oxides have been shown to be mutagenic and clastogenic, and fetotoxic in rats; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

- Victims exposed only to nitrogen oxide gases do not pose risks of secondary contamination to rescuers. Victims whose clothing or skin is contaminated with liquid nitrogen oxides or nitric acid can secondarily contaminate response personnel by direct contact or through off-gassing vapors.
- Most of the higher nitrogen oxides are eye, skin, and respiratory tract irritants. Initial respiratory symptoms after exposure to nitrogen oxides may be mild, but progressive inflammation of the lungs may develop several hours to days after exposure. Noncardiogenic pulmonary edema may develop even if initial pulmonary signs were minimal. Exposures may result in methemoglobinemia, depending upon the presence of nitric oxide (NO) in the gas mixture.
- There is no antidote for nitrogen oxides. Primary treatment consists of respiratory and cardiovascular support. Methylene blue may be necessary to treat methemoglobinemia.

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

Nitrogen oxides are severe respiratory tract irritants.

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

Skin Protection: Chemical-protective clothing is recommended when repeated or prolonged contact with liquids of nitrogen oxides or with high concentrations of nitrogen oxide vapors is anticipated because skin irritation or burns may occur.

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 nitrogen oxide gases may appear to have no skin or eye irritation. However, they should still be decontaminated as described below as irritation may not become evident until washing commences.

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 and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 20 minutes. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Immediately begin irrigation of exposed or irritated eyes with plain water or saline and continue for at least 20 minutes. Remove contact lenses if easily removable without additional trauma. Continue eye irrigation during other basic care and transport.

If the victim has ingested a solution of nitrogen oxides or nitric acid, **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.

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 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 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.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

If the patient has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Patients who are able to swallow should be given 4 to 8 ounces of water or milk, if not provided 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.

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.

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 solution of nitrogen oxides, which means in effect a mixture of nitric (HNO_3) and nitrous (HNO_2) acids, 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. Because delayed respiratory compromise may occur even with minimal initial symptoms, all patients who have histories or evidence of exposure should be transported to a medical facility for evaluation. Because of the danger of acute, though delayed, onset of severe, life-threatening pulmonary edema from 3 to 30 hours after what may appear to have been quite a trivial exposure it is important that exposed subjects be maintained under medical surveillance for the first 48 hours post-exposure. If such are allowed to return home and acute pulmonary edema develops in a home environment during sleep it may not be possible to get the patient to resuscitative medical treatment in time. Others may be discharged at 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).

Emergency Department Management

- Patients exposed only to nitrogen oxide gases do not pose risks of secondary contamination to rescuers. Patients whose clothing or skin is contaminated with liquid nitrogen oxides or nitric acid can secondarily contaminate response personnel by direct contact or through off-gassing vapors.
- Most of the higher nitrogen oxides are eye, skin, and respiratory tract irritants. Initial respiratory symptoms after exposure to nitrogen oxides may be mild, but progressive inflammation of the lungs may develop several hours to days after exposure. Noncardiogenic pulmonary edema may develop even if initial pulmonary signs were minimal. Exposures may result in methemoglobinemia, depending upon the presence of nitric oxide (NO) in the gas mixture.
- There is no antidote for nitrogen oxides. Treatment consists of respiratory and cardiovascular support. Methylene blue may be necessary to treat methemoglobinemia.

Decontamination Area

Previously decontaminated patients 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 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 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. Administer supplemental oxygen as required. Children may be more vulnerable to corrosive agents than adults because of the relatively 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).

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. If the patient's clothing is wet with nitrogen oxides or nitric acid, remove and double-bag the contaminated clothing and all personal belongings.

Flush exposed skin and hair with water for 20 minutes (preferably under a shower). Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Begin irrigation of exposed eyes **immediately** and continue for at least 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

If the patient has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Activated charcoal is unlikely to be of benefit and may obscure endoscopic findings if GI tract irritation or burns are present. Patients who are conscious and able to swallow should be given 4 to 8 ounces of water or milk if not provided earlier.

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. Administer supplemental oxygen as required. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously symptomatic patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular 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). Some clinicians recommend high doses of corticosteroids for seriously symptomatic patients, especially with severe bronchospasm; in patients with acute respiratory failure without bronchospasm, the value of steroids is unproven.

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 the skin was in contact with liquid nitrogen oxides or their solutions, 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.

Eye Exposure

Continue irrigation for at least 20 minutes. If liquid nitrogen oxides or nitric acid has been splashed in the eyes, irrigate 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.

Ingestion Exposure

If the patient has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Patients who are conscious and able to swallow should be given 4 to 8 ounces of water or milk if not provided earlier.

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 no 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.

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

There are no antidotes for nitrogen oxide poisoning. Methylene blue (tetramethylthionine chloride) should be considered for patients who have signs and symptoms of hypoxia (other than

cyanosis) or for patients who have methemoglobin levels >30%. Cyanosis alone does not require treatment. Methylene blue may not be effective in patients who have G6PD deficiency and may cause hemolysis.

The standard dose of methylene blue is 1 to 2 mg/kg body weight (0.1 to 0.2 mL/kg of a 1% solution) intravenously over 5 to 10 minutes, repeated in 1 hour if needed. The total initial dose should not exceed 7 mg/kg. (Doses greater than 15 mg/kg may cause hemolysis.) Clinical response to methylene blue treatment is usually observed within 30 to 60 minutes. Side effects include nausea, vomiting, abdominal and chest pain, dizziness, diaphoresis, and dysuria.

Consider exchange transfusion in severely poisoned patients who are deteriorating clinically in spite of methylene blue treatment. Intravenous ascorbic acid administered to severely poisoned patients has not proved to be effective.

Administration of steroids is thought by some physicians to reduce the likelihood of the development of bronchiolitis obliterans by reducing inflammation and therefore lung damage. Steroids should be started soon after exposure and continued for 8 weeks, then tapered gradually. The data on steroid use to prevent late sequelae (bronchiolitis obliterans) is anecdotal and somewhat controversial.

Laboratory Tests

The diagnosis of acute nitrogen oxide toxicity is primarily based on respiratory symptoms and establishing a history of exposure to nitrogen oxides. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to nitrous oxides include determination of methemoglobin levels. The condition of victims who have respiratory complaints should be evaluated with pulse oximetry (or ABG measurements), chest radiography, spirometry, and peak flow measurements. Pulse oximetry is not reliable if methemoglobin is present.

NO and NO_2 are metabolized to nitrite (NO_{2^-}) and nitrate (NO_{3^-}) and are excreted in the urine. The levels of these urinary metabolites are not medically useful but may be helpful in documenting exposure.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant inhalation exposure and are symptomatic.

Delayed Effects

Symptomatic patients should be observed in a controlled setting for 48 hours for delayed noncardiogenic pulmonary edema. All patients determined to have been exposed to nitrogen oxides should be advised that life-threatening symptoms may develop as late as several weeks after the exposure.

Patient Release

Patients who have been observed for several hours after minimal exposure and remain asymptomatic may be treated as outpatients. They should be advised to seek medical care promptly if symptoms develop (see *Nitrogen Oxides-Patient Information Sheet*). A patient whose symptoms resolve within 24 to 36 hours may be released with a follow-up appointment to assess pulmonary status.

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.

Close outpatient follow-up should be continued in patients who experienced significant respiratory compromise because these patients are at high risk of developing bronchiolitis obliterans within several weeks.

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.

Patient Information Sheet

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

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What are nitrogen oxides?

Nitrogen oxides are a mixture of gases that each contain nitrogen and oxygen. Nitrogen oxides are formed naturally when fossil fuels (e.g., coal, oil, gas, kerosene) are burned and when silage containing nitrate fertilizer ferments in storage silos. They are also formed during electric arc welding, electroplating, and engraving. They are part of airborne smog and are partly indirectly responsible for the burning eyes, nose, and throat caused by air pollution, through formation of the intensely irritating compound peroxyacetylnitrate, PAN.

What immediate health effects can be caused by exposure to nitrogen oxides?

Breathing low levels of nitrogen oxides may cause brief, nonspecific symptoms such as cough, shortness of breath, tiredness, and nausea. However, even if removed from exposure, a person who has breathed nitrogen oxides can develop more serious lung injury over the next 1 to 2 days. Exposure to massive concentrations can cause sudden death due to lung injury and suffocation or choking. Generally, the more serious the exposure, the more severe the symptoms.

Can nitrogen oxides poisoning be treated?

There is no antidote for nitrogen oxide poisoning. Treatment for exposure usually involves giving the patient oxygen and medications to make breathing easier.

Are any future health effects likely to occur?

A single small exposure from which a person recovers quickly may not cause delayed or long-term effects. After a serious exposure or repeated exposures, a patient may develop asthma or other lung conditions.

What tests can be done if a person has been exposed to nitrogen oxides?

Specific tests for the presence of nitrogen oxides 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 damage has been done to the lungs, heart, and brain. Testing is not needed in every case.

Where can more information about nitrogen oxides be found?
More information about nitrogen oxides 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.

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

[ ] 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
- weakness, fatigue, or flu-like symptoms
- 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 _____

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE, Mailstop F-62
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)
Fax: 1-770-488-4178
Email: cdcinfo@cdc.gov (mailto:cdcinfo@cdc.gov)

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

Information line and technical assistance:
Phone: 888-422-8737
FAX: (770)-488-4178

To order toxicological profiles, contact:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

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