Chlorine (Cl_2)
CAS 7782-50-5; UN 1017

Synonyms include molecular chlorine.

- **Persons exposed only to chlorine gas pose little risk of secondary contamination to others. However, clothing or skin soaked with industrial-strength chlorine bleach or similar solutions may be corrosive to rescuers and may release harmful chlorine gas.**
- **Chlorine is a yellow-green, noncombustible gas with a pungent, irritating odor. It is a strong oxidizing agent and can react explosively or form explosive compounds with many common substances. Chlorine is heavier than air and may collect in low-lying areas.**
- **Chlorine gas is highly corrosive when it contacts moist tissues such as the eyes, skin, and upper respiratory tract. Significant dermal absorption or ingestion is unlikely.**

Description

At room temperature, chlorine is a yellow-green gas with a pungent irritating odor. Under increased pressure or at temperatures below -30 °F, it is a clear, amber-colored liquid. It is generally shipped in steel cylinders as a compressed liquid. Chlorine is only slightly soluble in water, but on contact with moisture it forms hypochlorous acid (HClO) and hydrochloric acid (HCl); the unstable HClO readily decomposes, forming oxygen free radicals. Because of these reactions, water substantially enhances chlorine's oxidizing and corrosive effects.

Routes of Exposure

Inhalation

Most exposures to chlorine occur by inhalation. Chlorine's odor or irritant properties are discernible by most individuals at 0.32 ppm which is less than the OSHA permissible exposure limit (PEL) of 1 ppm. Chlorine's odor or irritant properties generally provide adequate warning of hazardous concentrations. However, prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of chlorine's irritant effects. Chlorine is heavier than air and may cause asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children are at increased risk for exposure to inhaled toxicants because they have a greater lung surface area:body weight ratio and an increased minute volume:weight ratio. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children also may be at

increased risk because of their short stature, when higher concentrations of the chemical are found at low-lying areas.

Skin/Eye Contact

Direct contact with liquid chlorine or concentrated vapor causes severe chemical burns, leading to cell death and ulceration.

Ingestion

Ingestion is unlikely to occur because chlorine is a gas at room temperature. Solutions that are able to generate chlorine (e.g., sodium hypochlorite solutions) may cause corrosive injury if ingested.

Sources/Uses

Chlorine is produced commercially by electrolysis of sodium chloride brine. It is among the ten highest volume chemicals manufactured in the United States, with 1998 production in excess of 14 million tons.

Chlorine's most important use is as a bleach in the manufacture of paper and cloth. Chlorine is also used widely as a chemical reagent in the synthesis and manufacture of metallic chlorides, chlorinated solvents, pesticides, polymers, synthetic rubbers, and refrigerants.

Sodium hypochlorite, which is a component of commercial bleaches, cleaning solutions, and disinfectants for drinking water and waste water purification systems and swimming pools, releases chlorine gas when it comes in contact with acids.

Standards and Guidelines

OSHA ceiling = 1 ppm

NIOSH IDLH (immediately dangerous to life or health) = 10 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 3 ppm.

Physical Properties

Description: Yellow-green gas at room temperature

Warning properties: odor and irritation are generally adequate, but olfactory fatigue can occur; pungent odor at about 0.31 ppm

Molecular weight: 70.9 daltons

Boiling point: (760 mm Hg) = -29 °F (-34 °C)

Freezing point: -150 °F (-101 °C)

Specific gravity: 1.56 at boiling point (water = 1)

Vapor pressure: 5,168 mm Hg at 68 °F (20 C)

Gas density: 2.5 (air = 1)

Water solubility: (0.7% at 68 °F) (20 °C)

Flammability: Not flammable, but reacts explosively or forms explosive compounds with many common substances

Incompatibilities

Chlorine reacts explosively or forms explosive compounds with many common substances such as acetylene, ether, turpentine, ammonia, fuel gas, hydrogen, and finely divided metals.

Health Effects

- **Chlorine gas is irritating and corrosive to the eyes, skin, and respiratory tract.**
- **Exposure to chlorine may cause burning of the eyes, nose, and throat; cough as well as constriction and edema of the airway and lungs can occur.**

Acute Exposure

The toxic effects of chlorine are primarily due to its corrosive properties. The action of chlorine is due to its strong oxidizing capability, in which chlorine splits hydrogen from water in moist tissue, causing the release of nascent oxygen and hydrogen chloride which produce major tissue damage. Alternatively, chlorine may be converted to hypochlorous acid which can penetrate cells and react with cytoplasmic proteins to form N-chloro derivatives that destroy cell structure. Symptoms may be apparent immediately or delayed for a few hours.

Respiratory

Chlorine is water soluble and therefore, primarily removed by the upper airways. Exposure to low concentrations of chlorine (1 to 10 ppm) may cause eye and nasal irritation, sore throat, and coughing. Inhalation of higher concentrations of chlorine gas (>15 ppm) can rapidly lead to respiratory distress with airway constriction and accumulation of fluid in the lungs (pulmonary edema). Patients may have immediate onset of rapid breathing, blue discoloration of the skin, wheezing, rales or hemoptysis. In symptomatic patients, pulmonary injury may progress over several hours. Lung collapse may occur. The lowest lethal concentration for a 30-minute exposure has been estimated as 430 ppm. Exposure to chlorine can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

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

Cardiovascular

Tachycardia and initial hypertension followed by hypotension may occur. After severe exposure, cardiovascular collapse may occur from lack of oxygen.

Metabolic

Acidosis may result from insufficient oxygenation of tissues. An unusual complication of massive chlorine inhalation is an excess of chloride ions in the blood, causing an acid-base imbalance.

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

Dermal

Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite injury.

Ocular

Low concentrations in air can cause burning discomfort, spasmodic blinking or involuntary closing of the eyelids, redness, conjunctivitis, and tearing. Corneal burns may occur at high concentrations.

Potential Sequelae

After acute exposure, pulmonary function usually returns toward baseline within 7 to 14 days. Although complete recovery generally occurs, symptoms and prolonged pulmonary impairment may persist. Exposure to chlorine can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Chronic Exposure

Chronic exposure to chlorine, usually in the workplace, may cause corrosion of the teeth. Multiple exposures to chlorine have produced flu-like symptoms and a high risk of developing reactive airways dysfunction syndrome (RADS).

Carcinogenicity

Chlorine has not been classified for carcinogenic effects. However, the association of cigarette smoking and chlorine fumes may increase the risk of cancer.

Reproductive and Developmental Effects

No information is available regarding reproductive or developmental effects of chlorine in experimental animals or humans. Chlorine gas has been used as a chemical warfare agent, but no retrospective reproductive studies of survivors have been published. Chlorine is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

- **Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to chlorine gas. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful chlorine gas.**
- **Acute exposure to chlorine gas initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may occur. Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite.**
- **There is no specific antidote for chlorine poisoning. Treatment is supportive.**

Hot Zone

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

Rescuer Protection

Chlorine is a severe respiratory-tract and skin irritant.

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

Skin Protection: Chemical-protective clothing should be worn because chlorine gas can condense on the skin and cause irritation and burns.

ABC Reminders

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

Victim Removal

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

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

Decontamination Zone

Victims exposed only to chlorine gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

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

ABC Reminders

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

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 3 to 5 minutes, then wash twice with mild soap. Rinse thoroughly with water.

Do not irrigate eyes that have sustained frostbite injury. Otherwise, irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

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

Transfer to Support Zone

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

Support Zone

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

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator. Use direct visualization to intubate. When the patient's condition precludes endotracheal intubation, perform cricothyroidectomy if equipped and trained to do so.

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

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.7 5 m of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

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

If frostbite is present, treat by rewarming in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Transport to Medical Facility

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

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

Multi-Casualty Triage

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

Patients with evidence of significant exposure (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel are at minimal risk of secondary contamination from patients who have been exposed only to chlorine gas. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to personnel and may release harmful chlorine gas.**

- **Acute exposure to chlorine gas initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction, noncardiogenic pulmonary edema, hemoptysis, and bronchopneumonia may occur.**
- **Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite.**

- **There is no specific antidote for chlorine poisoning. Treatment requires supportive care.**

Decontamination Area

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

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

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

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

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

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Otherwise, begin irrigation of exposed eyes. Remove contact lenses if it can be done without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

Critical Care Area

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

ABC Reminders

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

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

Inhalation Exposure

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

known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Children may be more vulnerable to corrosive agents than adults because of their smaller airways.

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

Skin Exposure

If concentrated chlorine gas or chlorine-generating solutions contact the skin, chemical burns may occur; treat as thermal burns. If the liquefied compressed gas is released and contacts the skin, frostbite may result. If a victim has frostbite, treat by rewarming affected areas in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

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

Eye Exposure

Chlorine-exposed eyes should be irrigated for at least 15 minutes. Test visual acuity and examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no specific antidote for chlorine. Treatment is supportive.

Laboratory Tests

The diagnosis of acute chlorine toxicity is primarily clinical, based on respiratory difficulties and irritation. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements) and chest radiography. Massive inhalation may be complicated by hyperchloremic metabolic acidosis; in addition to electrolytes, monitor blood pH.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected significant exposure or have eye burns or serious skin burns.

Delayed Effects

Symptomatic patients complaining of persistent shortness of breath, severe cough, or chest tightness should be admitted to

the hospital and observed until symptom-free. Pulmonary injury may progress for several hours.

Patient Release

Asymptomatic patients and those who experienced only minor sensations of burning of the nose, throat, eyes, and respiratory tract (with perhaps a slight cough) may be released. In most cases, these patients will be free of symptoms in an hour or less. They should be advised to seek medical care promptly if symptoms develop or recur (see the *Chlorine—Patient Information Sheet* below).

Follow-up

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

Follow up is recommended for all hospitalized patients because long-term respiratory problems can result. Respiratory monitoring is recommended until the patient is symptom-free. Chlorine-induced reactive airways dysfunction syndrome (RADS) has been reported to persist from 2 to 12 years.

Patients who have skin or corneal injury should be re-examined within 24 hours.

Reporting

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

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

Chlorine
Patient Information Sheet

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

What is chlorine?
Chlorine is a yellowish-green gas with a sharp, burning odor. It is used widely in chemical manufacturing, bleaching, drinking-water and swimming-pool disinfecting, and in cleaning agents. Household chlorine bleach contains only a small amount of chlorine but it can release chlorine gas if mixed with other cleaning agents.

What immediate health effects can be caused by exposure to chlorine?
Even small exposures to the gas may cause immediate burning of the eyes, nose, and throat, and shortness of breath, as well as coughing, wheezing, shortness of breath, and tearing of the eyes. However, once exposure is stopped, symptoms usually clear up quickly. Breathing large amounts of chlorine may cause the lining of the throat and lungs to swell, making breathing difficult. Generally, the more serious the exposure, the more severe the symptoms.

Can chlorine poisoning be treated?
There is no antidote for chlorine, but its effects can be treated and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, symptoms may worsen for several hours.

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

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

Follow-up Instructions

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

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

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from injured eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____ __
_____

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

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

Signature of patient _____ Date _____

Signature of physician _____ Date _____