



Phosgene September 2003

Introduction

Phosgene – Overview

Phosgene, which has the military designation of CG, is the chemical carbonyl chloride, a colorless gas at ambient temperatures. It is easily liquefied under pressure, has a boiling point of 8.2°C, and, with a density four times that of air, will settle in low-lying areas. It has been described as smelling like decaying fruit, fresh-cut grass or moldy hay, and the odor threshold is roughly 1.5 parts per million. Trained workers can detect it at concentrations of 0.4 parts per million. However, the sense of smell is a poor guide to possible concentrations, since olfactory fatigue can develop at high concentrations and mislead the victim as to the potential danger.

Toxicity (1)

Inhalation is the primary route of exposure and the lung is the main target. At high concentrations, skin irritation and eye injury can occur. The degree of injury is the product of concentration and the duration of acute exposure following Haber's Law. The LC_{50} is about 3200 mg•min/m³.

Toxicity (2)

At exposures as low as 3 to 4 parts per million the eyes, nose and throat become irritated. Exposures greater than 30 ppm•min will damage the lung. Pulmonary edema occurs at dosages exceeding 150 ppm•min, or 600 mg•min/m³. At dosages exceeding 30 ppm•min, the initial irritation and respiratory symptoms are followed by a second, sometimes asymptomatic, phase, often lasting 24 to 48 hours. The duration of this latent phase is inversely proportional to the inhaled dose: the larger the dose the shorter the latent period.

Protective Equipment

Respiratory protection is paramount and a military-style respirator offers good protection. Although chemical protective clothing is not typically necessary, it is still advised in high concentration spills.

Detection

The usual techniques used to determine air concentrations include passive dosimetry, manual and automated colorimetry, infrared spectroscopy and ultraviolet spectrophotometry. Paper tape monitors capable of detecting $5 \mu\text{g}\cdot\text{m}^3$ have been described, but no automated field detectors are currently available.

Decontamination

The first consideration during decontamination is to remove the victim from continued exposure. To remove the chemical, flush affected skin and eyes with running water for 15 to 20 minutes. If there has been contact with liquid phosgene, remove contaminated clothing and footwear; and thaw affected area with lukewarm water.

Signs and Symptoms

Phosgene's mode of action is not fully understood, and it has been suggested that it may act by inhibiting enzymes, or by producing HCl in the alveoli. More recently, some have suggested that, as a highly reactive molecule, it may react directly at the alveolar and capillary wall. The carbonyl group participates in acylation reactions with amino, hydroxyl, or sulfhydryl groups at the alveolar-capillary membrane and these acylations lead to capillary leakage of fluid into the interstitium. As this leakage outpaces normal drainage mechanisms, edema develops. The early-onset ocular, nasal, and central airway irritation from high concentration exposures is likely caused by the HCl released by the hydrolysis of phosgene in these moist tissues.

Signs and Symptoms

With exposure to concentrations exceeding 3 parts per million, burning and watering of the eyes, a sore or scratchy throat, dry cough, choking, nausea, headache, and chest tightness develop. Erythema of the oral and pharyngeal mucus membranes becomes evident at higher concentrations. These symptoms, however, do not accurately predict the potential for severe lung injury. Sustained exposures to just 2 parts per million for roughly 80 minutes will not cause any irritation, but will produce pulmonary edema 12 to 16 hours later. At concentrations greater than 200 parts per million, phosgene passes the blood-air barrier causing hemolysis in the pulmonary capillaries, congestion by red cell

fragments and stoppage of capillary circulation. Death occurs within a few minutes from acute cor pulmonale.

Signs and Symptoms

The trachea and bronchi are usually normal in appearance. With damage to the bronchiolar epithelium, narrowing of the lumen develops, causing a lengthening of the respiratory cycle. The development of moist rales in the lung fields indicates the presence of pulmonary edema. This is preceded by damage to the bronchiolar epithelium, development of patchy areas of emphysema, partial atelectasis, and edema of the perivascular connective tissue.

Signs and Symptoms

As the edema progresses, discomfort, apprehension and dyspnea increase and frothy sputum develops. Rales and rhonchi are audible over the chest, and breath sounds are diminished. The patient may develop shock-like symptoms, with pale, clammy skin, low blood pressure and a feeble, rapid heartbeat. Phosgene's effects usually reach a maximum 12 to 24 hours after exposure. In the terminal clinical phase of a lethal poisoning, extreme distress ensues with intolerable dyspnea until respiration ceases.

Signs and Symptoms

In addition to the pulmonary findings, other physical effects are also seen. The blood becomes viscous and coagulates easily. Methemoglobin levels increase; followed by cyanosis and reduced arterial blood pressure with tachycardia, as well as a metabolic acidosis and compensatory hyperventilation. Arterial blood gases will reveal significant hypoxia. Although skin injury is unlikely from phosgene, contact with liquid phosgene may cause burns or frostbite.

Treatment

The treatment for exposure victims is primarily supportive care, with warmth and forced bed rest being important since activity can shorten the latent period. It is important to differentiate between early irritant symptoms and pulmonary edema. Early edema may be detected by chest x-ray, before evident clinical signs, using 50-80 kilovolts. At 100-120 kilovolts, this may not be seen. Irritation typically precedes edema, but edema in the absence of lung irritation has been reported. Observe patients for up to 48 hours. If pulmonary edema is to develop, it will be apparent by this time. The onset of edema within 2 to 6 hours is predictive of severe injury.

Treatment

The early use of positive airway pressure intermittent positive pressure breathing (IPPB) or a positive end-expiratory pressure (PEEP) mask may delay and/or minimize the pulmonary edema and reduce the degree of hypoxia, but intubation is critical at the first sign of edema or pulmonary failure. Provide adequate oxygenation, and determine the appropriate mode of ventilation for each individual.

Treatment

An elevation of the pCO₂ greater than 45 mm Hg suggests that bronchospasm is the more likely cause of hypercarbia and bronchodilators should then be used aggressively. If the patient has a prior history of clinical bronchospasm, steroids should be added immediately. In all other patients, the efficacy of steroids in a chemically induced pulmonary edema is unproven, yet steroids are still advised if given within 15 minutes of exposure. The steroid doses used are much greater than those prescribed in asthma and should be given by inhalation or, in severe cases, intravenously. The typical dose is methylprednisolone, 700-1000 mg, in divided doses on day one and tapered from there.

Treatment

Sedatives should be used with caution and they should be withheld until adequate oxygenation is assured and facilities for possible respiratory assistance are available. Barbiturates, atropine, antihistamines and analeptics are all contraindicated. Antibiotics are reserved for those with documented pulmonary infection.

Long-term Medical Sequelae

Pulmonary function studies and a chest x-ray should be performed on each patient at a 2 to 3 month follow-up exam. Most survivors of acute exposure have a good prognosis, but shortness of breath and physical limitations may persist. Smoking worsens the chances of full recovery, as does pre-existing chronic pulmonary disease. Phosgene does not appear to be mutagenic, and data on carcinogenicity are insufficient for an assessment.

Environmental Sequelae

Phosgene is very persistent in the atmosphere because it does not absorb UV light and is not subject to photolysis by sunlight in the troposphere. Its half-life in the atmosphere is estimated at 113 years at sea level. The minimal water solubility and vapor pressure of phosgene allow it to rapidly hydrolyze in water.

Summary

In summary, at ambient temperatures phosgene (CG) is a colorless gas. Its potential use by terrorists is one of disruption and fear, and inhalation is the primary route of exposure with the lung being the main target. Eye and pharyngeal irritation occurs at 3 to 4 parts per million, while exposures > 30 ppm•min damage the lung and dosages exceeding 150 ppm•min (600 mg•min/m³) rapidly cause pulmonary edema. The treatment of phosgene exposure is primarily supportive care, emphasizing ventilation, oxygenation and general pulmonary care. Fortunately, most survivors of acute exposure have a good prognosis.