Sulfur Dioxide
September 2003

Introduction

Sulfur Dioxide – Overview

Sulfur dioxide, SO_2, is a colorless, non-flammable gas that is heavier than air. It has a strong, suffocating odor that most people can readily identify as one of rotting eggs. It is a liquid when under pressure, and dissolves in water very easily.

Over 65% of SO_2 released in the air, more than 13 million tons per year, comes from electric utilities, especially those that burn coal. On a global basis, fossil fuel combustion accounts for 75 to 85% of man-made sulfur dioxide emissions, and industrial processes such as refining and smelting account for the remainder. As a result, SO_2 is a major component of acid rain. In nature, sulfur dioxide can be released to the air from volcanic eruptions. In addition, hydrogen sulfide from the natural decay of vegetation on land, marsh lands and in the oceans, is probably oxidized to sulfur dioxide within hours. Sulfur dioxide is used industrially in the manufacture of sulfuric acid, paper, food preservatives, and fertilizers.

In the hands of terrorists, sulfur dioxide has the potential to cause significant fear and disruption, but such an attack would likely result in little death.

Sulfur Dioxide – Toxicity

As a gas, sulfur dioxide's major route of toxicity is inhalation. However, it is also a strong irritant to the eyes and moist skin where the gas combines with water to form both sulfuric and sulfurous acids. Victims with chronic pulmonary disease, particularly asthma, have been shown to be much more sensitive to the gas at lower concentrations. Children, too, may be at higher risk because of their greater lung surface area to body weight ratio, increased minute volume to weight ratio, and shorter stature.

Sulfur Dioxide – Toxicity

Workplace exposure to SO_2 can cause both acute and chronic effects, and exposure to very high levels can be life threatening. With acute exposure to 5 parts per million, the victim will notice only dryness of the nose and throat, yet a measurable increase in airway restriction is already developing. At levels of 6 to 8 parts per million, there is a measurable decrease in tidal volume. Sneezing, cough, expectoration, and eye symptoms develop at levels of 10 parts per million, while exposure to 20 parts per million causes severe bronchospasm. At 50 parts per million, the victim will experience extreme upper respiratory symptoms, but no significant injury will occur with exposures limited to less than 30 minutes.

Sulfur Dioxide – Toxicity

Exposures at 100 parts per million can cause an immediate health risk and at 1000 parts per million, death can occur within 10 minutes from severe respiratory depression.

The EPA has established an air quality standard of 0.03 parts per million for long-term, 1-year average concentrations of sulfur dioxide and short-term, 24-hour air concentrations should not exceed 0.14 parts per million more than once a year. OSHA has set a limit of 2 parts per million over an 8-hour workday, 40-hour workweek, and 5 parts per million as the short-term (15 minute) exposure limit. The NIOSH IDHL, the level immediately dangerous to life and health, is 100 parts per million.

Protective Equipment

Positive-pressure, self-contained breathing apparatus (SCBA) is advised in situations that involve exposure to potentially unsafe levels of sulfur dioxide. However, chemical-protective clothing is only indicated when there is potential exposure to the liquefied gas, or in situations where high concentrations of the gas may combine with water or sweat on the skin. In other situations, safety glasses or face shield, and rubber gloves should provide adequate eye and skin protection.

Detection

Although sulfur dioxide is easily detected by its distinct odor and olfactory fatigue does not occur rapidly, the sense of smell alone should not be relied upon for detection. A variety of sulfur dioxide monitors and gas sensors are available commercially and are more reliable for the detection of the gas.

Decontamination

To decontaminate, remove exposed individuals from the contaminated area as soon as possible, and remove and double-bag contaminated clothing and personal belongings. For eye exposure, flush the eyes immediately with water for at least

15 minutes, then irrigate each eye continuously with normal saline during transport to the hospital. Use proparacaine hydrochloride to assist eye irrigation if necessary. For skin exposure, flush with water for 5 to 10 minutes, and then wash well with soap and water, followed by another thorough rinsing. Cover skin burns with sterile dressings after decontamination. Use caution to avoid hypothermia in children and the elderly.

Signs and Symptoms

Sulfur dioxide's adverse effects are believed to be increased by the formation of sulfates or higher sulfur oxides from interactions between SO_2 and water or SO_2 and particulate matter. However, the diagnosis of exposure is mainly a clinical one, confirmed by the detection of the chemical at the scene. Since sulfur dioxide readily dissolves in water, it is intensely irritating to the eyes and respiratory tract. Its predominant effects are in the upper respiratory tract.

Signs and Symptoms

The acute effects of exposure include upper respiratory tract irritation, rhinorrhea, choking, expectoration, nosebleeds, difficulty swallowing, oropharyngeal erythema, and coughing. Within 5 to 15 minutes from the onset of exposure, victims develop temporary reflex bronchoconstriction and increased airway resistance. Continued exposure can result in high pitched rales, thoracic pain, nasopharyngitis, tracheitis, laryngeal edema, chemical bronchopneumonia, pulmonary edema, cyanosis, asphyxia and death. Destruction of the ciliated epithelium also leads to increased risks of pulmonary infection. The most common form of death is asphyxiation from severe glottal and bronchiolar constriction, so it is imperative that the airway be secured immediately in any victim displaying pulmonary symptoms.

Signs and Symptoms

The eyes will develop lacrimation, conjunctival injection, and blepharitis initially, and iritis may develop with higher exposures. Fortunately, severe eye injury is only seen with contact to the liquid form of SO_2. After being sprayed, the corneal epithelium turns gray and irregular, but it remains attached to the stroma. After several hours, the lids become edematous and the conjunctiva appears white and opaque due to thrombosed blood vessels. This corneal damage can result in blindness.

Signs and Symptoms

Dermal exposure can result in irritation, urticarea, and burns. The major risks to the skin are from exposure to liquid sulfur dioxide.

Signs and Symptoms

Because of its high solubility, SO_2 is rapidly distributed throughout the body and produces a metabolic acidosis. This results in a reduction of blood alkali reserves and a compensatory elimination of ammonia in the urine. The generalized toxic effect is one of protein and carbohydrate metabolism disorders, along with possible effects on the hemopoietic system and the production of methemoglobin. Vomiting, diarrhea, abdominal pain, fever, headache, vertigo, agitation, tremor, convulsions, and peripheral neuritis have also been noted.

Signs and Symptoms

The chronic effects of exposure include permanent pulmonary impairment as a result of repeated episodes of bronchoconstriction. Such chronic pulmonary symptoms will be mentioned later.

Treatment

Following decontamination, the first aid for exposure victims is basic. However, there is no antidote for sulfur dioxide exposure and subsequent care is supportive. Monitor the cardiac rhythm and treat arrhythmias as appropriate. A precautionary intravenous line should be started in all patients, using D_5W at a "to keep open" rate. If signs of hypovolemia or shock are present, use normal saline or lactated Ringer's at 150 to 250 mL/hr and consider vasopressors, remaining mindful of the potential for pulmonary edema and the need to avoid fluid overload. In the acidotic patient, anticipate seizures and treat with diazepam if necessary. Skin irritation and burns should be treated topically.

Treatment

It is critical that a patent airway be established, and intubation at the first sign of upper airway obstruction may be necessary. An open airway must be maintained and aggressive suctioning may be required. Watch for signs of respiratory insufficiency and consider assisted ventilation if indicated. Hypoxia is another concern, so administer oxygen by a non-rebreather mask at 10 to 15 L/min and monitor the patient's oxygenation status with arterial blood gases or pulse oximetry. Finally, watch closely for signs of pulmonary edema, which may be delayed, and treat accordingly. The early use of positive airway pressure intermittent positive pressure breathing (IPPB), a positive end-expiratory pressure (PEEP) mask or intubation (with or without a ventilator) may delay and/or minimize pulmonary edema and reduce the degree of hypoxia.

Treatment

For ingestions, rinse the mouth and administer 5 mL/kg, up to 200 mL, of water for dilution if the patient can swallow, has a strong gag reflex, and does not drool. **Do not use emetics.** Instead, administer activated charcoal as a slurry at 1 gm/kg. The usual adult dose is 60 to 90 gm, while the pediatric dose ranges from 15 to 50 gm. Also consider a cathartic.

Long-term Medical Sequelae

Acute high-dose sulfur dioxide exposures have resulted in severe obstructive and restrictive defects 3 months post-exposure, which failed to respond to bronchodilators. Exposure to high concentrations of SO_2, in the range of 80 to 100 parts per million, may cause an increased chronic incidence of nasopharyngitis, dyspnea on exertion, and chronic fatigue. Exposures in the range of 2 to 36 parts per million can produce a significantly higher frequency of chronic respiratory disease symptoms, including chronic coughing, expectoration, and dyspnea. There are no studies that definitively link sulfur dioxide to cancer, and the EPA has classified it in Group D, not classifiable as to human carcinogenicity. In addition, its reproductive and teratogenetic effects are not known.

Environmental Sequelae

When released into the air, sulfur dioxide can be converted to sulfuric acid, sulfur trioxide, and sulfates. Easily dissolved in water, it can also form sulfurous acid. Sulfur dioxide can be absorbed into the soil, but once absorbed, its changes are not precisely known.

Summary

In summary, sulfur dioxide is a readily available gas that could be used by terrorists to spread fear and disruption. Exposures as low as 5 parts per million can produce dryness of the nose and throat and a measurable increase in airway restriction, while exposures at 100 parts per million are immediately dangerous to life and health. Its acute effects include upper respiratory tract irritation, rhinorrhea, choking, expectoration, nosebleeds, dysphagia, oropharyngeal erythema, and coughing, progressing to chemical bronchopneumonia, pulmonary edema, cyanosis, asphyxia and death with continued exposure. There is no antidote and care is supportive with special attention to maintaining a patent airway and adequate oxygenation. The most common form of death is asphyxiation from severe glottal and bronchiolar constriction.