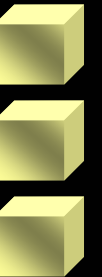


Lethal Occupational Exposures

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Lethal Occupational Exposures

- Magnitude of the problem
- “Occupational Emergency Medicine”
- Specific lethal exposures



Magnitude of the Problem

- In 1994, 6.8 million non-fatal illnesses and injuries were reported in private industry in the USA
 - The true number far exceeds 6.8 million



The Problem

- Annually, over 6,000 deaths occur on the job
 - 1/3 of these due to motor vehicle accidents and homicides





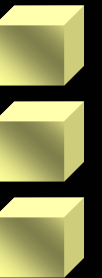
- **Clearly, the majority of these acute events are initially evaluated in the ED**





**In 1987, an editorial entitled “Occupational
Medicine: Where Do We Get the Training?”
appeared in the Annals of Emergency
Medicine***

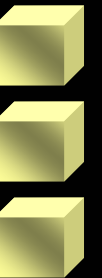
*** Van Dyke MW Ann Emerg Med, 1987;17:1179**





Occupational exposures

- **1998 AAPC data reports**
 - **44,849 (2.2%) occupational exposures**
 - **54,368 (2.4%) environmental exposures**
 - **80,334 (3.6%) bites and stings**



Worker Deaths Each Year.....

- 30 die from heatstroke.
- 30 die from carbon monoxide poisoning.
- 15 workers are killed by lightning
- 10 are killed by exploding tires
- 10 are killed in manure pits/sewers
- 8 die after being burned by hot water or steam
- 4 workers die from allergic reaction to bee stings



Toxic Death in the Workplace

- 401 occupationally related toxic deaths (1992-96: BLS; CFOI)
 - 1.2% of all work related deaths
 - Males predominate (30:1)
 - Most in 35-44 y.o. age group
- Carbon monoxide (35.8%)
- Hydrogen sulfide (7.7%)

– Greenberg M, Hamilton R. J Tox Clin Tox 1998: 36(5)





Mechanisms of exposure

- Inhalation
- Dermal
- Ingestion
- Immersion





Immersion injuries

- Uncommon but often fatal
- Various fluids
 - Acids
 - Manure
 - Alcohols
 - Hot wax
 - Yes....even chocolate





Specific Lethal Workplace Toxicants

- Inhalation Exposures

- Carbon monoxide (CO)
- Hydrogen sulfide (H₂S)
- Hydrofluoric acid (HF)
- Nitrous oxide (NO) & oxides of nitrogen
- Carbon dioxide (CO₂)
- Arsine
- Phosphine
- Phosgene (CG)
- Chlorine/ ammonia/ chloramine


- Dermal exposures

- 2,4-DCP
- Hydrofluoric acid (HF)





Carbon Monoxide

- **Leading cause of occupational toxic death**
 - **Incidence has remained stable year to year**
 - **Construction workers are primary group**
 - **Most common in small businesses and self-employed**
 - **Motor vehicles at fault in almost 50% cases**
 - **Small motor use is special hazard**
- 



Some numbers

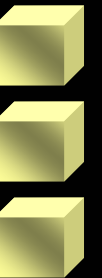
- The OSHA PEL is 50 ppm
- Maritime workers must be removed from exposure if the CO concentration in the atmosphere exceeds 100 ppm.
- The peak CO level for employees engaged in “Ro-Ro” operations (roll-on roll-off operations during cargo loading and unloading) is 200 ppm.
- AIHA IDLH = 1200 ppm



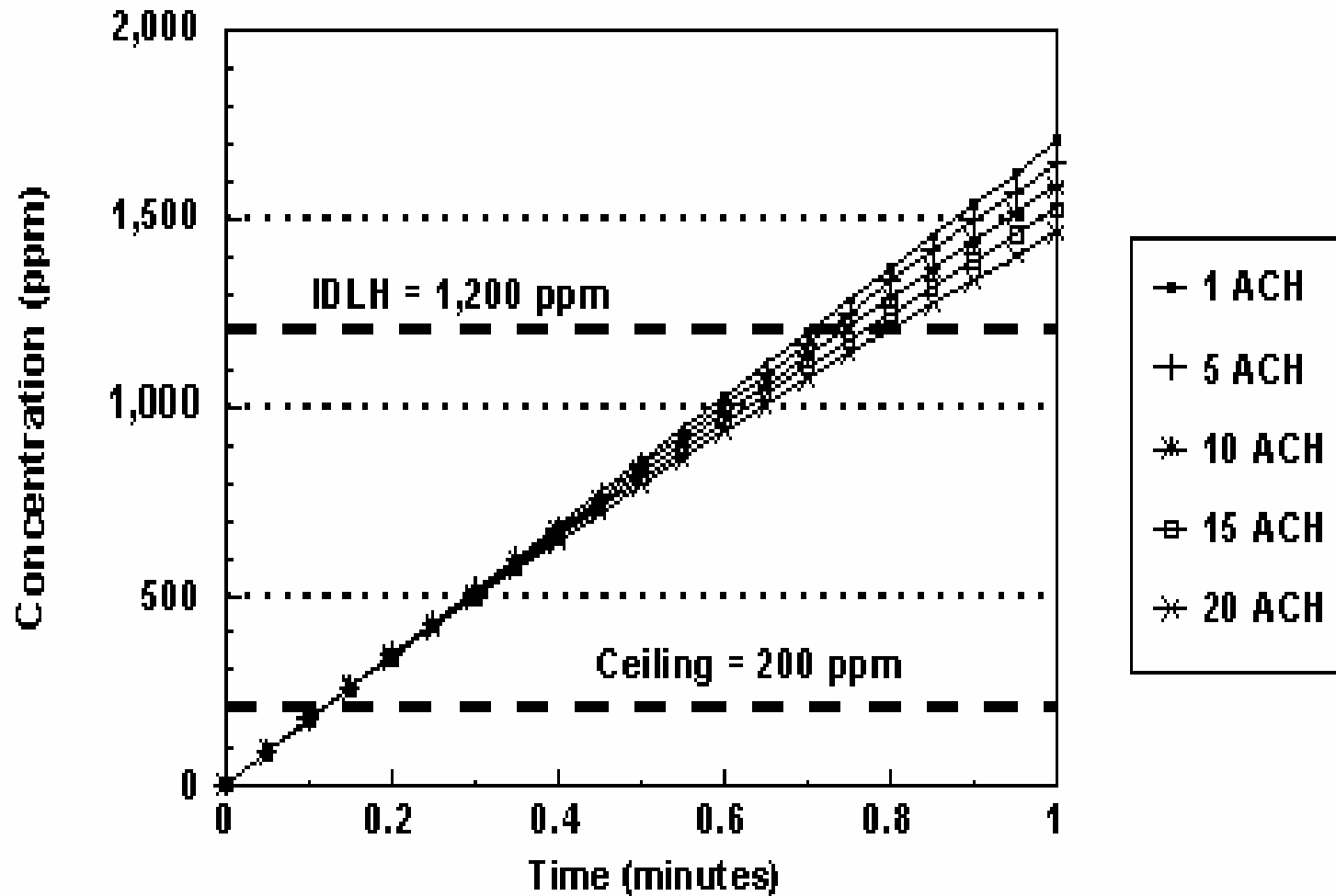


Small Motor Hazard

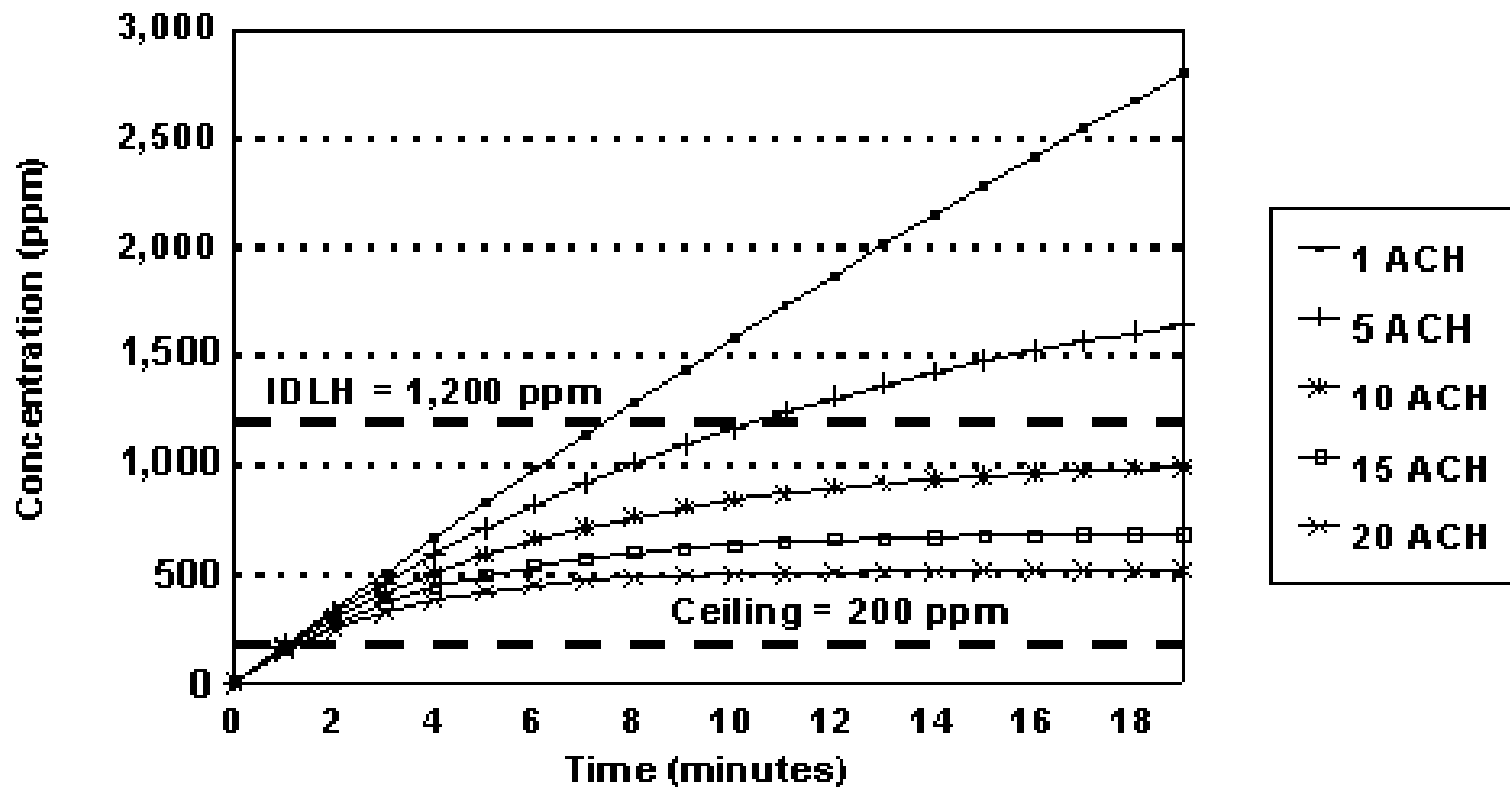
- **Low horse power, gas powered motors**
 - **Power washers**
 - **Tile cutters**
 - **Floor polishers**
 - **Industrial spray painters**
- **False ideas about safety**



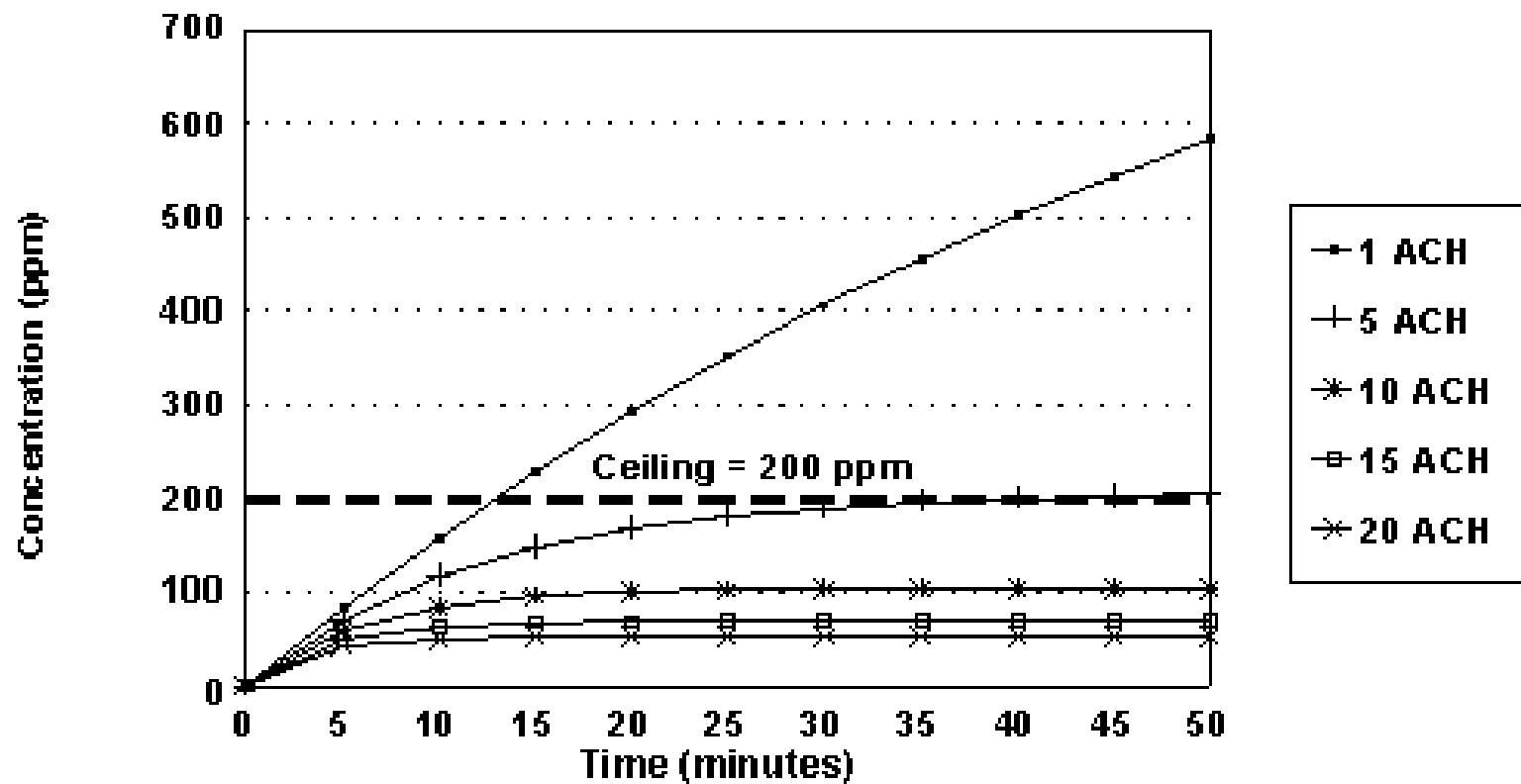
CO Concentration versus time (1,000 cubic foot room)



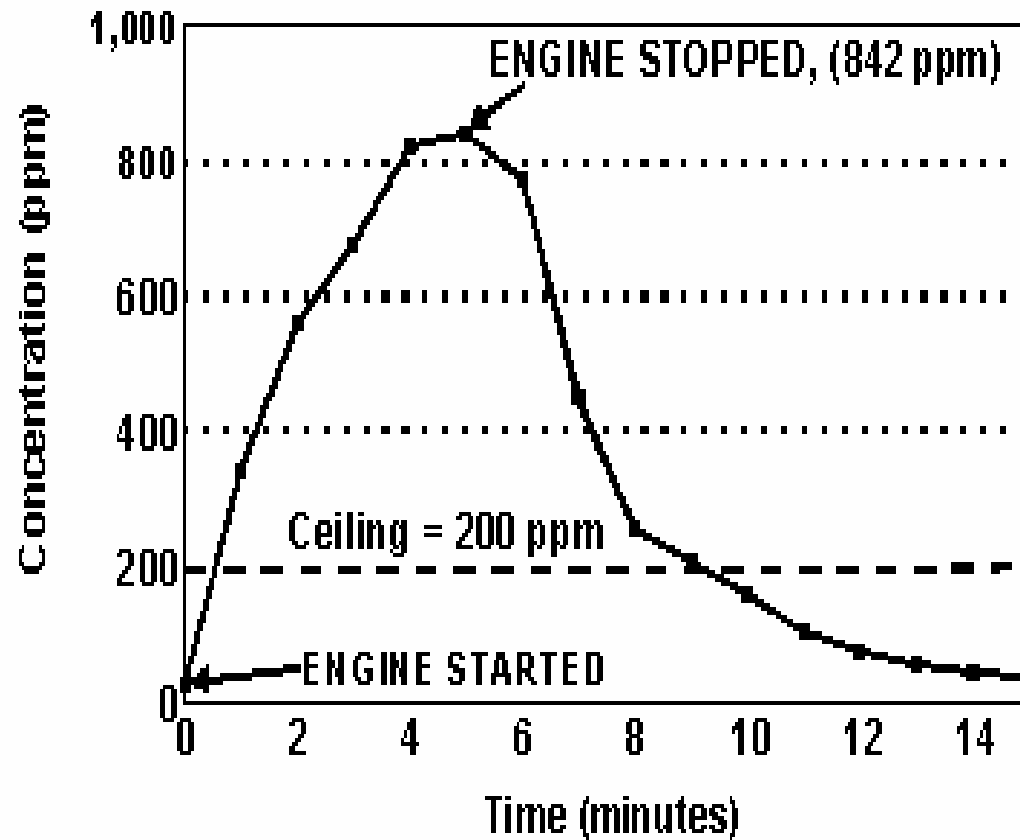
CO Concentration versus time (10,000 cubic foot room)



CO Concentration versus time (100,000 cubic foot room)



CO Concentration versus time (2,332 cubic foot room)





Gas Powered Pressure Washers

- **23/26 rental agencies surveyed by phone rented GPPW**
- **7/23 (30.4%) were specifically unaware of CO as a hazard and gave no precautions for indoor use when asked**



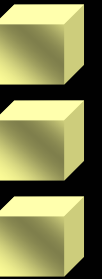


Phosphine

- Aluminum phosphide used as grain preservative
- Water contact----> phosphine gas
- Phosphine produces direct non-competitive inhibition of cytochrome oxidase resulting in widespread cellular hypoxia
- Damage to vessel walls and can causes bleeding diathesis as well as hemolysis

– Aggarwal P et al. Am J Em Med 1999 17 (5)



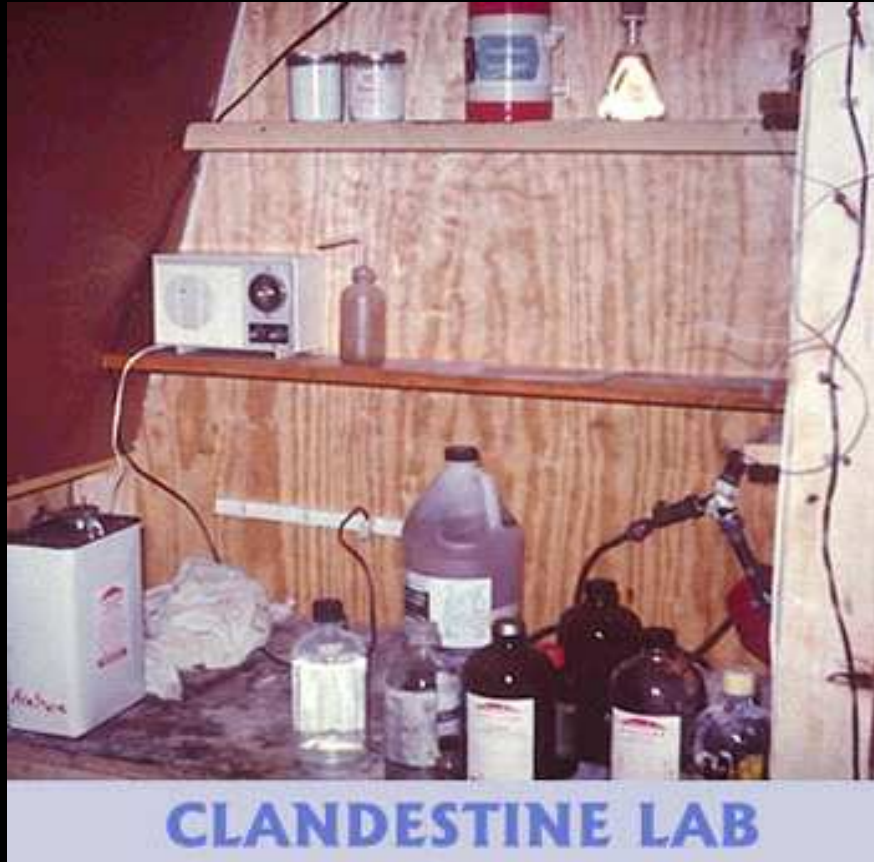




Occupational Phosphine Exposure

- Phosphine gas may be liberated during illicit meth production
- Burgess reported the first case of occupational exposure to phosphine in law enforcement personnel entering a clandestine “meth” lab

– Burgess. J Tox Clin Tox, 2000; 38(5)





Arsine

- Colorless, odorless, gas
- Produced when acids contact crude metals that contain As impurities
 - Galvanizing
 - Soldering
 - Plating
 - Chip manufacture
- Acute toxicity..... 25% mortality*
 - *Goldfrank's Toxicologic Emergencies






Arsine

ACUTE:

- Weak, dizzy, H/A, malaise
- Abdominal pain, intravascular hemolysis, renal failure after latent period up to 24 hrs
- Hematuria is hallmark finding (4-6 hrs post exp)

CHRONIC:

- Jaundice (24-48 hrs) w/ hepatosplenomegaly
 - Oliguria/anuria
 - Heart failure
- 

Arsine-Related Hemolysis

- Hgb < 10.0
- Low rbc counts
- Methemoglobinemia
- Coombs test (-)
- Serum K⁺ usually elevated
- BUN/Cr elevated





Case Report-Occupational Arsine Exposure

- **Gallium arsenide (GaAs) in semiconductor industry**
- **A worker failed to use the proper ventilation hood when acid washing GaAs chips and inhaled arsine fumes**
- **Over 48 hrs developed hemolytic anemia and dark urine**

↓ Hct 45.3% to 37.7%

↑ Blood arsenic

– **Caravati et al J Tox Clin Tox 2000; 38 (5)**





Treatment for Arsenic

- Remove from exposure
- Decontamination
- Stabilization
- Stop hemolysis/ restore renal function
- Exchange transfusion if free Hgb > 1.5 g/dl
- HD for renal failure
- Tx life threatening hyperkalemia
- No role for chelation





“Confined Space-Hypoxia Syndrome”

Two meter readers found dead in underground water meter pit. Studies revealed a decrease in oxygen and increase in carbon dioxide as a result of aerobic microorganisms present in the pit.

-Zugibe FT et al. J Forensic Sci
32(2),1987;554-559




DANGER-CO₂
—
Do not enter
without a
Safe-to-Work
Permit



“Confined Space-Hypoxia Syndrome”

- Proposed for all deaths occurring in:
 - Water meter pits
 - Tanks
 - Holds of ships
 - Mines
 - Underground storage bins, etc



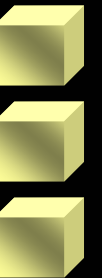
- 
- Also, in environments where oxygen has been consumed in a confined space:

- Welding

- Cutting

- Heating

- Brazing





% oxygen in atmosphere/health effects

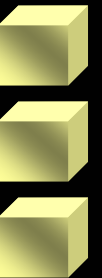
21 (normal oxygen content).....	None
19.5 (minimum oxygen level for safe entry).....	None
16	Impaired judgment and breathing
14	Faulty judgment, rapid fatigue
6.....	Difficult breathing, death in mins.

Source: NIOSH [1987]



Dry Ice...an Interesting Source of CO₂

- Dry ice is compressed, frozen CO₂
 - Sublimates and releases CO₂
- Density > air, displaces O₂ from lower to upper
- ↑ Ambient CO₂ levels
- Symptoms result from both decreased FIO₂ and increased inspired CO₂





Case report

- 50 yo researcher found dead in small freezer room containing 15 blocks (10 in x 10 in x 10 in) dry ice
- Room ventilation system was non-functional
- Air samples revealed 13.6% oxygen and 27.6 % Co_2 at 9 inches from floor

– Ely, et al. J Tox Clin Tox
1999; 37 (5)

Solid Carbon Dioxide (Dry Ice) WARNING

- Use in accordance with manufacturers Material Safety Data Sheet (M.S.D.S.)
- Extremely Cold (-109°F) Avoid Contact with skin, can cause frostbite.
- Dry Ice evaporates (Sublimes) to form Carbon Dioxide gas, which does not support life. Do not breathe gas. Exposure can cause rapid suffocation.
- Being heavier than air, Carbon Dioxide accumulates in low areas.
- Store and use with adequate ventilation.
- Wear suitable clothing such as long sleeve shirts/gloves appropriate to prevent skin from freezing.
- Use equipment designed for low temperatures.
- NON-Flammable — Does Not support combustion.

FIRST AID: In case of frostbite, obtain medical treatment immediately. If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Call physician.

DO NOT Remove this product label.

New England Dry Ice Company

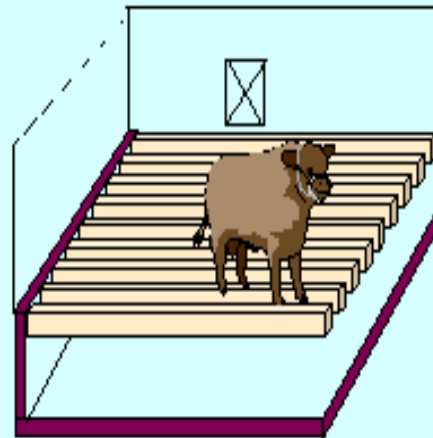
1-800-544-1012



Manure Pits

What are manure pits?

- Manure pits are underground tanks where manure is stored.
- Pits are located directly underneath where the animals live.
- Some manure falls through the slats in the floor. The rest is flushed away and into the pit with water.



Indoor Manure Pit





Manure pits...cont'd

- **Of the approximately 2.3 million farms in the United States [USDA 1985], an unknown number contain manure pits or tanks.**
- **Manure pit systems are used primarily on livestock farms (including dairy operations) to allow for the easy cleaning of animal confinement buildings and the efficient underground storage of large amounts of raw manure.**






The Boston Globe

5 killed in methane gas accident on Virginia dairy farm.

Poisonous fumes accumulated in manure pit

By Dionne Walker, Associated Press | July 4, 2007

BRIDGEWATER, Va. -- Deadly methane gas emanating from a dairy farm's manure pit killed five people: a Mennonite farmer who climbed into the pit to unclog a pipe, and then in a frantic rescue attempt that failed, his wife, two young daughters, and a farmhand who tried to help. "They all climbed into the pit to help," Sheriff Donald Farley said. "Before they hit the floor, they were probably all dead."





Manure pits...cont'd

- In the pit, manure undergoes anaerobic digestive fermentation and can generate four potentially lethal gases:
 - Methane
 - Hydrogen sulfide
 - Carbon dioxide
 - Ammonia
- Within the confined space of the manure pit can produce an oxygen-deficient, toxic, and/or explosive environment.






- **When manure remains in a pit, 4 gases can accumulate in high concentration:**

- Hydrogen sulfide
- CO₂
- Ammonia
- Methane

- **Some pits can be as deep as 8 feet**
- **Often have steep walls**
- **Drowning is also a hazard**





Five farm workers died after consecutively entering a manure pit


(20 x 24 x10 ft deep). Victims were a 65-year-old farmer, his two sons aged 37 and 28, 15-year-old grandson, and a 63-year-old nephew. The younger son initially entered the pit to replace a shear pin on an agitator shaft. (Agitation of the manure, which is required to facilitate transfer, causes a rapid release of the gases formed during decomposition.) While climbing from the pit, victim #1 was overcome and fell to the bottom. Grandson then entered the pit to attempt a rescue and was overcome. Nephew, older son, and the dairy farmer then entered the pit one at a time, attempting to rescue those already overcome. Each was overcome and collapsed in turn. A carpet installer working at the farm house then entered the pit to attempt a rescue. He too was overcome but was rescued by his assistant and subsequently recovered. Finally, the owner of a local farm implement business arrived on the scene with two of his workers and, using a rope, extricated the five victims from the pit.





Case Report: Two Fatalities

A pump intake pipe in a 25-foot-square, 4-1/2-foot-deep manure pit inside a building had clogged. The farmer descended into the pit to clear the obstruction and collapsed. Victim's brother, standing at the entrance of the pit saw the victim collapse and entered the pit to rescue him. The brother was overcome and collapsed inside the pit. 4 hours later, another family member discovered the two victims inside the pit and called the local fire department. Victims pronounced dead at scene by coroner who attributed the cause of death in both cases to methane asphyxiation



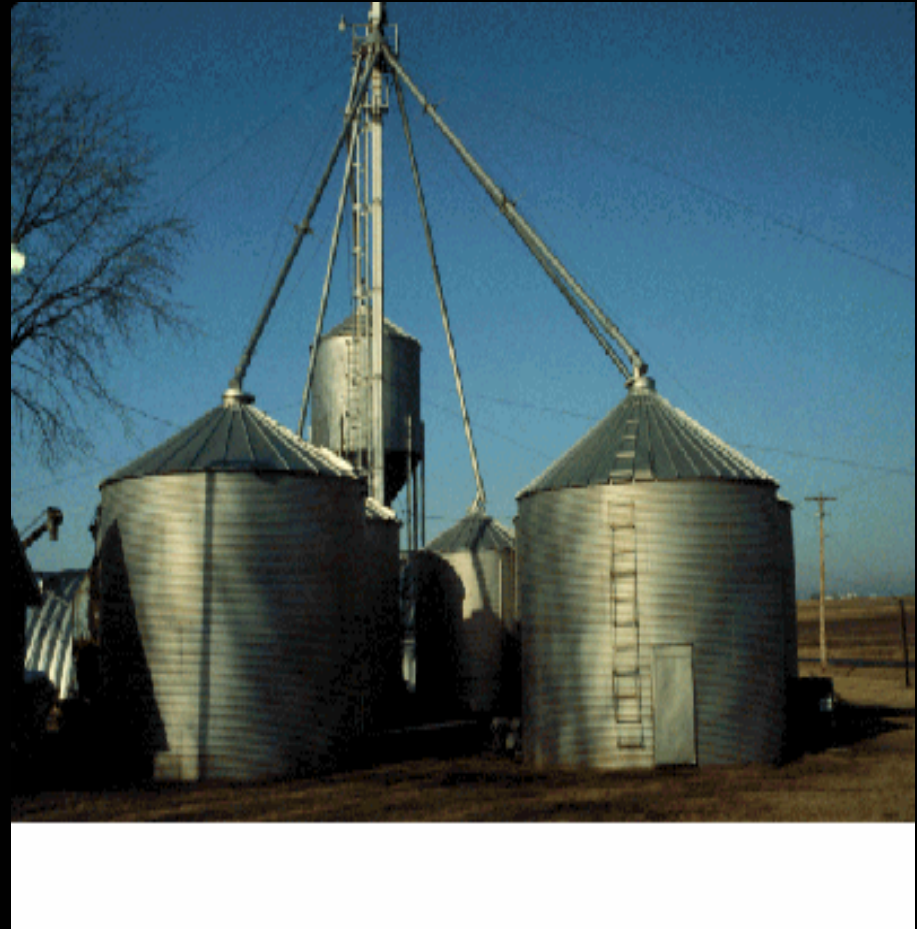
(NIOSH, 1989)

Surface Leaching Pit



Silo Hazards

- Oxides of nitrogen
- Produced when silage is oxidized to NO_2/NO_4
- Reacts w/ lung water forming nitric (HNO_2) and nitrous (HNO_3) acids
- Chemical pneumonitis & pulmonary edema





Silo Hazards...cont'd

- **Severe sx present within hours**
 - Cyanosis
 - Chest px
 - SOB, cough
 - N,V
- **Case fatality rate as high as 30-40%**
- **Sudden relapses occur after 2-6 wk latent period**
 - Bronchiolitis obliterans



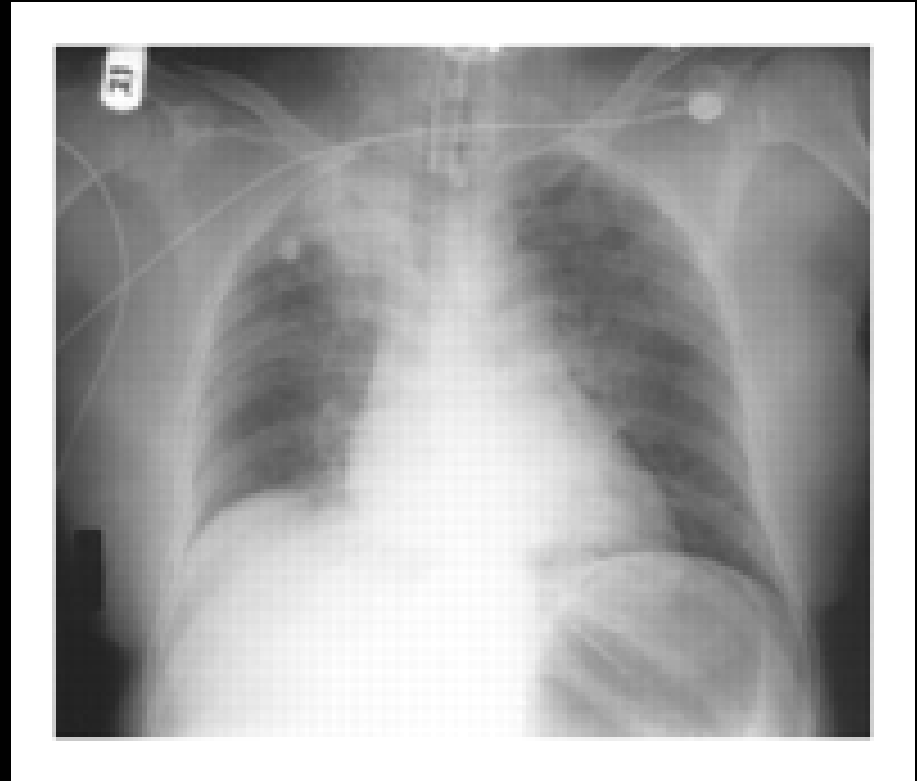
Chlorine/Chloramine

- Hypochlorite + Ammonia = **CHLORAMINE**
- Chloramine + lung $H_2O = \text{Hypochlorous acid} + NH_4$
- Ocular/upper respiratory irritants
- Pneumonitis
- Metabolic acidosis
- ARDS
- Death



Chloramine

- May also be formed when hypochlorite (bleach) is added to septic systems or when pipes are clogged
- Bleach + urine =
Chloramine





Chlorine/Chloramine

- Pneumomediastinum has been reported from chlorine gas produced by mixing cleaning products*
- Tanen et al reported on upper airway swelling requiring tracheostomy and ventilatory support after chloramine exposure in a walk-in freezer**

*Gapany-Gapanavicious, et al. 1982 JAMA; 248

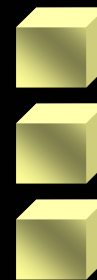
**Tanen, et al., 1999 J Tox Clin Tox; 37 (5)





Hydrogen Sulfide--Uses

- In metallurgy for the preparation of metallic sulfides
- In the preparation of phosphors, oil additives
- Analytical reagent in chemical analysis
- In metals separation
- Removal of metallic impurities
- Reaction with numerous functional organic compounds.





H₂S-Dx

- **Tx based on history/clinical findings**
 - “Knock-down” agent
- **No specific means of detection at bedside**
- **Odor of rotten eggs**
- **Darkening of jewelry and coins**
- **Confirm with environmental testing**





H₂S...The “Coin Darkening” Sign

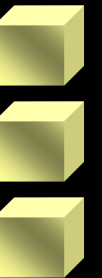
- Graeme* et al evaluated recently minted coins for darkening in H₂S environment
- Purple-purple/blue color changes at edges of pennies were the earliest most consistent change





- **Corrugated edges of dimes were similar**
- **May be earlier and more sensitive marker of clinically significant H₂S exposure**

– Graeme KA,et al J Tox Clin Tox, 1998 36 (5)





Case Report

- Petroleum industry worker investigating possible gas leak in at ceiling level
- Overcome by H₂S; fell from ladder
- Sustained non-life threatening T-spine fracture

– Perrone JM, personal communication; 1999





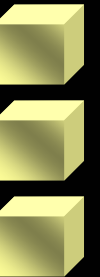
H₂S- Tx

- **Death rapid/ few human cases in literature**
- **Oxygen**
- **Treat acidosis**
- **Reports imply HBO may be helpful**
- **Animal work suggests sodium nitrite may help**
 - **H₂S affinity for Met-Hgb > cytochrome oxidase**



American Dentist Horace Wells (1815-1845)

- First to use nitrous oxide as an anesthetic in dentistry.





Nitrous Oxide: Acute Effects

- Death secondary to asphyxia
 - Inadequate O₂/ high conc. of gas
- Inhaled contaminants
- 35 x more soluble in blood than nitrogen
 - Inhalation
 - Compliant spaces expand
 - Non-compliant increase pressure
 - Tension pneumothorax





NO₂-Bone Marrow Effects

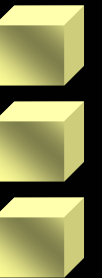
- **Oxidizes cobalt, converting B12 to inactive form**
- **This inactivates methionine synthase needed for methionine production**
- **Methionine is essential for myelin production and DNA synthesis**
- **Bone marrow depression and polyneuropathy results**





CNS Effects of NO₂

- **Disabling sensori-motor polyneuropathy**
- **Similar to pernicious anemia**
- **Requires months (not years) to develop**
- **May be seen in dentists and O.R. personnel (under-diagnosed)**

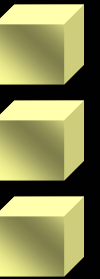


Nitrous Oxide...cont'd

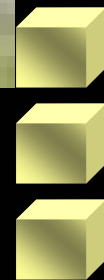
- Nitrous is used in the dairy industry as a mixing and foaming agent
- Nitrous is also used in auto racing to speed engines.
- Nitrous is also used in diving to prepare divers for nitrous-like effects.

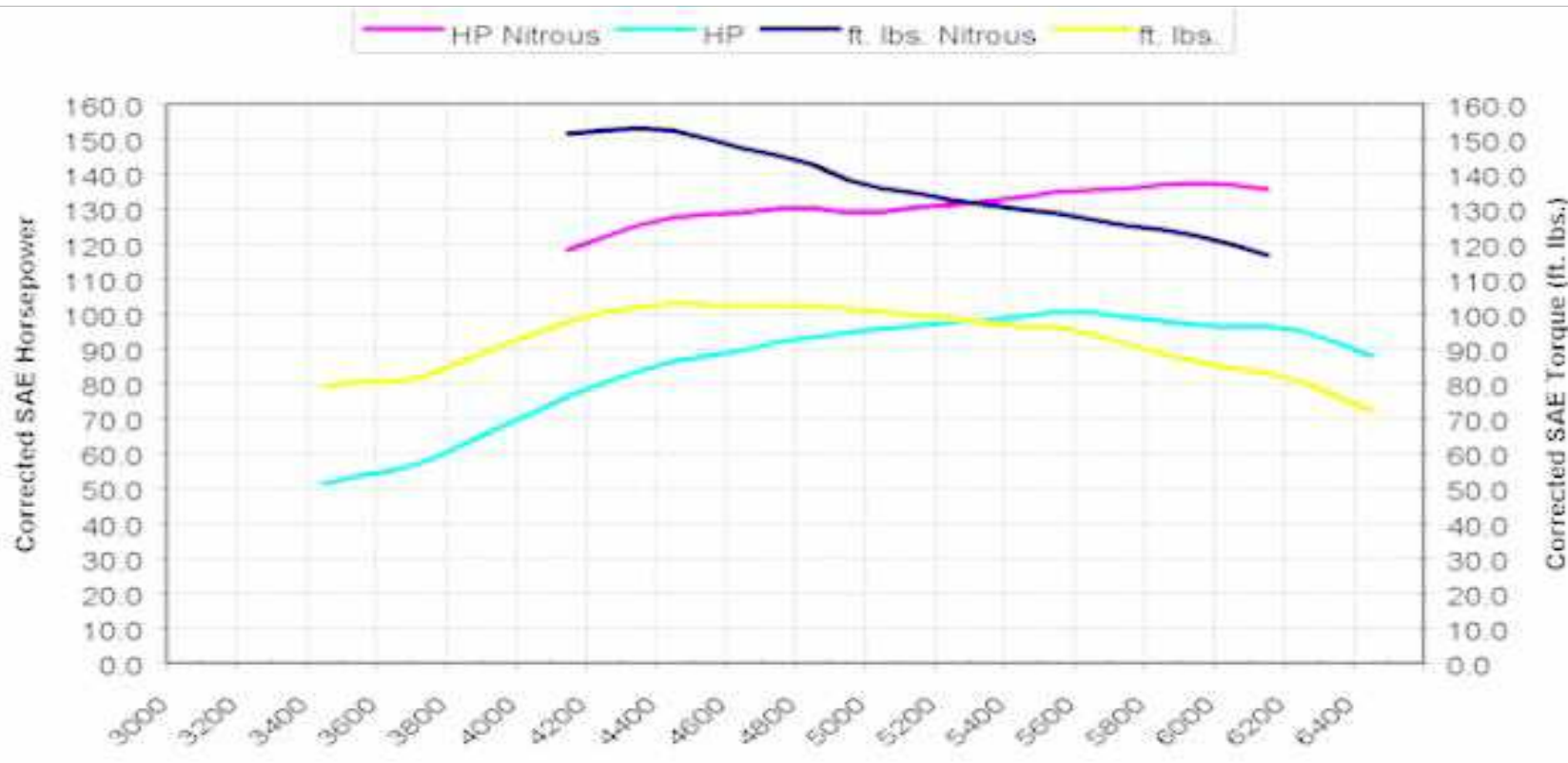






Nitrous Oxide





How much extra performance can nitrous oxide give your bike? Here is a comparison for an 89 CID Sportster. With "Juice" the horsepower jumps from 101 to 138. The increase in torque was even more impressive, from 103 ft. lbs. to 154 ft. lbs. Riding this bike down the drag strip is not for the faint of heart.



Famous Nitrous Oxide Users

Samuel Taylor Coleridge, 1772-1834, English Poet

Robert Southey, 1774-1843, English Poet

Humphrey Davy, 1778-1829, English Chemist

Peter Mark Roget, 1779-1889, Author of 'Roget's Thesaurus'

Samuel Colt, 1814-1862, American Inventor of the Colt .45

William James, 1842-1910, American Philosopher

Theodore Dreiser, 1871-1945, American Writer and Journalist

Winston Churchill, 1874-1965, English Politician

Allen Ginsberg, 1926-, American

Gregori Corso, 1930-, American Poet

Ken Kesey, 1965-, American Writer



Hydrofluoric Acid

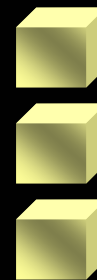
- This facility has enough HF on-site, over 260,000 pounds, to have impacts quite a distance away in the event of a catastrophic release or spill. A large freeway interchange is within a half mile.





Hydrofluoric Acid

- Fatalities are only rarely reported
- Kao et al reviewed 1772 HF exposures looking for ingestions (n=135)
 - All involved consumer products; 6-8% HF
 - Most had mild GI symptoms
 - 2 pts died
 - Of 29 cases with recorded Ca levels, only 4 involved hypocalcemia
- Kao, Dart et al J Tox Clin Tox 1998; 36 (5)






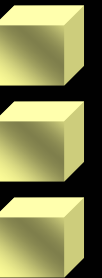
Hung et al reported 51 yo sanitation worker sprayed with HF (80%) while working.

- Immediate dyspnea and chest pain
- 5% body exposure
- EKG---- NSR QTc= 491 msec
- K= 5.8 mEq/L
- Expired 43 hrs after presentation
- Autopsy:
 - Multi-organ hemorrhage
 - Severe laryngeal edema
 - Coagulopathy
 - **Hung, Flomenbaum, et al J Tox Clin Tox 1998 36 (5)**



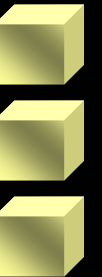
- 
- 51 yo male fell and was totally immersed in HF solution (10-12%)
 - Removed clothing/washed immediately
 - Initial serum Ca=3.9 mEq/L (nl: 4.2-5.1)
 - Exam:
 - Mild respiratory distress
 - Facial edema
 - Skin erythema
 - + Chvostek's sign

• Sadove R. et al South Med J 83:1990





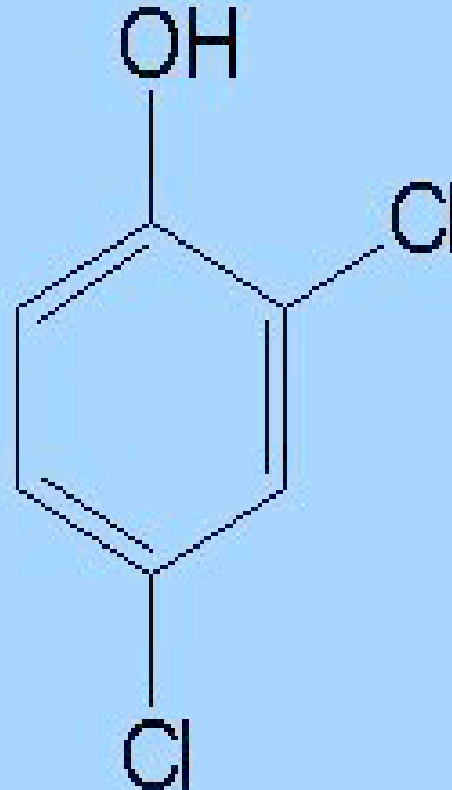
- 3 Hrs post exposure, Ca=3.0
- Pt improved with iv calcium and magnesium
- Elevated urine and serum flouride levels returned to normal in 25 days



2,4-Dichlorophenol (2,4-DCP)

- Rapid death with skin exposure to heated form of the chemical

-MMWR June 16, 2000

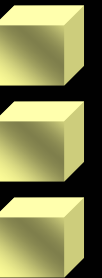




2,4-Dichlorophenol (2,4-DCP)

- **A feedstock chemical used to produce the herbicide 2,4-D**
(dichlorophenoxyacetic acid)
- **Several acute and rapidly occurring deaths following skin exposure have been reported**
- **All followed dermal exposure to heated form of the chemical**

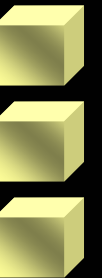
-MMWR June 16, 2000






2,4-DCP cases

- **Worker at chemical co. producing 2,4 D sprayed with 2,4,-DCP from a leak in tubing while using steam to clear a blocked pump (died in 60 mins)**
- **Worker splattered with pure 2,4-DCP while disposing of industrial waste (died in 20 mins)**
- **Worker at manufacturing plant splashed with 51% 2,4-DCP (died in 90 mins)**





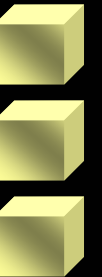
2,4-DCP

- **White solid at RT; liquifies at 111F-116F**
 - **Rapidly absorbed through skin**
 - **At least 8 US facilities handle this agent**
 - **Estimated annual production = 88 million pounds**
 - **No exposure limits exist**
- 



2,4-DCP

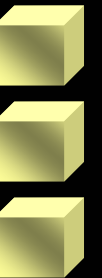
- **Most ATP results from oxidative phosphorylation**
- **Chlorinated phenols uncouple oxidative phosphorylation**
- **In animals: tremor, weakness, incoordination, seizures, dyspnea, coma, respiratory arrest**





2,4-DCP-Treatment

- **No antidote**
- **Decontamination**
- **Copious water irrigation**
- **Supportive care**



Go Eagles!!







Phosgene

- One of the first chemical weapons used in warfare. (Verdun, 1917)
- No longer stockpiled by any armed forces
- Commercially used in the production of pesticides and dyes
- By-product of burning paint, chlorinated compounds
- Phosgene is a respiratory irritant





Phosgene

- Phosgene is produced commercially by chlorinating carbon monoxide
- Combustion or decomposition by-product of most volatile chlorinated compounds:
 - Household substances
 - Solvents
 - Paint removers
 - Dry cleaning fluids
 - Produced during the welding of metal parts that have been cleaned with chlorinated hydrocarbons.





Phosgene

- **Workplace exposure to phosgene occurs during its manufacture, handling, and use**
- **Exposure to phosgene may occur in the ambient air from direct industrial emissions of phosgene and thermal decomposition of chlorinated hydrocarbons**





Phosgene

- **Dermal** - If the skin is wet or moist, contact with phosgene vapor can cause irritation and erythema. Contact with liquid phosgene under pressure can result in frostbite injury.
- **Ocular** - High vapor concentrations can cause lacrimation and conjunctival hyperemia. Contact with liquid phosgene may result in corneal opacification and delayed perforation.





Pathophysiology

- Phosgene is poorly water soluble and hydrolysis tends to be slow
- Victims inhaling low concentrations experience no symptoms/ mild irritation of upper airway
- Lack of irritation allows victims to inhale the gas deeper into the lungs and for a prolonged period

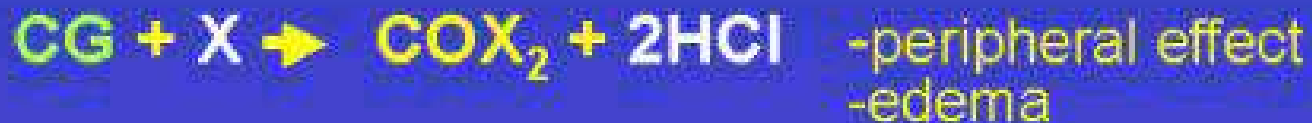


PHOSGENE - Mechanism of Injury

- **Reaction 1:** hydrolysis, generation of HCl



- **Reaction 2:** acylation, X = NH, NR, O, S





Phosgene...cont'd

- **Direct cytotoxicity causes increased capillary permeability with large fluid shifts with resultant decrease in plasma volume**
- **When phosgene hydrolyzes, it forms hydrochloric acid which causes epithelial damage and cellular necrosis in the bronchi and small bronchioles**





Phosgene-Pulmonary Sx

- **Low concentrations may cause no signs or symptoms initially, or only mild irritation of the airways, with dryness and burning of the throat and cough**
- **These symptoms may cease when the patient is removed from exposure**
- **After an asymptomatic interval of 30 minutes to hours, chest pain, bronchospasm, hypoventilation, and bradycardia can develop**





Pulmonary Sx...cont'd

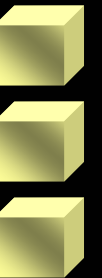
- Latency period of up to 24 hours may occur before profound damage manifests:
 - dyspnea,
 - hypoxemia
 - severe transudative (non-cardiogenic) pulmonary edema
- Hemolysis in pulmonary circulation can cause capillary plugging that leads to cor pulmonale and death





Phosgene-Cardiovascular Sx

- **Cardiovascular collapse may occur if the patient is severely hypoxemic from pulmonary edema**





Phosgene-Potential Sequelae

- **If the patient survives the initial 48 hours, recovery is typical**
- **Sensitivity to irritants may persist, causing bronchospasm and chronic bronchitis**
- **Pulmonary tissue destruction and scarring may lead to bronchiectasis and increased susceptibility to infection**





Phosgene Treatment

- Supportive care/ strict rest
- Methylprednisolone blocks leukotriene synthesis*
- Ibuprofen decreased pulmonary edema
- Colchicine*
- Cyclophosphamide*
- ET NAC in rabbits decreased leukotriene levels and limited pulmonary edema**
- IV NAC

– *Guo, et al. J Appl Physiol 1990; 69

– ** Sciuto et al. J Appl Tox 1996; 16

