Chemical
SAFETY AND SECURITY TRAINING

## Chemical Safety and Security Officer Training

**Kuala Lumpur, Malaysia**
**December 2010**

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Sandia National Laboratories

# Chemical Toxicology and Physiology



**US National Institutes of Health,**
**National Library of Medicine (NIH/NLM)**
**on-line**
**Toxicology Course**

**I. Basics**
**II. Toxicokinetics**
**III. Cellular Toxicology**

**http://sis.nlm.nih.gov/enviro/toxtutor.html**



# Simplified Physiology

## Major Parts of the Cell

**All organisms are made up of cells: (eukaryotic, prokaryotic)**

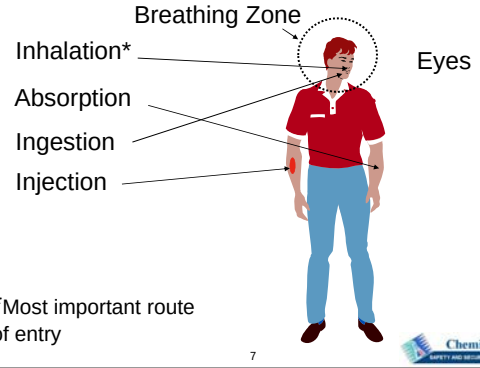
- **Cells membrane** – regulate entry
- **Cytoplasm** – liquid atmosphere of cell
- **Mitochondria** – energy production – ATP
- **Nucleus** – DNA – genes, cell division
- **Golgi** – secretory function
- **Lyzosome** – digestive function

## In the Body…

- **Cells** combine to form tissues which are specialized – connective, nerve, muscle
- **Tissues** combine to form organs which can perform complex functions
- **Organs** combine to form systems, e.g., respiratory, reproductive, nervous, circulatory system



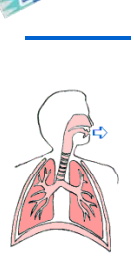
## Routes of Exposure

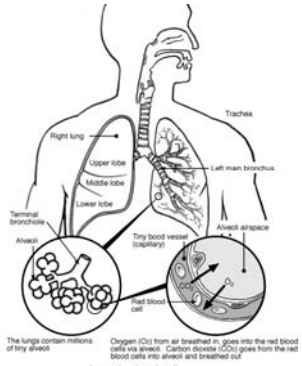


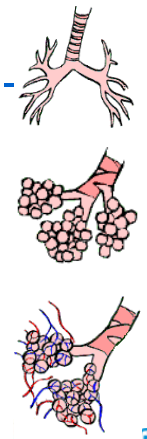

*Most important route of entry



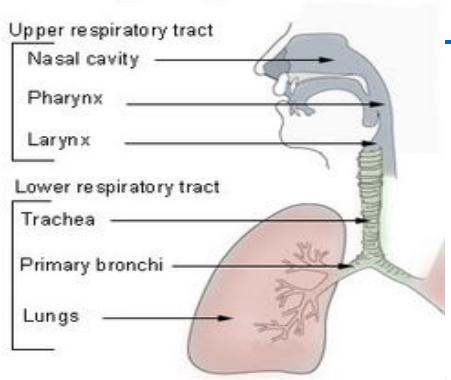
## Respiratory System





## Conducting Passages






## The Lungs
## Defense Mechanisms

- **Cilia**
  - Mucus traps dirt and foreign particles.
  - Little hairs (**cilia**) beat back and forth in the airways to move mucus and dirt up where it can be expelled by coughing.
- **Macrophages**
  - Special mobile cells that eat up toxins in the airways and lungs .
- **Requirements:**
  - Regular supply of air with $O_2$
  - Open, clear airways.



## Gas Exchange Region

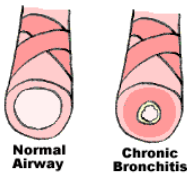
- About 70 sq meters – the serving area of a tennis court.
- Consists of alveolar duct and alveoli with surfactant to keep open.

- Close contact with capillaries to exchange $O_2$ for $CO_2$ and exhale other gases/vapors.



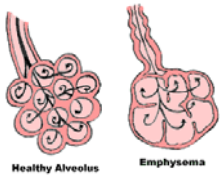
## Common Respiratory Issues

Chronic Bronchitis




- Cells inflamed
- Airway narrow and clogged

Emphysema




- Normal elasticity destroyed
- Forcefully blow the air out, pressure on the airways
- Excessive coughing

## Routes of Exposure

### Inhalation (lungs)

- **Most important route if exposed to gases, vapors, mists, aerosols.**
- **Influenced by respiration rate, concentration, duration.**
- **Key factors for gases and vapors:**
  - solubility and reactivity
- **Key factors for aerosols:**
  - particle size and solubility
    - respirable size: 0.1 μm to 10 μm
  - < 5 μm reach alveolar region

## Aerosol Penetration into the Lung

| Size (micrometers) | % Deposition |
|---|---|
| > 20 | 100% in upper airways |
| 10 – 20 | 80% upper, 0+ alveoli |
| 5.0 – 10 | 50% upper, 50% alveoli |
| 0.1 – 5.0 | 0+ upper, 90+ alveoli |

## Potential Response

- **Lung tissue damage**
- **Transfer point direct to bloodstream**
  - **transported to target organs - systemic**
- **Responses:**
  - **respiratory tract irritation**
    - **airway constriction**
    - **infection or fluid build-up (edema)**
  - **sensitization**
    - **allergic response, chronic pulmonary disease**
  - **fibrosis**
  - **carcinogenesis**

## Certain Effects of Chemicals on the Lungs

- **Irritations** – acid mists (HCl)
- **Edema** – phosgene ($COCl_2$)
- **Emphysema** – smoke (esp. tobacco)
- **Fibrosis** – silicon dioxide ($SiO_2$)
- **Cancer** – asbestos (mesothelioma)

## Asphyxiant / Suffocating Agent

- **Physical** – dilute oxygen in air to below 10%, non-irritant gases – methane, $N_2$, $CO_2$, Freon®
- **Chemical** – displace oxygen on hemoglobin – cyanide, carbon monoxide

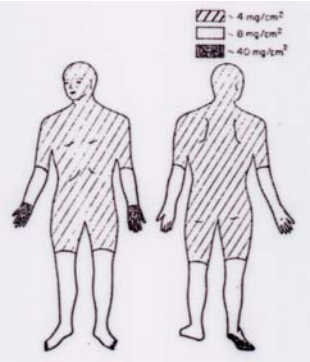


## Routes of Exposure

**Skin absorption**

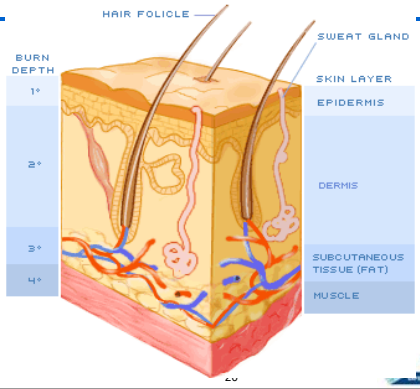
- **Depends on *site* of contact**
  - temperature (vasodilatation)
  - thickness, blood flow
- **Depends on skin *condition***
  - integrity; pH
- **Time-dependent (*duration*)**
- ***Properties* of the toxin**
  - concentration
  - reactivity
  - solubility (in fat/water)
  - molecular size

## Skin Thickness

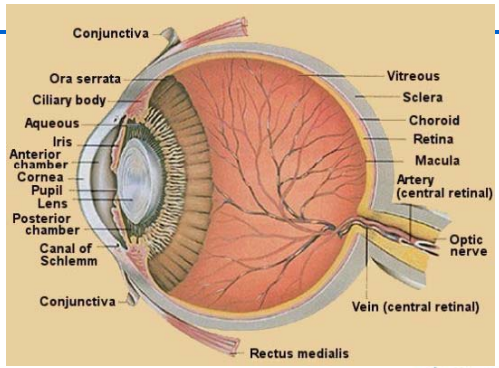





## Skin



# The Eyes






# Routes of Exposure

## Ingestion (mouth)

- **Rare, but contamination can = intake**
  - mucociliary action of respiratory tract
- **Stomach → GI tract → bloodstream**
- **Absorbed - systemic injury**
- **Liver, kidney; Detoxification process**
  - Inflammation
  - cirrhosis - fibrotic liver disease
  - malignant tumors
- **Factors: physical state, duration**

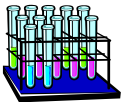
# Routes of Exposure

- **Injection**
  - **Directly into bloodstream**
    - "sharps", needles, broken glassware
    - skin puncture or injuries
  - **Bypasses protective mechanisms**
  - **Usually rare in workplace**
    - primarily associated with bloodborne pathogens (biomedical facilitates)
    - especially hazardous in health care industry

# Chemical Toxicology

## The World of Chemicals

- **Universe of Chemicals > 5 Million**
- **Industrial Inventories ~ 55,000**
- **Regulated Occupationally ~ 600**





## Toxicology

**Poisons** - *the adverse effects of substances on living systems.*

"All substances are poisons; There is none which is not a poison. The right dose differentiates a poison from a remedy…" — Paracelsus (1493-1541)

**Chemical Toxicology –** *The potential adverse effects and control of chemicals in the workplace.*



## Terminology

| | |
|---|---|
| **Toxicants** | • Substances that produce adverse biological effects of any nature<br>• May be chemical or physical in nature<br>• Effects may be of various types (*acute, chronic, etc.*) |
| **Toxins** | • Specific proteins produced by living organisms (*Mushroom toxin or tetanus toxin*)<br>• Most exhibit immediate effects |
| **Poisons** | Toxicants that cause immediate death or illness when experienced in very small amounts |



## Basic Concepts

- ***Toxicity* – capacity to cause injury**
- ***Hazard* – potential harm associated with a specific substance under potential exposure conditions**
- ***Risk* – the likelihood or chance that harm will occur under actual conditions**

**(Toxicity) X (Exposure) = Risk**

## Basic Concepts

- All chemicals have the capacity to be toxic
- All chemicals act in the body according to the principles of chemistry, physics and biology
- Natural chemicals are not inherently harmless
- Synthetic chemicals are not inherently hazardous



## The Dose Makes the Poison

| Chemical | Beneficial Dose | Toxic Dose |
|---|---|---|
| Aspirin | 300-1000 mg | 1000-30,000mg |
| Vitamin A | 500 units/d | 50,000 units/d |
| Oxygen | 20% in air | 50-100% in air |



## Lethal Dose

| Agent | $LD_{50}$ (mg/kg) |
|---|---|
| Ethyl Alcohol | 7060 |
| Sodium Chloride | 3000 |
| Naphthalene | 1760 |
| Ferrous Sulfate | 1500 |
| Aspirin | 1000 |
| Formaldehyde | 800 |
| Ammonia | 350 |
| Dextromethorphan Hydrobromide | 350 |
| Caffeine | 192 |
| Phenobarbital | 150 |
| Chlorpheniramine Maleate | 118 |
| DDT | 100 |
| Strychnine Sulfate | 2 |
| Nicotine | 1 |
| Dioxin | 0.0001 |
| Botulinus Toxin | 0.00001 |



There are no harmless substances.

Only harmless ways of *using* substances.

## Chemical Toxicology

***The study of the effect the chemical has on the body.***

## Pharmacokinetics

***The study of the effect the body has on the chemical.***



## Toxicity Studies

**Determine toxic effect** – local effect, target organ, systemic effect, acute, chronic effects.

**Determine toxic dose** – identify the dose that will produce a given toxic effect.



## Factors Influencing Toxicity

- **Concentration of toxin**
- **Duration and frequency of exposure**
- **Route of exposure**
- **Environmental factors — temperature, humidity, atmospheric pressure**
- **Chemical combinations (difficult and expensive to test)**



## Factors Influencing Toxicity

- **Age**
- **Gender and hormonal status**
- **Genetic makeup**
- **State of health—presence of disease or stress**
- **Nutrition**
- **Lifestyle**

## Toxicity Testing Assumptions

- Effects seen in animals apply to humans

- High doses in animals are needed to predict possible hazard to humans

## Routes of Chemical Exposure

**Occupational**

- Inhalation
- Dermal/ocular
- Ingestion

**Experimental**

- Subcutaneous
- Gavage/ip/iv

## Duration of Exposure

- Acute 1 to 5 days
- Subchronic 14 to 90 days
- Chronic 6 months to lifetime

## Basic Concepts

- Dose and response can be measured
- Response magnitude is related to dose
- All toxic interactions follow a dose-response relationship

## Dose-Response Relationship

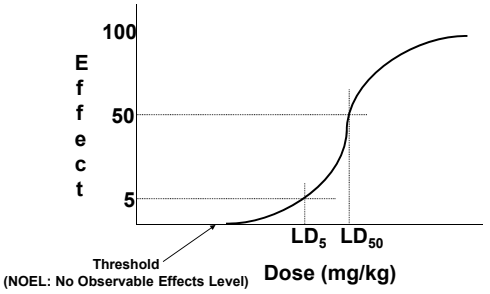
- With increasing dose, there is an increase in the number affected and/or an increase in the intensity of the effect: e.g., mortality; cancer; respiratory depression; liver pathology

**Dose = (Concentration) x (Time)**



## Dose-Response Relationship

This relationship is unique for each chemical






## Slope of Dose-Response Relationship

- Determines tradeoffs between drug effectiveness and toxicity.
- Low doses may be effective without producing toxicity.
  - More patients may benefit from higher doses.
  - Offset by the higher probability that toxicity or death could occur.
- Slope important in comparing toxicity of various substances.
  - For some, a small increase in dose causes a large increase in response.
  - For others, a much larger increase in dose is required to cause the same increase in response.



## Subchronic/Chronic Terms

- NOAEL **no observed adverse effect level**
- LOAEL **lowest observed adverse effect level**
- MTD **maximum tolerated dose**
- RfD **reference dose = safe daily dose for almost every individual**

## Threshold Concept

- No-observed (adverse) effect-level (NOEL)(NOAEL)
  - *the highest dose in an experiment which did not produce an observable effect.*
- Lowest observed (adverse) effect-level (LOEL)(LOAEL)
  - *the lowest dose which produced an observable adverse effect.*



## Dose-Response Relationship

- Fundamental concept in toxicology
- The relationship between the degree of exposure (dose) and the magnitude of the effect (response)
- Provides basis for evaluating a chemical's relative toxicity



## Dose and Dosage

- Dose is *quantity* (mg, mL)
- Dosage includes *frequency* (10 mg, 4 times/day)
- Exposure dose – quantity administered
- Absorbed dose – Actual quantity absorbed



## Dose-Response Terms

- $TD_{lo}$ – Toxic dose low - lowest dose for effect
- $LD_{10}$ – Lethal dose 10% - dose that causes death in 10% of the test population
- $LD_{50}$ – Lethal dose 50% - dose that causes death in 50% of the test population
- $TC_{lo}$ – Toxic concentration low - used to express toxic concentration *via* inhalation
- $LC_{10}$ – Lethal concentration 10% - dose that causes death in 10% of the test population –*via* inhalation
- $LC_{50}$ – Lethal concentration 50% - concentration that causes death in 50% of the test population *via* inhalation

## Concentration Units

**Mass per Volume**

- mg/m$^3$ (milligrams per cubic meter)
- µg/m$^3$ (micrograms per cubic meter)
- ng/m$^3$ (nanograms per cubic meter)
- PPM: Parts of a substance per million parts of air
  - 1 minute in 2 years
- PPB: Parts of a substance per billion parts of air
  - 1 second in 32 years
- PPT: Parts of a substance per trillion parts of air
  - 1 second in 320 centuries (1 century = 100 years)



| Unit | Gram Equivalents | Exp. Form |
|---|---|---|
| Kilogram (kg) | 1000.0 g | $10^3$ g |
| Gram (g) | 1.0 g | 1 g |
| Milligram (mg) | 0.001 g | $10^{-3}$ g |
| Microgram (µg) | 0.000,001 g | $10^{-6}$ g |
| Nanogram (ng) | 0.000,000,001 g | $10^{-9}$ g |
| Picogram (pg) | 0.000,000,000,001 g | $10^{-12}$ g |
| Femtogram (fg) | 0.000,000,000,000,001g | $10^{-15}$ g |



## Dose Units

Mass per weight or surface area of subject:

- Quantity per unit mass (mg/kg)
- Quantity per unit area of skin surface (mg/m$^2$)



## Pharmacokinetics

Rate of:

- Absorption (uptake) – chemical enters
- Distribution (transportation) – spread/storage
- Metabolism (biotransformation) – processing
- Excretion – elimination

## Metabolism

One purpose of metabolism is to make the chemical more water soluble so it can be excreted.

Done by adding oxygen molecules in the form of -OH, =O, -COOH, or by conjugation with glutathione, sulfonate, glycine, etc.

Some chemicals are not directly carcinogenic, but are metabolized to intermediates, e.g, epoxides, which are highly carcinogenic.



## Metabolism, cont'd.

Chemicals not metabolized are stored in the body (e.g.):

- Lipid soluble materials in fat cells
- Metals are bound to proteins (hemosiderin)
- Dusts are deposited at surface of lung

*This is why tattoos stay in place!*



## Metabolites

Benzene ($C_6H_6$)
carcinogenic
phenol, S-phenylmercapturic acid in urine

Toluene

CNS depressant
hippuric acid in urine

Ethyl benzene

irritant, dermatitis
mandelic acid in urine

Xylene ($C_6H_4(CH_3)_2$)
CNS, irritant
methyl hippuric acid in urine

Styrene

dermatitis
mandelic acid in urine



## Interaction of Chemicals

- **Additive Effect**
  - Combined effect of 2 chemicals equals sum of each agent alone…(2 + 3 = 5)
- **Synergistic Effect**
  - Combined effect of 2 chemicals is greater than sum of each agent alone…(2 + 3 = 20)

## Interaction of Chemicals

- **Potentiation**
  - **One substance does not have toxic effect on certain organ or system, but when added to another chemical, it makes the latter more toxic…(0 + 2 = 10)**
- **Antagonism**
  - **2 chemicals, when given together, interfere with each other's actions or one interferes with the action of the other chemical…(4 + 6 = 8)**



## Site of Effects

- **Local**
  - **Effects occurring at site of first contact between biologic system and toxicant**
    - **Ingestion of caustic substances**
    - **Inhalation of irritant materials**
- **Systemic**
  - **Require absorption and distribution of toxicant to a site distant from entry point where effects are produced; most substances produce systemic effects**
    - **$CCl_4$ effects on the liver**



## Target Organs for Chemicals

**Systemic toxin** - affects entire body or many organs rather than a specific site, e.g., KCN affects virtually every cell and organ in the body by interfering with the cell's ability to utilize oxygen.

**Toxicants** - may also affect only specific tissues or organs while not producing damage to the body as a whole. These specific sites are known as Target Organs.

**Benzene** - a specific organ toxicant that it is primarily toxic to the blood-forming tissues.

**Lead** - has three target organs (central nervous system, kidney, and hematopoietic system).



## Comparative Toxicity

| Toxicity Rating | Dose for a 70 kg Person (154 lb) | |
|---|---|---|
| Super Toxic | < 5 mg/kg | (a taste, < 7drops) |
| Extremely Toxic | 5-50 mg/kg | (7 drops – 1 tsp) |
| Very Toxic | 50-500 mg/kg | (1tsp – 30g) |
| Moderately Toxic | 0.5-5 g/kg | (30g – 500g) |
| Slightly Toxic | 5-15 g/kg | (500g – 1kg) |
| Practically Nontoxic | > 15 g/kg | (>1kg) |

## Target Organs

**Organs selectively affected by harmful agent:**

- Lungs (pneumotoxicity)
- Blood (hematotoxicity)
- Liver (hepatotoxicity)
- Kidneys (nephrotoxicity)
- Nervous system (neurotoxicity)
- Immune system (immunotoxicity)
- Embryos/fetuses (reproductive & developmental toxicity)

## Target Organ Effects

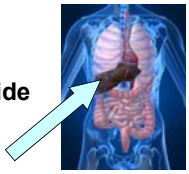
| Toxins | Target organ | Signs & Symptoms | Examples |
|---|---|---|---|
| HEPATOTOXIN | LIVER | JAUNDICE | $CCl_4$ |
| NEPHROTOXINS | KIDNEY | EDEMA | HALOGENATED HYDROCARBONS |
| NEUROTOXINS | CNS | NARCOSIS BEHAVIOR | MERCURY |
| HEMATOPOIETIC SYSTEM | HEMOGLOBIN | CYANOSIS | CO, $CS_2$ |
| LUNG AGENTS | PULMONARY TISSUE | COUGH,CHEST TIGHTNESS | SILICA, ASBESTOS |
| REPRODUCTION TOXIN | REPRODUCTIVE SYSTEM | BIRTH DEFECTS | LEAD |
| CUTANEOUS AGENTS | SKIN | RASHES; IRRITAION | KETONE |
| EYE HAZARDS | EYES | CONJUCTIVITIS | ORGANIC SOLVENTS |



## Target Organs

**Liver Diseases**

- **Fatty liver – carbon tetrachloride**
- **Cirrhosis – ethanol**
- **Liver cancer – vinyl chloride and chlorinated solvents/pesticides**





## Target Organs

**Skin**

**The protective barrier wrapped around the body (surface area about 2 $m^2$).**

**Helps maintain temperature, prevents water soluble materials entry, site of excretion, sensory activities, protective coating.**

## Target Organs

**Sensory Activities**

- **Heat, touch, and pain receptors**
- **Irritation/corrosion**
- **Sensitization/allergy (immune system)**
- **Phototoxicity (light directly, sun burn)**
- **Photoallergy (light + chemical)**

## Target Organs

**Skin Diseases**

- **Sensitization – chemical allergy**
  TDI – toluene – 2,4-diisocyanate
- **Oil/coal tar acne – chloroacne**
  PCBs-polychlorinatedbiphenyls
- **Contact dermatitis – fat soluble solvents**
- **Leukoderma (depigmentation) – $H_20_2$**
- **Allopecia (loss of hair) - thallium**



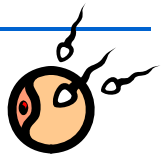
## Target Organs

**Reproductive and Developmental Disorders**

**Concern for spermatogenesis, hormonal status, maternal toxicity, and embryo or fetal toxicity.**

## Target Organs

**Spermatogenesis**



- **Rarely destroys the testes.**
- **Usually blocks sperm development.**
- **EGME (ethylene glycol monoethyl ether)**
- **Completely reversible after exposure ends.**

## Target Organs

**Developmental Effects:**

- **Lethality – resorptions/stillbirths**
- **Toxicity – body weight/behavioral effects**
- **Teratogenicity – malformations (thalidomide)**
- **Delayed development/structural anomalies/variations**



## Teratogenicity

**A specific type of developmental toxicity**

**Derived from Greek - monster formation**

e.g., thalidomide

http://www.hemonctoday.com/images/hot/200904/aprila_thalidomide.jpg



## Target Organs

**Maternal Toxicity:**

- **Oxygen depletion**
- **Nutrient intake**
- **Lead or other metals**

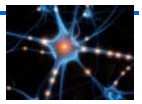


## Target Organs

**Maternal Toxicity:**

- **The ovary is more protected than the testes. So, it is not toxicity, but changes in hormonal regulation that is upset**
- **Endocrine modulation, DDT, and raptor eggs, ovulation, gestation**

## Target Organs

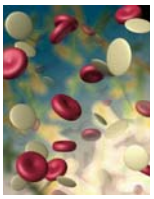


**Nervous System:**

- CNS depression – many organic solvents
- Cholinesterase inhibition – organophosphorus & carbamate pesticides
- Nerve conduction velocity – myelin sheath, peripheral nerve destruction – n–hexane



## Target Organs



**Circulatory System:**

- Hemoglobin – CN and CO
- Red cells – lysis or lead poisoning
- Leukemia – benzene
- Arterial blockage – cholesterol, HDL/LDL



## Toxic Effects of

## Some Specific Chemicals



## Metals

## Arsenic (in detail)

A. **Exists in elemental form and in the tri- and pentavalent oxidation states, copper mining & smelting**

B. **Toxicity rating: RAs –X < $As^{+5}$ < $As^{+3}$ < $AsH_3$**

C. **Absorption, distribution and excretion**
   1. Variable absorption, soluble salts well absorbed and insoluble salts are poorly absorbed
   2. Distribution: liver and kidney, hair and nails
   3. Excretion
      a) **Excreted in urine**
      b) **Half-life about 2 days**

D. **Biochemical mechanism of toxicity**
   1. $As^{+5}$ reacts with thiols, uncouples energy production
   2. $As^{+3}$ uncouples oxidative phosphorylation



## Arsenic (detail continued)

E. **Arsenic poisoning**
   1. Early signs and symptoms
      a) **Diarrhea**
      b) **Skin pigmentation**
      c) **Hyperkeratosis**
      d) **Edema of lower eyelids, face and ankles**
      e) **Garlic odor of breath**
   2. Progression
      a) **Dermatitis and keratosis of palms, soles – skin cancer**
      b) **Enlarged liver**
      c) **Renal injury**
      d) **Peripheral neuropathy (legs more than arms – contrast to lead)**
      e) **Encephalopathy**
      f) **Aplastic anemia, lung & skin cancer**

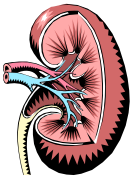
F. **Arsine ($AsH_3$)**
   1. Gas
   2. Hemolysis



## Cadmium (summary)

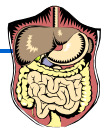
A. **Acute cadmium poisoning**
   1. Oral – GI effects
   2. Inhalation – local irritation of respiratory tract

B. **Chronic cadmium poisoning**
   1. Kidney - **Most cadmium sensitive organ**
   2. Lungs
      a) **After inhalation**
      b) **Emphysema**
   3. Cardiovascular – hypertension
   4. Bone
   5. Testes – sensitive after acute, not after chronic
   6. Itai-itai (ouch-ouch disease)





## Lead (Summary)



A. **Acute lead poisoning**
   1. **Rare**

B. **Chronic inorganic lead poisoning (plumbism)**
   1. **Gastrointestinal effects**
      a) **More common among adults**
      b) **Referred to as lead colic, often symptoms for which patient seeks relief**

C. **Organic lead poisoning**
   1. **CNS: insomnia, nightmares, irritability, anxiety, anemia, kidney**
   2. **Car exhaust is organic**

## Mercury (Summary)

**Chronic mercury poisoning**

1. **CNS effects**:
   a) **Mercury vapor (elemental mercury): largely neuropsychiatric: depression, irritability, shyness, insomnia, emotional instability, forgetfulness, confusion, excessive perspiration, uncontrolled blushing (erethism) and tremors**
   b) **Methylmercury**
      1) **Paresthesia (abnormal spontaneous sensation, ex. tingling)**
      2) **Visual changes (constriction of visual field)**
      3) **Hearing defects**
      4) **Dysarthria (speech disorder)**
      5) **Ataxia (unstable gait, coordination, loss of muscle movement)**
      6) **Fetus is extremely susceptible**
   c) **Inorganic mercury: little known**

1. **Kidney: target organ of inorganic mercury toxicity**
   a) Organomercurials-high fetal toxicity



## Other Metals

**A. Aluminum**
1. **Low toxicity, aluminum hydroxide is antacid**
2. **Shaver's disease – by inhalation in industry – lung fibrosis**

**B. Antimony: toxicity similar to arsenic, garlic breath**

**C. Beryllium**
1. **Mining**
2. **Berylliosis / granuloma**

**D. Chromium**
1. **Necessary for glucose metabolism (trivalent)**
2. **Insoluble hexavalent cause lung cancer by inhalation**



## Other Metals

**E. Cobalt**
1. **Essential element in vitamin $B_{12}$**
2. **Polycythemia (increase in RBC)**
3. **Goiter**
4. **Cardiomyopathy – beer drinkers**

**F. Copper**
1. **Essential element**
2. **Wilson's disease (hereditary, retains copper)**
3. **Metal fume fever**

**G. Fluoride**
1. **Reduces dental caries at 0.7-1.2 mg/1 or ppm**
2. **Dental fluorosis (discoloration and/or pitting) in children above 2 ppm**
3. **Brittle bones at higher concentrations**
4. **Discolors leaves**



## Other Metals

**H. Iron, $Fe_2O_3$**
1. **Metabolic acidosis – cell death through hemosiderin**

**I. Manganese**
1. **Manganese pneumonitis**
2. **CNS: Parkinson's disease**

**J. Metal fume fever - ZnO, MgO, CuO**

**K. Nickel**
1. **Dermatitis (nickel itch, jewelers itch)**
2. **Nickel carbonyl ($Ni[CO]_4$) – carcinogenic, highly acutely toxic, pneumonitis leukocytosis, temperature, delirium**
3. **Nickel subsulfide – carcinogen in humans (nose)**

## Other Metals

L. Phosphorus
1. Used in matches, rat poisons, fireworks
2. GI upset – vomitus may be phosphorescent
3. Liver injury – jaundice
4. Chronic – necrosis of bone "phossy jaw," Alice Hamilton

M. Selenium
1. Essential (glutathione peroxidase)
2. Excess in livestock – "blind staggers or alkali disease" characterized by lack of vitality, loss of hair, sterility, atrophy of hooves, lameness and anemia
3. Excess in humans – discolored/decayed teeth, skin eruptions, GI distress, partial loss of hair and nails, garlic breath
4. Liver injury

N. Silver
1. Skin – argyria (blue skin)



## Other Metals

O. Thallium
1. Rodenticides, ant poison (discontinued many countries)
2. Distributed like potassium, mining
3. GI irritation – acute
4. Alopecia

P. Uranium
1. Kidney injury

Q. Zinc
1. Essential
2. Acute oral toxicity: vomiting, diarrhea, fever
3. Inhalation: metal fume fever - fever



# Solvents and Vapors



## Halogenated Hydrocarbons

(low flammability, excellent solvents)

- Acute – CNS depression, defatting skin, myocardium
- Chronic – liver, kidney
- Chlorinated – solvents (CNS/skin/cancer)
  $CCl_4$-carcinogenic, liver, kidney
- Brominated – fumigant, solvents (CNS/skin)
- Fluorinated – refrigerants (ozone layer/myocardium)

## Structure Affects Activity

- Useful, but dangerous – i.e., guilty by association, e.g., $C_4F_8$
- Branched chain isomer – lethal @ 0.5ppm
- Linear isomer – lethal @ 6,100ppm in 4 hr
- Cyclic isomer – essentially non-toxic



## Aromatic Hydrocarbons

- Benzene – CNS depression, leukemia
- Toluene – CNS depression (glue sniffers)
- Styrene – dermatitis, CNS depression
- Poly-aromatic hydrocarbons – doxin, PCBs, biphenyls – liver/thyroid/skin
- Nitrobenzene – CNS, jaundice (liver effect), methemoglobin - blue lips & fingernails
- Phenol – CNS, liver, kidney, skin effects (absorbed readily through skin)



## Aliphatic Alcohols

- Methanol – alcohol dehydrogenase-blindness-treat with ethanol
- Ethanol – CNS depression, fetal alcohol syndrome, liver cirrhosis
- Isopropanol – CNS depression, gastritis



## Glycol Ethers

**Ethylene glycol monomethyl ether (EGME)**
$CH_3OCH_2CH_2OH$

1. Disrupts sperm development
2. Developmental toxin – day 7,8-neural tube; day 10-11-digit/paw effects, brain, liver, and kidney

**Ethylene glycol monoethyl ether (EGEE)**
$CH_3CH_2OCH_2CH_2OH$

1. Testicular degeneration
2. Reproductive/developmental toxins, but less severe

**Propylene glycol monomethyl ether (PGME)**

– Not a reproductive/developmental toxin

## Ketones

- Acetone (dimethyl ketone) – CNS, skin effects
- Methyl ethyl ketone – CNS, skin, reproductive and developmental effects
- Methyl butyl ketone – CNS and peripheral nervous system effects



## Pesticides

- Organophosphates – cholinesterase inhibitor; parathion, dursban, dichlorvos,
- Organochlorine – CNS; DDT, aldrin, kepone, mirex
- Carbamates – reversible cholinesterase inhibitor; sevin
- Chlorophenoxy – liver, kidney, CNS; 2,4-D, agent orange, 2,4,5-T
- Pyrethrins – CNS effects; resmethrin



## BREAK



## Occupational Exposure Limits (OELs)

### Requirements, Recommendations, and Guidelines

## Goals of OELs

- Control health effects of exposures to "agents" (chemical, biological, physical).
- Designed to protect workers against adverse health effects day-after-day.
- Applies only to the traditional workplace.



## Healthy Worker Syndrome

**OELs are set for:**

**Healthy, young, male workers**

**Able to report for work every day**

**Work 5 days of 8 continuous hours work per week**

**Based on data that varies widely in accuracy and age**

**Presumed to be an adequate margin of safety**



## Exposure is Affected by:

- **Genetics**
- **Age**
- **Personal habits**
  - **Smoking**
  - **Alcohol**
  - **Drugs**
- **Medication**
- **Previous Exposure**
- **Environmental Exposure**

## Basis for Setting OELs

**Paracelsus (~1500) said – "all substances are poisons… only the dose differentiates a poison from a remedy"**

- **Human use and experience**
  - Epidemiological data
  - Medical case histories
  - Human exposure data on adverse effects
- **Long term animal toxicity studies**
  - Best for chronic toxicity and carcinogenicity
- **Short term animal toxicity studies**
  - Dermal data on skin penetration
  - Basis for STEL or Ceiling Limit

## Basis for Setting OELs

**Special animal studies**:

- **Genetic toxicity**
- **Developmental/reproductive toxicity**
  - **Unique hazard (e.g., thalidomide)?**
  - **Male or female reproductive performance?**
- **Metabolism/pharmacokinetics**
  - **Absorption, distribution, fate and elimination**
- **Physical/chemical properties**



## Animal Toxicology Information

- Route of exposure
- Route of administration
- Species tested
- Chemical/physical/biological factors
- Test material
- Dose, route, frequency, concentration, duration
- Genetic factors
- Immunologic and dietary factors
- Gender, age and emotional status



## Extrapolation of Animal and Other Data

- **Application of known data and/or experience to areas not known.**

- **Based on assumptions**:
  - **Continuity**
  - **Parallelism between what is known and unknown.**



## Exposed Dose vs. Absorbed Dose

- **Exposed Dose:**
  Amount of substance which a given organism is exposed, expressed as:
  - parts per million (ppm) for gases & vapors
  - milligram per cubic meter ($mg/m^3$) for solids
  - Fibers per cubic centimeter (fibers/cc) for fibers
- **Absorbed Dose:**
  Amount of substance deposited in or absorbed by an organism, expressed as:
  - mg/kg

## Occupational Exposure Limits (OEL)

**OELs are country specific and variously know as:**

- **PEL – Permissible Exposure Limits –** OSHA, USA, required legal limits.
- **REL – Recommended Exposure** Limits **–** NIOSH, USA, recommendations.
- **TLV® – Threshold Limit Values® –** ACGIH, USA, recommendations
  - **(OSHA adopted 1968 TLV list – PELs)**
- **WEEL – Workplace Environmental Exposure Limits –** AIHA, USA, recommendations.
- **MAK – Maximium Workplace Concentrations –** German, required legal limits.
- **BEI® – Biological Exposure Indices –** ACGIH, USA, recommendations.



## Permissible Exposure Limit (PEL)

- ***Legal* US exposure limit** to control health effects from exposures to "agents."
- Protect workers day-after-day without adverse health effects.
- Applies only to workplaces covered by US OSHA.



## Action Levels and Policies

- **Action Level (usually ½ PEL)**
- **Other US OSHA Policies**

  **Carcinogens**
  - ***Zero tolerance***
  - **No known safe exposure level**

## TLV® Definitions

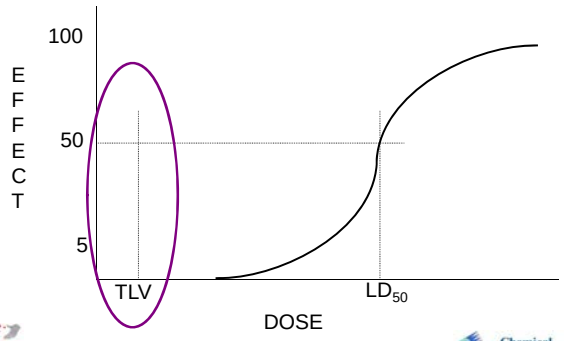
**Threshold limit values refer to:**

… airborne concentrations of substances and represents conditions under which it is ***believed* that *nearly all workers may be repeatedly exposed day after day without adverse health effects*.**

… a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit.

… may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

## Threshold Limit Values (TLV)






## Categories of TLV's

*AIR CONTAMINANTS*

- **Time-weighted average (TWA)**
- **Short-term exposure limit (STEL)**
- **Ceiling value (C)**

- **TLV Range:**
  HIGHEST
  - Carbon dioxide - 5000 ppm

  LOWEST
  - Osmium tetroxide - 0.0002 ppm



## TLV Limitations

- **Not** a relative index of toxicity.
- **Not** intended to apply to general public.
- **Not** for exposures >8 hr/day; 40 hr/wk.
- **Not** used as proof of hazard.
- ***Not for other countries with different working conditions.***



## Biological Exposure Indices (BEIs®)

- **BEIs are indications of a person's "uptake" of a substance.**
  - **Chemical, metabolite, characteristic or reversible biochemical change**
    - Urine, blood, exhaled air
  - **Represent levels observed in healthy workers exposed at the TLV.**
    - Not always the case…e.g. lead, based on health effect.
  - **Indirectly reflects dose**
  - ***Not* a measure of adverse effects or diagnosis of illness**
  - ***Not* a distinction between hazard and non-hazard.**

## Biological Exposure Indices (BEIs)

- **BEIs can assist CHHO Professionals:**
  - » Used as a guideline
  - » Apply to 8 hr day, 5 day week
    - – Adjustment to irregular work schedules is not recommended
  - » Detect and determine absorption by skin or GI
  - » Assess body burden
  - » Reconstruct past exposure in absence of exposure data
  - » Test efficacy of PPE and engineering controls
  - » Monitor work practices
- **BEI does <u>not</u> indicate need for biological monitoring.**



## Working with BEIs

- **Sample collection time is very important.**
- **Sample acceptability:**
  - » Reject highly diluted or concentrated urine samples.
- **Sample collection requires proper quality assurance.**
  - » Include blind challenges to assess lab capability.
  - » B – background (may be present in unexposed)
  - » Nq – non-quantitative
  - » NS – nonspecific (observed with other chemicals)
  - » Sq – semi-quantitative (interpretation may be ambiguous)



## BEIs vs. TLVs

- **BEIs – Index of uptake**
  - » Uptake may vary between workers.
  - » Measurement on a person
- **TLVs – indicate potential for inhalation exposure**
  - » Measurement on an environment
- **Inconsistencies between BEIs and TLVs due to:**
  - » Physiological makeup and health status
  - » Occupational exposure factors
  - » Non-occupational exposure factors
  - » Sampling location
  - » Particle size distribution
  - » Effectiveness of PPE or controls



## Classification Schemes

### *ACGIH CARCINOGEN*

- **A1 Confirmed human carcinogen**
  - » Human data
- **A2 Suspected human carcinogen**
  - » Animal data due to conflicting or insufficient human data
- **A3 Animal carcinogen**
  - » Not relevant for extrapolation to humans

## Classification Schemes

### *ACGIH CARCINOGEN*

- **A4 Not classified as a human carcinogen**
  - » Inadequate data
- **A5 Not suspected as a human carcinogen**
  - » Good negative human
  - » Considers animal data

**NOTE: If no data exists, compound remains unclassified**



## Time Weighted Average (TWA)

- **Average exposure for an individual over a working period of time, determined by taking one or more samples during the working period:**

$$\text{TLV-TWA*} = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{T_1 + T_2 + \ldots + T_N}$$

**Where:**
C = airborne concentration
T = time

*** A TLV expressed as a TWA**



## 8-Hr Time Weighted Average

- **Average exposure for an individual over an 8-hr working period of time, determined by taking one or more samples during the 8-hr working period:**

$$\text{TLV-TWA}_8 = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{8 \text{ hrs}}$$



## Example 1

**A degreaser operator is monitored for exposure to Stoddard solvent. The monitoring data is:**

| *TIME PERIOD (NUMBER)* | *CONCENTRATION (PPM)* | *TIME (HOUR)* |
|---|---|---|
| 1 | 80 | 2 |
| 2 | 110 | 4 |
| 3 | 55 | 2 |

## Solution

$$\text{TLV-TWA}_8 = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{8 \text{ hrs}}$$

$$\text{TLV-TWA}_8 = \frac{(80 \times 2) + (110 \times 4) + (55 \times 2)}{8 \text{ hrs}}$$

**EIGHT HOUR TLV-TWA = 89 ppm**

Over exposed?
(TLV = 100 ppm)



## Example 2

**Consider the same example with no exposure for the last two hours:**

| *TIME PERIOD (NUMBER)* | *CONCENTRATION (PPM)* | *TIME (HOUR)* |
|---|---|---|
| 1 | 80 | 2 |
| 2 | 110 | 4 |
| 3 | 0 | 2 |



## Solution

$$\text{TLV-TWA}_8 = \frac{C_1T_1 + C_2T_2 + \ldots + C_NT_N}{8 \text{ hrs}}$$

$$\text{TLV-TWA}_8 = \frac{(80 \times 2) + (110 \times 4) + (0 \times 2)}{8 \text{ hrs}}$$

**EIGHT HOUR TLV-TWA = 75 ppm**



## Unit Concentration

$$\text{TLV (ppm)} = \frac{\text{TLV (mg/m}^3\text{) } 24.45}{\text{(molecular weight)}}$$

$$\text{TLV (mg/m}^3\text{)} = \frac{\text{TLV (ppm) (MW)}}{24.45}$$

## TLV - Short Term Exposure Limit (STEL)

- **A 15-minute TWA exposure.**
- **No more than 4 times per day, with at least 60 minutes between.**
- **Should not be exceeded anytime during workday, even if 8-hour TWA is within TLV-TWA.**



## Excursion Limit (without STEL)

- **Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday.**
- ***Under no circumstances* should they exceed 5 times the TLV-TWA, provided the TLV-TWA is not exceeded.**
  - **Applicable to TLV-TWAs that do not have STELs**



## Other TLV Notations …

- "Skin" potential exposure by the cutaneous route, including mucous membranes and the eyes.
- "SEN" potential to produce sensitization.



## Unusual Work Schedules

**Application of TLVs to unusual work shifts:**

**Different from 8-hour day, 40-hour week**

***Requires judgment.***

## OSHA model Modified PEL

$$PEL_{modified} = PEL \frac{8\ (hours)}{T\ (hours)}$$

**T > 8 Hours**



## Example

- 1,1,2-trichloroethane has a biologic half-life of 16 hours in people. What modified TLV or PEL is appropriate for persons who want to work 3 days at 12 hours per day for the work week?
- The ACGIH TLV & OSHA PEL for 1,1, 2-trichloroethane is 10 ppm.

$$PEL_{modified} = 10 \frac{8\ (hours)}{12\ (hours)} = 6.66\ ppm$$



## Mixtures

If the biological effects of mixture components are additive:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_N}{T_N} = K$$

Where:

$C_N$ = Measured TWA concentration

$T_N$ = TLV for a substances

If k is **<** 1, combined exposure is less than TLV

If k is **>** 1, combined exposure exceeds the TLV



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# Laboratory Emergency Planning, Response, and Management



## Video – Explosion and Fire at T2 Lab

## Emergency Planning and Response is based on principles of:

- Anticipation
- Recognition
- Evaluation
- Control

## Preparing For Emergencies

- Emergencies
  - potentially life threatening
  - occur suddenly without warning
- Quick response will:
  - make difference between life and death
  - minimize damage
  - prevent panic, timely control
- Emergency responders
  - organize, stabilize, administer
- Adequate preparation requires
  - planning, practice, evaluation, adjustment

## Emergency Management

- **Mitigate**
  - eliminate / reduce occurrence or effects of an emergency
- **Preparedness**
  - plan how to respond; resources
- **Response**
  - assist victims, reduce damage
- **Recovery**
  - return to normal and assess

## Planning & Preparation

Anticipate types of emergencies:

- Step-by-step procedures
- Assess resources available
- Coordinate with all responding agencies
- Chain of command
- Roles & assignments
  - Clearly spelled out and understood
- Accident prevention strategies
- First aid – inspect, date, replacements
- Site maps – update
- Train & practice
- Evaluate & improve

## Emergency Response Plan

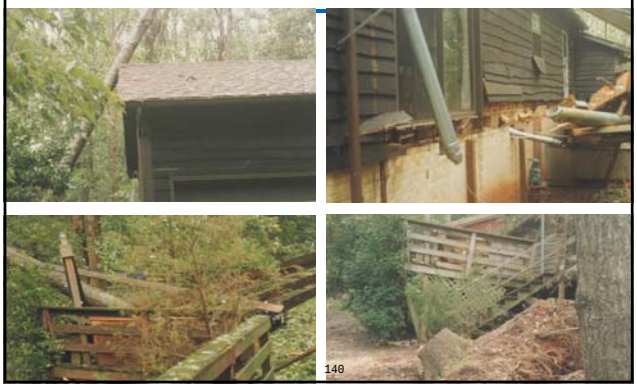
Include all situations and conditions:

- Weather emergencies:
  - Flood
  - Tidal waves
  - Cyclones
  - Heavy rains
  - High winds
- Fire
- Earthquakes
- Security breaches
- Distraught employees
- Medical Emergencies
- Student unrest
- Political unrest
- Explosion
- Evacuation
- Terrorism

*Prepare for and expect the unexpected*



## Dr. Walters home, Raleigh NC, USA After Hurricane Fran 1996



## Emergency Action Plan

- Have a written plan and distribute it to all employees, especially *new* employees:
  - Emergency escape/evacuation procedures & routes
  - Critical process emergency shutdown procedures
  - Procedures to account for evacuated employees
  - Rescue or medical duties if employees required to perform them
  - Procedure for reporting emergencies
  - Contact information for Q&A
- Alarm systems
- Training

## Emergency Response Plan

- Comprehensive employee training
  - General employee training
  - Specialized & emergency responders
  - Annual refresher training or drills
  - Untrained personnel should not participate
- Spill & emergency response plans
- Contingency plans
- Medical response/first aid
- Personal Protective Equipment
- Safety Data Sheet's
- Site maps
- Clean up procedures
- Decontamination techniques

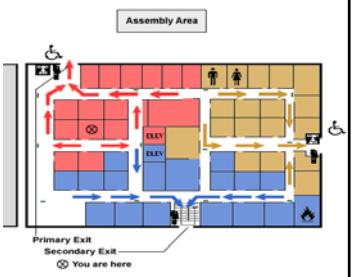
## Include:
### Fire Prevention Plan

- Written plan
  - List major fire hazards
  - Proper handling and storage procedures
  - Potential ignition sources & controls
  - Type of fire prevention systems
  - Contact information for those responsible for system maintenance
  - Contact information for Q&A
- Housekeeping requirements
- Training
- Maintenance requirements

## Emergency Planning & Response

Have an evacuation plan for all buildings and areas and

**POST IT**



## Emergency Planning & Response

Don't use hallways for storage

**Dangerous!!**

Blocks passage and emergency exit path

## Emergency Planning & Response

Label and keep *all* exits clearly.
Keep unlocked or equipped with panic bars.

## Emergency Planning & Response

- Have routine, unannounced evacuation drills.
- Test and maintain alarms.
- Designate person for each area to ensure bathrooms, etc. are evacuated.

- Locate outside staging areas sufficient distance from building.
- Designate person to meet/direct emergency vehicles.



## Emergency Planning & Response

Alarm systems need to be properly located, maintained, and serviced regularly.

## Alarm Systems: *Reminder*

- **Will it be recognized and followed?**
  - **Audible, visual, public address systems…**
- **What about deaf or blind employees?**
  - **Are there "dead spaces"…**
- **System reliability**
  - **System failure may not be obvious**
  - **Supervised systems (built-in monitoring)**
  - **Testing, maintenance and backup systems**

## Manual Pull Stations: *Reminder*

- Manual Pull Stations are devices located on the wall (usually near an exit)
  - Send a signal to the building's fire alarm system when activated
  - Places the building into alarm

***Remember:***
***People are reluctant to sound fire alarms!***



## Emergency Planning & Response

**If people are expected to use extinguishers, they *must* be trained.**

## Emergency Planning & Response

**Backup power**

**Does switch-over automatically?**

**How long will it run?**

**How much fuel do you have?**

**What areas will it support?**

**How often is it tested and maintained?**

## Emergency Planning & Response

**Post each room with:**

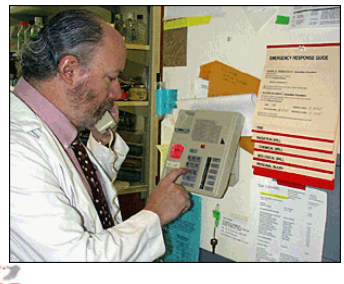
- Emergency phone numbers
- After hours phone numbers
- Person(s) to be contacted
- Alternate person(s)
- Unique procedures to be followed

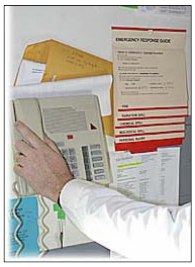
| Location | |
|---|---|
| Hazards Within: | |
| Primary Contact: | |
| Second Contact: | |
| Building Monitor/Safety: | |
| Department Head: | |
| Fire/Police/Ambulance: | 911 |
| Envir. Health & Safety (or RSO, if needed) | 686 3327 |



## Emergency Phone Numbers

**Clearly post emergency numbers**
**Do employees know what to do?**







## Emergency Planning & Response

***Hoods should have low flow alarms.***

**Chemical specific toxicity alarms may be needed in certain areas.**



## Emergency Planning & Response

**Centrally locate safety showers and eyewashes.**

**Schedule routine, periodic maintenance of all safety equipment.**

## Teach employees to properly use the Safety Shower

Time can make a difference…

## Chemical Spills

**Centrally locate spill clean-up kits**

***Clean up spill only if you know the chemical hazards, have appropriate equipment and are trained to do so!***

- Alert colleagues and secure area
- Assess ability to clean-up spill
- Find spill kit
- Use appropriate PPE and sorbent material
- Protect sinks and floor drains
- Clean-up spill, collect/label waste for disposal
- Report all spills

## Centrally locate, inspect and maintain:

- First aid kits
- Special chemical antidotes, if necessary
- Respirators
- Specially train emergency personnel, if necessary
- Post inspection dates on equipment, including hoods

## Always Expect the Unexpected

## Lunch



## Chemical Spill Response and Clean-up



## Size of spill determines response

## Emergency Notification and Response

- The notification and emergency response procedure for accidents and incidents should be written and understood by everyone.
- A rapid and effective response helps insure injured persons receive rapid and correct medical attention and/or that incidents are quickly contained and controlled, and that effects and damage to people, facilities, the environment and the community are minimized.

## Chemical Spill Response Medical Treatment

- Employer should provide the following medical services in emergencies:
  - Medical examination after exposures
  - If exposures are above required/regulated levels of exposure
  - Follow-up exams as necessary
- Employer should provide to the physician:
  - Identity of chemical
  - Description of exposure conditions
  - Description of signs and symptoms of exposure
- Employer and victim should obtain a confidential written report from the examining physician

## Chemical Spill Response Record Keeping

- Maintain accurate records of accidents/incidents response.
  - All involved personnel
  - Exposure measurements
  - Medical examination, consultations
  - Medical tests
  - Medical follow-ups
- Records should be confidential and protected from unauthorized disclosure.
- Records should be shared with victim.
- Records should be examined for patterns.

## Chemical Laboratory First Aid

- First aid kits for minor injuries should be centrally located and available in or nearby each laboratory.
- Use for minor accidents/incidents.
- Determine if medical attention is necessary.
- Immediately notify proper authorities, if necessary or in doubt.
- Determine if chemical exposure occurred.
- If necessary, take immediate preventative action to make lab safe, e.g., shut down reactions, electricity, etc.

## Chemical Laboratory First Aid

**Wounds:**

- If bleeding is profuse, apply steady, direct pressure over the wound using a sterile dressing, if possible, or clean cloth.
- Keep the wound as clean as possible.
- Remove or cut away any clothing covering the wound.
- Flush with water to wash out loose dirt and debris.
- Do NOT try to remove foreign matter embedded in the wound
- If there is an impaled object, Do NOT try to remove it. Efforts to do so may cause severe bleeding and further damage.
- Control bleeding by direct pressure, but do not apply pressure on the impaled object itself or on immediately adjacent tissues.
- Stabilize the impaled object with a bulky dressing.

## Chemical Laboratory First Aid

**Thermal Burns:**

- Immerse burned area in cold water or apply cold compresses for 30 minutes
- Do NOT attempt to rupture blisters on the burn



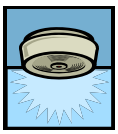
## Chemical Laboratory First Aid

- Chemical Burns:
  - Speed is essential.
  - Consult chemical labels & MSDS for special instructions.
  - Flush burn area immediately with water for 15 minutes.
  - Taking care not to spread the chemical, remove any clothing,especially shoes and socks, that may be contaminated.
  - Do NOT use salves, ointments, cream, sprays, or any other covering except for chemical-specific remedies such as for HF or phenol.
  - Do NOT attempt to rupture blisters over the burn.
- If chemicals splashed into the eyes:
  - Flush the affected area with water for a minimum of 15 minutes.
  - Remove contact lenses, if present, as rapidly as possible, since they prevent water from reaching the cornea.
  - Eyelids may have to be forced open so eyes can be totally flushed.
  - If large particles are in the eye, an eye wash should not be used.
  - Do NOT use salves, ointments, cream, sprays, or any other covering except for chemical-specific remedies such as for HF or phenol.



## Spill Cleanup Preparation

- Emergency Equipment
  - Internal communication/alarm system
    - Telephones (Label all phones with emergency numbers)
    - Alarm pull boxes
  - External communication/alarm system
  - Fire extinguishers
  - Emergency eyewash and showers
  - Spill stations





## Spill Cleanup Preparation

- Knowledge Needed
  - Location of emergency electrical circuit breakers, shutoff valves, switches, disconnects for building, area, laboratory, room, equipment
  - Response procedures for personal injuries/ exposures and emergencies
  - Emergency evacuation routes (posted)

## Spill Cleanup Preparation

- Maintain Current Safety Data Sheets
  - Attention to:
    - Chemical hazards
    - First aid information
    - Spill response
    - Firefighting information
    - Engineering controls
    - Stability and reactivity
    - Proper storage
    - Disposal considerations

## Spill Cleanup Preparation

- Maintain complete Spill Kits
  - Absorbent material
    - Absorbent pillows or powders
    - Activated carbon for organic solvents
  - Neutralizing agents
    - Acid Neutralizers –e.g., sodium bicarbonate ($NaHCO_3$) powder
    - Base Neutralizers-e.g., citric acid powder
    - Solvent Spills-activated carbon

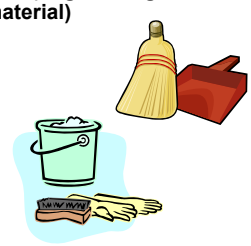
## Spill Cleanup Preparation, cont'd.

Spill Kit should also contain:

- Personal Protective Equipment (PPE)
  - 2 pairs of chemical splash proof goggles
  - Several pair of disposable gloves
  - Disposable, charcoal (volatile, aerosol) respirators
  - Disposable aprons or jump suits
  - Disposable shoe covers (for floor spills)

## Spill Cleanup Preparation

- Additional cleanup equipment:
  - Plastic pail/bucket(s) with lids (large enough to contain spill and cleanup material)
  - Plastic dust pan
  - Broom or brush
  - Plastic bags
  - Sealing tape
  - pH paper
  - Sign(s):
    - *Danger Chemical Spill*
    - *Keep Out*



## Spill Cleanup Preparation

### SCBA Respirators

- Two persons are required to use a Self Contained Breathing Apparatus (SCBA)
- One person stands-by to rescue/assist the other in case of a problem
- Never rely on a single SCBA
- Never use a SCBA alone
- SCBAs must be well maintained and inspected weekly if they are part of the safety program



## Spill Cleanup Preparation Risk Assessment

### (Anticipation)

- What is the worst thing that could happen if a chemical was dropped/spilled, etc.?
  - inconvenience
  - skin burns
  - fire
  - explosion
  - chemical exposure ( fatality; injury, permanent, temporary)
- Know the worst case scenario for a spill.
- How you would respond to a spill, emergency situation?
- What are the appropriate clean-up and decontamination procedures?



## Spill Cleanup Preparation Risk Assessment

### Estimating Potential Hazards (Evaluation)

- What are the chemical, physical and toxicological properties of the chemicals you are using?
- What is the amount of chemical?
- What are your knowledge and skills?
- What are possible locations/conditions of a spill, accident?
- Ask for assistance if you are unsure



## Spill Cleanup Preparation Risk Assessment

### Chemical Toxicity (Evaluation)

- Route of exposure
- Acute toxins
- Acids and corrosives
- Lachrymators, irritants and allergens
- Carcinogens, repro-toxins, etc.
- Biohazardous, radioactive material

## Spill Cleanup Risk Assessment

### Chemical Flammability (Evaluation)

- Hazardous locations
- Ignition sources
- Presence of other flammables
- Store excess flammables in flammable storage cabinets
  - Use external flammable storage rooms for large quantities.

## Spill Cleanup Prevention

### (Control)

- Eliminate clutter
- Purchase only amount of chemical required
- Understand work practices and procedures
- Use unbreakable secondary containers
- Store chemicals properly
- Dispose of waste and excess chemicals properly and timely



## Cleanup Responsibilities

- Laboratory Staff:
  - Ensuring timely spill reporting and cleaned up
  - Cleaning up nuisance spills in their area, even if someone else spills them (janitors, service people)
  - Knowing the properties of what they work with
  - Taking reasonable steps to prevent spills
- Specially trained Safety Cleanup Team:
  - Assist researchers not comfortable cleaning up spills (including nuisance spills)
  - Clean-up serious/major spills

## Nuisance Spills

- Spills of < 4L of known hazard, that you are comfortable cleaning up
  - Assess the hazard
  - Wear appropriate PPE

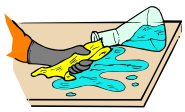
- If unsure or need assistance with PPE selection or cleanup, call the Safety Cleanup team.

## Nuisance Chemical Spill Cleanup Procedure

- Alert people in immediate area
- Post area
- Confine spill
- Absorb excess, surround area with absorbent material
- Wear appropriate PPE
- Avoid breathing aerosols
- Use forceps, etc., to pickup broken glassware, etc.
- Work from outer edge toward center to cleanup
- Do not dry sweep
- Clean spill area with soap & water, specific solvent or neutralizing material (if known)
- Collect contaminated absorbent, gloves, residues in plastic bag(s)
- Label, with chemical name if possible, and dispose of waste properly



## Potentially Hazardous Spills



- **Spills of > 4L or**
- **Smaller spills of:**
  - **Low $LD_{50}$ (high acute toxicity)**
  - **Carcinogens, repro-toxins, etc.**
  - **Flammable liquids or metals**
  - **Chemicals of unknown toxicity or hazards**



## Potentially Hazardous Chemical Spill Cleanup Procedure

- Attend to injured/contaminated or exposed individuals.
- Remove persons from the exposure without endangering yourself.
- Alert persons in the immediate area to evacuate.
- Consider people with disabilities.
- If spill is flammable, turn off heat and ignition sources (if possible).
- Call Emergency Phone Number to report incident.
- Post area—**Danger, Keep Out! Hazardous Chemical Spill**
- Close doors to affected area.
- Locate MSDS.
- Assist Specialized Safety Cleanup personnel if you are knowledgeable about the spill.

***Only trained personnel should do cleanup!***



## Mercury Exposure and Cleanup

- **Mercury metal exposure can cause severe health problems:**
  - **Tremors**
  - **Changes in vision or hearing**
  - **Insomnia**
  - **Weakness**
  - **Memory difficulty**
  - **Headaches**
  - **Irritability**
  - **Nervousness or shyness**
  - **Acrodynia (painful extremities) - *a condition caused by chronic exposure to mercury***

## Mercury Exposure & Prevention

- Routes of exposure
  - Inhalation
    - Main hazard
    - Evaporates releasing hazardous vapors
  - Skin absorption
- Personal Protective Equipment Required
  - Nitrile gloves
  - Safety glasses
  - Closed-toed shoes
  - Lab coat

## Mercury Spill and Exposure

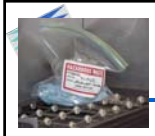
- Preparation is critical.
- Substitution/elimination is the best prevention.
- All mercury spills, including those from broken laboratory thermometers and manometers, should be cleaned up immediately.

## Mercury Spill Prevention

- Trays should be used under equipment where mercury is used.
- Mercury beads, splashes, and rolls around.
- Prevent mercury from entering cracks, crevices, and drains.
- Cease activities.
- Secure spill area, contain mercury spill area.
- Restrict area until entire spill is cleaned up.
- Do not walk in spill area.
- Evacuate room via route away from spill.
- Lower room temperature to reduce evaporation.

## Mercury Spill Cleanup

- Spill powders can be used as temporary controls:
  - Commercial spill kits are available
  - Or mix 85 grams of finely powdered sodium thiosulfate with 15 grams of powdered EDTA



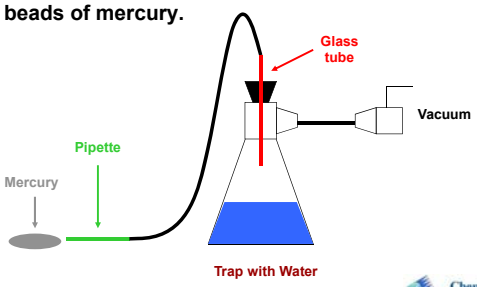
## Mercury Spill Cleanup

- Cover spill from perimeter toward the center.
- Remove debris:
  - Dispose of as hazardous waste and cleanup material (gloves, towels, etc).
  - All waste should be placed in labeled, sealed, leak-proof, containers.
  - Never dispose of mercury waste in sewer system.
- Special vacuum cleaners designed to pick up mercury safely are available for cleanup.
- NEVER sweep up spill or use a regular vacuum.



## Other Mercury Spills Cleanup Equipment

- A side-arm flask connected to a vacuum pump or sink aspirator can be used to vacuum up small beads of mercury.






## Mercury Spill Cleanup Special Precaution

- Special attention should be given to cleaning cracks and crevices where the mercury beads may have settled.

## Mercury Spill Cleanup Special Precautions

- Large spills
- Spills in confined areas with poor ventilation
- Spills in areas heated above room temperature
- Should be cleaned up by trained personnel with protective equipment
- There is a risk of high exposure to mercury vapors in these situations.

## Acknowledgement

**Mercury Spill Cleanup,**
**University of Wisconsin Safety Office**
http://www.uwm.edu/Dept/EHSRM/LAB/labHg.html

## Accident and Incident Investigation



## Reporting Chemical Incidents and Accidents

- All accidents, incidents, or suspicious occurrences should be reported to the supervisor, regardless of the perceived seriousness of the incident.
- Reporting helps indicate potential problem areas.
- Reports serve as a basis for corrective measures to prevent accidents/incidents from re-occurring with a more serious outcome.



## Serious Chemical Accidents and Incidents

- Should be reported in detail and should include:
  - Cause of accident/incident
  - Place, time, personnel involved
  - Diagram if necessary
  - Type of contamination or hazard
  - List of personnel possibly exposed
  - Decontamination procedures
  - Corrective actions taken
  - Medical attention taken (if appropriate)

## Investigation and Prevention of Chemical Laboratory Accidents

- Emergency notification and response
- Written report of accident/incident
- Accident/Incident investigation response
- Review/investigation of accident/incident
- Determination of Cause
- Report and Implementation of Corrective Measures
- *Follow-up*

## Accident/Incident Investigation Personnel

- Laboratory staff exposed or involved in accident/incident
- Laboratory Supervisor
- Safety/Security staff
- Medical personnel
- Administrative personnel
- Safety/Security Committee
- External experts, if needed

## Written Accident/Incident Report

- A well written A/I Report provides quality information and data for investigation and remediation.
- Complete and accurate A/I information is critical to investigate the circumstances and to help prevent against future A/I occurrences.



## Accident/Incidence Investigation Response

- Have a written procedure to submit A/I reports
- Include:
  - Procedure to form an *ad hoc* A/I Safety/Security Investigation Team for each A/I with designation of special A/I investigation team members if necessary (e.g., biological, radiation).
  - Specify an odd number of Investigation team members.
  - Specify that CSSO or organization SO is secretary but *ex-offico* (non-voting) member of Investigation Team.
  - Designate time required for A/I Investigation Team members to review and respond (by e-mail, if possible) on A/I Report.
  - Time required for Safety/Security Committee to determine if an A/I Investigation is necessary, when it is to be conducted, and who should be on Team.
  - Time required for Investigation Team and Safety/Security Committee to issue written investigation report, who the report goes to and that it contain corrective recommendations to help assure A/I will not reoccur, if appropriate.

## Review/Investigation of Accident/Incident

- Site investigations and interviews can be the center of an A/I investigation program
- An A/I analysis and corrective actions can be determined from the data and information provided during this phase
- The data quality is important and a uniform approach to conducting the investigation is essential
- It is important in this step to obtaining and verify relevant personal and facility information
- The data may include testing, evaluation or verification of records for safety procedures, training, reporting, regulations, documentation and equipment
- The use of interviews of injured persons and witnesses can be very important to obtain all the facts



## Determination of Cause

- An analysis of the A/I is performed using the information collected during the site investigation and interviews
- The analysis determines the cause of an A/I and tracks it back to the cause
- The object is to reveal the causes of the A/I and to understand what happened, how, when and why it occurred

## Report and Implementation of Corrective Measures

- After the investigation and interviews, Team members meet to draft an Investigative report .
- An objective written report is issued that summarizes the feeling of the Team members that includes effective corrective measures to be implemented to prevent or minimize similar future accidents/incidents.
- The Team's recommended corrective actions should include:
  - The extent of the measures (i.e., specific to a laboratory or wider).
  - Resources needed for implementation.
  - Expected outcome.
- The Team's Report should be sent to all individuals involved in the A/I as well as the Laboratory Supervisor, Administration, and Institute Higher Management, External Government Agencies, if appropriate.



## Accident/Incident Follow-up

- The corrective measures recommended by the Investigation team should be monitored to insure they implemented properly and have the desired effect
- Recommended actions should include a timeframe for completion

## Accident/Incident Follow-up Timeline

- Length of timeline depends on nature and severity of incident.
- Starts at time/date of accident or incident.
- Incident should be reported immediately to:
  - CSSO, PI, Security Office, and/or Medical Office
  - Management or administration. Depends on incident severity, but usually with 2 days.
- Investigation usually starts within 24 hours.
- Written report is issued within a week.
- Report should include time for recommended follow-up actions, usually days to months.



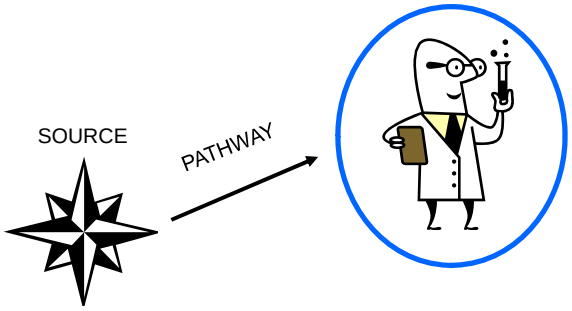
## CSB Video –Incident Investigation Example

## BREAK



## Personal Protective Equipment (PPE) and Safety Equipment Performance Specifications

## Worker Protection






## Personal Protective Equipment (PPE)

- Should be a last resort, but may be necessary if:
  - engineering controls inadequate or being installed
  - administrative controls don't do the job
  - emergency response or spill cleanup
  - supplement other control techniques if can't achieve required level
- Depends upon human behavior
  - proper selection, fit and comfort issues
- Hazard is still present with PPE …

## US/OSHA PPE Regulations

- Eye and face protection
  - 29 CFR 1910.133
- Respiratory protection
  - 29 CFR 1910.134
- Head protection
  - 29 CFR 1910.135
- Foot protection
  - 29 CFR 1910.136
- Hand protection
  - 29 CFR 1910.138
- Hearing Protection
  - 29 CFR 1910.95

www.cdc.gov/nasd/menu/topic/ppe.html
www.osha.gov/SLTC/personalprotectiveequipment/index.html
www.osha.gov/Publications/osha3151.pdf



## Training and Qualification

### Employees should be trained to know:

- When PPE is necessary?
- What PPE is necessary?
- How to properly don, doff, adjust and wear PPE.
- Limitations of PPE.
- Proper care, storage, maintenance, useful life, and disposal of PPE.

www.free-training.com/osha/ppe/ppemenu.htm

## Training and Qualification

### Retraining is necessary when there is:

- **Change in the process.**
- **Change in type of PPE used.**
- **Inadequate employee knowledge or use of PPE.**
  - retrain to reinforce understanding or skill

## Personal Protective Clothing (PPE)

- Evaluate task, select appropriate type and train to use it properly
  - lab coats, gowns, aprons
  - safety glasses (with side shields), goggles, face shields
  - gloves
- Remove PPE before leaving the lab

## Protective Equipment Works

"It's a hot day, why wear a lab coat?"

**An experiment reacted unexpectedly and a flammable solvent from a hood splashed out and landed on the bottom of the lab coat**



## Eye and Face Protection

- **Thousands are blinded each year from work-related eye injuries.**
- **Nearly *three out of five* workers are injured while failing to wear eye and face protection.**

## Eye & Face Protection

- Safety glasses
- Goggles
- Face shield

## Eye and Face Protection

**Eye protection shields eyes by:**

- Primary protection:
  - Safety glasses with side shields protect from flying objects.
  - Goggles prevent objects from entering under or around the eyewear.
- Secondary protection:
  - Face shields
    - Combine with safety glasses or goggles
    - Do not protect from impact hazards

## Hazard Assessment

| Hazard Type | Hazard Type | Common related tasks |
|---|---|---|
| Impact | Flying objects such as large chips, fragments, particles, sand, and dirt | Chipping, grinding, machining, masonry work, wood working, sawing, drilling, riveting, sanding,… |
| Heat | Anything emitting extreme heat | Furnace operations, pouring, casting, hot dipping, welding, … |
| Chemicals | Splash, fumes, vapors, and irritating mists | Acid and chemical handling, degreasing, plating, and working with blood or OPIMs |
| Dust | Harmful dust | Woodworking, buffing, and general dusty conditions |
| Optical Radiation | Radiant energy, glare, and intense light | Welding, torch-cutting, brazing, soldering, and laser work |



## Biohazards

Use caution *anytime* you are working with blood or other bodily fluids.

**Contaminated blood or bodily fluids may result in transmission through the eyes.**

## Eye and Face Protection

### Optical Hazards

- Welding helmets are secondary protection to shield from UV, heat, and impact.
- Exposure to laser beams requires suitable laser safety goggles with protection for the *specific wavelength.*

## Eye and Face Protection Requirements

- Eye and face protection should comply with the American National Standards Institute:
  - ANSI Z87.1-1989
- Ensure employees who wear prescription lenses or contact lenses:
  - Use safety eyewear that incorporates the prescription
  - Use eye protection that can be worn over prescription lenses

## Additional Considerations

- Provide adequate protection against the specific hazards.
- Safe design and construction for the work to be performed.
- Comfortable.
- Don't interfere with the wearer's movements.
- Durable!
- Capable of being disinfected.
- Easily cleaned.
- Distinctly marked to indicate they are approved eye protection.
- Worker satisfaction.
  - – Include workers in the selection process.

## Eyewash and Showers

- US regulations
  - 29 CFR 1910.151(c)
  - ANSI Z358.1-2004
- Types
  - eyewash
  - shower
  - drench hose
- Concerns
  - drainage
  - freezing
  - contaminated water

## Eyewash and Showers

- Know their locations
- Maintenance and testing program
- Concerns:
  - drainage
  - freezing
  - contaminated water

## Eyewash Standards

- Eye wash stations
  - Minimum 0.4 to 3.5 gal/min (1.4 – 13.2 l/min.)
  - Flush for 15 minutes
- Provide flow for both eyes
  - Hold eyes open
  - Tepid, pH match eye (preferred)
- Easily accessible locations
  - 33 to 45 in. (84-114 cm) from floor
  - 6 in. (15cm) from wall
- Test weekly
  - Portable: clean/refill (6 mo – 2 yrs)
- Various types

ANSI Z358.1
NC DOL Guide:
www.nclabor.com/osha/etta/indguide/ig28.pdf



## Safety Shower Standards

- Within 55 ft. (17 m) or 10 seconds
  - Normal walking = 3.8 mph (6.1 km/hr)
- Test monthly
- Pull within reach (highly visible)
  - 82 to 96 in. high (208 – 244 cm)
  - Deliver 20 in (51 cm) column
  - Height: 60" (152 cm) above floor
- 20–30 gal/min (76-114 L/min)
- Tepid: 60 to 100 °F (16 – 38°C)

## Safety Shower Standards cont.

Consider:
- Drains
- Blankets/modesty curtains

Avoid or protect electrical outlets

- ANSI Z358.1-2004

## Blocked Eyewash & Safety Shower

## Dirty Eyewash Station

## Blocked Eye Wash Station

## Hand Protection

- Glove considerations
  - Type glove
    - Dexterity required
    - Chemical & physical
      - material
      - strength
    - Exposure time
      - breakthrough time
    - Size, comfort, reusable/disposable
  - Manufacturer selection charts

## Glove Selection

- Considerations:
  - Chemicals (splashes vs immersion)
  - Thermal (extreme heat/cold)
  - Abrasion; cuts; snags; splinters; punctures
  - Grip: oily, wet, dry
  - Comfort, fit, size
  - Ergonomics

## Chemical Protective Gloves/ Clothing

- Permeation ("silent killer")
  - Substances pass through intact material on a molecular level.
- Penetration
  - Substances pass through seams, zippers, stitches, pinholes, or damaged material.
- Degradation
  - Substance damages material making it less resist or resulting in physical breakdown.
- Contamination
  - Substances transferred inside material (improper doffing or decontamination).

| Permeation Rate (PR) | Permeation Breakthrough (PB) | Permeation Degradation rate (DR) |
|---|---|---|
| E- Excellent; permeation rate of less than 0.9 mg/cm$^2$/min | >Greater than (time - minutes) | E - Excellent; fluid has very little degrading effect. |
| VG - Very Good; permeation rate of less than 9 mg/cm$^2$/min | < Less than (time - minutes) | G - Good; fluid has minor degrading effect. |
| G - Good; permeation rate of less than 90 mg/cm$^2$/min | | F - Fair; fluid has moderate degrading effect. |
| F - Fair; permeation rate of less than 900 mg/cm$^2$/min | | P - Poor; fluid has pronounced degrading effect. |
| P - Poor; permeation rate of less than 9000 mg/cm$^2$/min | | NR - Fluid is not recommended with this material. |
| NR - Not recommended; permeation rate greater than 9000 mg/cm$^2$/min | | † Not tested, but breakthrough time > 480 min DR expected to be Good to Excellent |
| | | †† Not tested, but expected to be Good to Excellent based on similar tested materials |



## Gloves

- It's important to have the *right glove* for the job and know *how long* it will last.
- Glove Chart Examples:
  - Consider several glove manufactures data before final selection.
  - www.bestglove.com/site/chemrest/

The first square in each column for each glove type is color coded. This is an easy-to-read indication of how we rate this type of glove in relation to its applicability for each chemical listed. The color represents an overall rating for both degradation and permeation. The letter in each square is for Degradation alone.

GREEN: The glove is very well suited for application with that chemical.

YELLOW: The glove is suitable for that application under careful control of its use.

RED: Avoid use of the glove with this chemical.

| CHEMICAL | LAMINATE FILM BARRIER | | | NITRILE SOL-VEX | | | UNSUPPORTED NEOPRENE 29-865 | | | SUPPORTED POLYVINYL ALCOHOL PVA | | | POLYVINYL CHLORIDE (Vinyl) SNORKEL | | | NATURAL RUBBER CANNERS AND HANDLERS* | | | NEOPRENE/ NATURAL RUBBER BLEND CHEMI-PRO* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Degradation Rating | Permeation: Breakthrough | Permeation: Rate | Degradation Rating | Permeation: Breakthrough | Permeation: Rate | Degradation Rating | Permeation: Breakthrough | Permeation: Rate | Degradation Rating | Permeation: Breakthrough | Permeation: Rate | Degradation Rating | Permeation: Breakthrough | Permeation: Rate | Degradation Rating | Permeation: Breakthrough | Permeation: Rate | Degradation Rating | Permeation: Breakthrough | Permeation: Rate |
| 1. Acetaldehyde | ■ | 180 | E | NR | — | — | E | 10 | F | NR | — | — | NR | — | — | E | 7 | F | E | 10 | F |
| 2. Acetic Acid | ■ | 150 | — | G | 270 | — | E | 60 | — | NR | — | — | F | 180 | — | E | 110 | — | E | 260 | — |
| 3. Acetone | ▲ | >480 | E | NR | — | — | E | 10 | F | F | — | — | NR | — | — | E | 10 | F | G | 10 | G |
| 4. Acetonitrile | ▲ | >480 | E | F | 30 | F | E | 20 | G | ■ | 150 | G | NR | — | — | E | 4 | VG | E | 10 | VG |
| 5. Acrylic Acid | — | — | — | G | 120 | — | E | 390 | — | NR | — | — | NR | — | — | E | 80 | — | E | 65 | — |
| 6. Acrylonitrile | E | >480 | E | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 7. Allyl Alcohol | ▲ | >480 | E | F | 140 | F | E | 140 | VG | F | — | — | F | 60 | G | E | >10 | VG | E | 20 | VG |
| 8. Ammonia Gas | ■ | 19 | E | ▲ | >480 | — | ▲ | >480 | — | — | — | — | ■ | 6 | VG | — | — | — | ■ | 27 | VG |
| 9. Ammonium Fluoride, 40% | — | — | — | E | >360 | — | E | >480 | — | NR | — | — | E | >360 | — | E | >360 | — | E | >360 | — |
| 10. Ammonium Hydroxide | E | 30 | — | E | >360 | — | E | 250 | — | NR | — | — | E | 240 | — | E | 90 | — | E | 240 | — |
| 11. Amyl Acetate | ▲ | >480 | E | E | 60 | G | NR | — | — | G | >360 | E | F | — | — | NR | — | — | F | — | — |
| 12. Amyl Alcohol | — | — | — | E | 30 | E | E | 290 | VG | G | 180 | G | G | 12 | E | E | 25 | VG | E | 45 | VG |
| 13. Aniline | ▲ | >480 | E | NR | — | — | E | 100 | P | F | >360 | E | F | 180 | VG | E | 25 | VG | E | 50 | G |
| 14. Aqua Regia | — | — | — | F | >360 | — | G | >480 | — | NR | — | — | G | 120 | — | NR | — | — | G | 180 | — |
| 15. Benzaldehyde | ▲ | >480 | E | NR | — | — | NR | — | — | G | >360 | E | NR | — | — | G | 10 | VG | G | 25 | F |
| 16. Benzene, Benzol | ▲ | >480 | E | NR | — | — | NR | — | — | E | >360 | E | NR | — | — | NR | — | — | NR | — | — |
| 17. Benzotrichloride | — | — | — | E | >480 | E | NR | — | — | — | — | — | — | — | — | NR | — | — | NR | — | — |
| 18. Benzotrifluoride | — | — | — | E | 170 | G | ■ | — | — | E | — | — | G | <10 | F | F | 50 | G | — | — | — |
| 19. Bromine Water | — | — | — | E | >480 | E | E | >480 | E | — | — | — | — | — | — | — | — | — | — | — | — |
| 20. 1-Bromopropane | ▲ | >480 | E | ■ | 23 | F | ■ | <10 | P | ▲ | >480 | E | ■ | <10 | F | ■ | <10 | P | ■ | <10 | P |

## Types of Gloves

### *Polyethylene/Ethylene-vinyl Alcohol {"Silver Shield®"}*

- Resists permeation and breakthrough with chemicals.
- Uses: aromatics, esters, ketones, and chlorines.

### *Butyl*

- Highest permeation resistance to gas or water vapors.
- Uses: ketones (MEK, acetone) and esters (amyl acetate, ethyl acetate).



## Types of Gloves

### Viton®

- Highly resistant to permeation by chlorinated and aromatic solvents
- Can be used with water/water based solvents

### Nitrile (acrylonitrile-butadiene rubber)

- Good replacement for latex
- Protects against acids, bases, oils, aliphatic hydrocarbon solvents and esters, grease, fats
- Resists cuts, snags, punctures and abrasions



## Types of Gloves

### Neoprene

- Protects against acids, caustics, DMSO.
- Resists amines, alcohols, glycols.
- Limited use for aldehydes and ketones.

### Poly vinyl chloride (PVC)

- Protects against acids, caustics.
- Resists alcohols, glycols.
- Not useful for aromatics, aldehydes and ketones.

## What is latex allergy?

- Natural rubber latex is from the rubber tree *Hevea brasiliensis.*
- The major route of occupational exposure is absorption of latex protein through the skin.
- Allergens in or on gloves can be transferred to the person's tissue.

## Latex Allergies

- Symptoms may occur within minutes of exposure or may take several hours depending on the individual.
  - Skin Redness
  - Hives
  - Itching
  - Respiratory Symptoms
    - Runny Nose
    - Itchy Eyes
    - Scratchy Throat
    - Asthma

## Latex Allergy

## Latex Allergies

- To prevent latex allergies consider:
  - Using non-latex gloves.
  - If you choose latex gloves, use the powder-free version.
  - When using gloves, do not use oil-based hand cream or lotions (these cause glove deterioration).
  - Recognize the symptoms of latex allergy.
  - Always wash hands after removing gloves.

http://www.cdc.gov/niosh/topics/latex/

http://www.nursingworld.org/osh/latex.htm

## Proper Steps for Removing Gloves

1

2

3

4

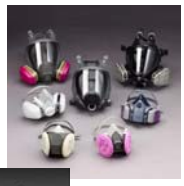
5

6



## Respiratory Protection Program

- Written program
- Administered by Safety Office
- Medical clearance
  - Respiratory Protection Questionnaire
  - *No beards*
- Fit testing
- Respirator selection
  - Air monitoring
- Training (annual refresher)



## Respiratory Protection Standards

- 29 CFR 1910.134
  - OSHA Respiratory Protection Standard
  - New OSHA Assigned Protection Factors
- ANSI Z88.2–1992
  - ANSI Voluntary Consensus Standard

Conduct an Exposure Assessment:
www.osha.gov/SLTC/etools/respiratory/haz_expose/haz_expose.html



## Types of Respirators

- Air purifying (APR)
  - Half Face
  - Full Face
  - PAPR
- Air supply
  - Air line
  - SCBA

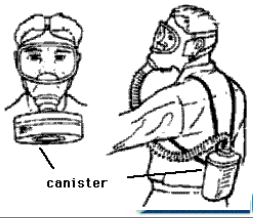
## Air Purifying Respirators

- *Must have at least 19.5% oxygen.*
  - Never use in $O_2$ deficient atmospheres
- *Only filters the air.*
  - Particulate filters
    - Removes aerosols
  - Chemical cartridges or canisters
    - Remove gases and vapors
- *Concentrations must not exceed limitations of filter/cartridge.*
- PAPR (Powered Air Purifying Respirator)
  - Uses a blower to force air through an air purifying element



## APR Chemical Cartridge Selection

- Specific gases or vapors
- NIOSH or MSHA approval
- Adequate warning properties
- End of service life
- Mechanisms
  - adsorption
  - absorption
  - chemical reaction
- Breakthrough times
- *Proper maintenance and storage*






## Cartridge Selection

| Cartridge | Description |
|---|---|
| | Organic Vapor |
| | Organic Vapor and acid gases |
| | Ammonia, methylamine and P100 any particulates filter 99.97% minimum filter efficiency |



## End of Service Life Indicators (ESLI)

There are very few NIOSH-approved ESLI's:

- ammonia
- carbon monoxide
- ethylene oxide
- hydrogen chloride
- hydrogen fluoride
- hydrogen sulfide
- mercury
- sulfur dioxide
- toluene-2,4-diisocyanate
- vinyl chloride

## Assigned Protection Factors (APF)

- Level of workplace respiratory protection that a respirator or class of respirators is expected to provide.
- Each specific *type* of respirator has an Assigned Protection Factor (APF).
- Select respirator based on the exposure limit of a contaminant and the level in the workplace.

***Maximum Use Concentration (MUC)***

***= APF x Occupational Exposure Limit (e.g.OEL, TLV)***



## Assigned Protection Factors

| Type of Respirator | Half Face Mask | Full Facepiece | Helmet/ Hood | Loose-Fitting Facepiece |
|---|---|---|---|---|
| Air-Purifying | 10 | 50 | - | - |
| PAPR | 50 | 1,000 | 25/1,000 | 25 |
| Supplied-Air or Airline | | | | |
| – Demand | 10 | 50 | - | - |
| – Continuous flow | 50 | 1,000 | 25/1000 | 25 |
| – Pressure demand | 50 | 1,000 | - | - |
| SCBA | | | | |
| – Demand | 10 | 50 | 50 | - |
| – Pressure Demand | - | 10,000 | 10,000 | - |



## Assigned Protection Factors

**Workplace air sampling indicates the exposure to benzene is 30 ppm. OEL is 1 ppm. What respirator should you choose?**

Maximum Use Concentration (MUC) = OEL x APF
Half Face Mask: MUC = 1 ppm x 10 = 10 ppm
PAPR (LFF): MUC = 1 ppm x 25 = 25 ppm
Full Face Respirator: MUC = 1 ppm x 50 = 50 ppm



## Dust Masks *vs.* Hospital Masks

## High Efficiency Particulate Air Filter (HEPA) Respirator

## Fit Testing

- **Qualitative**
  - **Irritant smoke (stannic chloride)**
  - **Isoamyl acetate (banana oil)**
  - **Saccharin**
  - **Bitrex (bitter taste)**
  - *Employees should perform a user seal check each time they put on a tight-fitting respirator*
- **Quantitative**
  - **Portacount**

## Qualitative Fit Test

***Pass/Fail Fit Test***

- **Assess the adequacy of respirator fit**
- **Relies on the individual's response to a test agent**

## Qualitative Fit Test

**Positive / Negative pressure fit test**

## Supplied Air

- Supplies breathing air to employee
- Examples:
  - SCBA
  - Airline
- Grade D Air
- Limitations

## Breathing Air Quality and Use

- Compressed breathing air must be at least Type 1 - Grade D [ANSI/CGA G-7.1-1989]:
  - Oxygen content = 19.5 - 23.5%
  - Hydrocarbon (condensed) = 5 mg/m$^3$ or less
  - CO ≤ 10 ppm or less
  - $CO_2$ of 1,000 ppm or less
  - Lack of noticeable odor
- Compressors equipped with in-line air-purifying sorbent beds and filters.



## Breathing Air Quality and Use

- Non-oil lubricated compressors
  - CO levels in the breathing air ≤ 10 ppm
- Oil-lubricated compressors
  - High-temperature or CO alarm, or both
  - If only high-temperature alarm, the air supply must be monitored to prevent CO levels from exceeding 10 ppm



## Maintenance and Storage Procedures

- Disposable filtering face-piece:
  - Dispose after use
- Half-mask:
  - Write expiration date (current date +estimate) making sure to keep entire label legible
  - Discard cartridges based on expiration date, end-of-service life indicator or calculated service life
  - Clean
  - Dry
  - Place in sealable bag (write your name on bag)
  - Contact Safety Office for repairs

## Maintenance and Storage Procedures

- Exclusive use of an employee:
  - Clean and disinfect as often as necessary to be maintained in a sanitary condition.
  - Discard cartridges based on expiration date, end-of-service life indicator or calculated service life.
- Respirators issued to more than one employee or maintained for emergency use:
  - Clean and disinfect before worn by different individuals or after each use.
- Respirators used in fit testing and training:
  - Clean and disinfect after each use
- All respirators *must* be stored in clean, dry bags



## Hazards Requiring Body Protection

- *Hazardous chemicals.*
- Potentially infectious materials.
- Intense heat.
- Splashes of hot metals and hot liquids.



## Body Protection for Emergency Response

Full suits:
- Class A
- Class B
- Class C
- Class D

## Level A Protective Suits

Potential exposure to unknown:

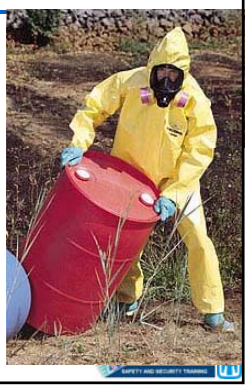
- Greatest level of skin, respiratory, and eye protection.
- Positive-pressure, full face-piece Self Contained Breathing Apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA.
- Totally encapsulated (air-tight) chemical and vapor protective suit.
- Inner and outer chemical-resistant gloves, and boots.

## Level B Protective Suits

- Atmospheric vapors or gas levels not sufficient to warrant level A protection.
- Highest level of respiratory protection, with lesser level of skin protection.
  - Positive-pressure, full face-piece self contained breathing apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA
  - Hooded chemical resistant clothing or coveralls (non-totally-encapsulating suit), inner and outer chemical-resistant gloves, and boots

## Level C Protective Suits

- Concentration or contaminant known
- Full-face air purifying respirator permitted with a lesser skin protection
- Inner and outer chemical-resistant gloves, hard hat, escape mask, disposable chemical-resistant outer boots
  - *Difference in Level C and level B is respiratory protection*





## Level D Protective Suits

- Minimum protection.
- *No* respiratory or skin protection.
- Used only if no known or suspected airborne contaminants present.
- May include gloves, coveralls, safety glasses, face shield, and chemical-resistant, steel-toe boots or shoes.

## Foot Protection

**Should meet or exceed ANSI Standard.**

**Types:**

- Impact,penetration, compression, steel toe, etc.
- Non-skid, with slip resistant soles.
- **Chemical resistant** (rubber, vinyl, plastic, with synthetic stitching to resist chemical penetration).
- Anti-static
- Temperature resistant (high or low extremes).
- Electrical protection (non-conducting).
- Water resistant
- Combination shoes

## Personal Protective Equipment
## Foot Protection

Steel toe-safety shoes are not necessary for laboratory work *unless* there is a serious risk from transporting or handling heavy objects.

**However,**
**open toe shoes**
**should <u>NOT</u> be worn in labs.**



## Head Protection

**Should meet or exceed Z89.1-2003**

**<u>Types:</u>**

- Bump caps - don't meet ANSI standard, provide minor protection
- Electrical protection 2200-22,000 v, depends on class)
- Mining protection
- Classic-- high impact general purpose protection.
- Impact 850-1000 pounds (386 - 454Kg)
- Penetration 3/8" (~1cm)



## Any Questions?

**Questions?**
**Open Discussion**
**Homework**