Chemical Security Engagement Program

Chemical Safety and Security Officer Training

23-26 October, 2012

SAND 2009-8395P
Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Welcome to Chemical Safety and Security Officer (CSSO) Training

Objectives

- Promote the safe and peaceful use of chemistry
- Encourage the creation of networks of people interested in CSS

Goals:

- Train The Trainer: Propagate the Knowledge and Practices Forward
- Provide resources to enhance your future trainings

CSP Website

https://chemsecurity.sandia.gov/

- Offers networking opportunities
- Provides resources
- Discussion boards
  - Share best practices
  - Ask questions/get answers
- Upload/view photos from workshops
- View/download training materials
- See upcoming and past events

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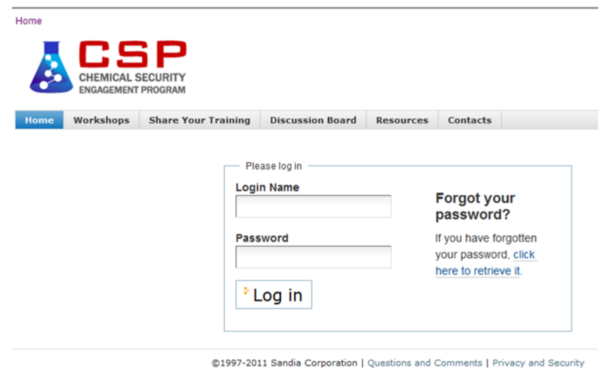
CSP Website – log in



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CSP Website – Workshops

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Chemical Safety and Security Overview

Day 1

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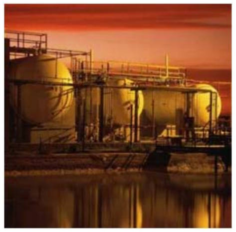
Why worry about chemical safety?

- Chemicals used everyday in labs and factories can be hazardous



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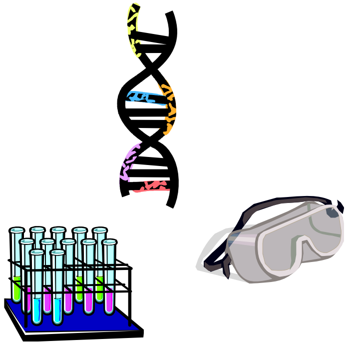
Disease depends on many factors…

- Genetics
- Specific chemical
- Protection controls used
- Dose
- Concentration
- Duration
- Life style
- Environment



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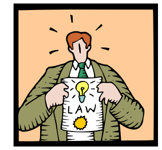
Why worry about chemical safety?

- Health of the workers
- Safety of the workers
- Safety of the community
- Safety of the environment

…It's the right thing to do!

Chemical accidents are now under stricter control and scrutiny

- Better individual country regulations
- Better international regulations
  - IATA
  - GHS
  - REACH
- Environmental problems after natural disasters
  - Earthquakes, cyclones, hurricanes, floods
- Increased public awareness
- Increased media coverage
- Less public tolerance



University of California Santa Cruz: Fire

January 11, 2002:
about 5:30 am, 4th floor of Sinsheimer Lab building, Dept. of Molecular, Cell and Developmental Biology

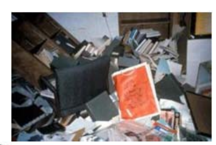
- Professors and students lost equipment, notes, materials, samples.
- Other labs in building closed for weeks to months.
  - Water and smoke damage
- Burned labs took 2 years to reopen.
- Cause never determined.

http://ehs.ucsc.edu/emergency/pubs/sinshfire2.htm

Environmental hazards California State Univ. Northridge

Earthquake

- Magnitude 6.7
- January 17, 1994 – 4:31 am
- 57 deaths, 11000 injuries
- Epicenter a few km from California State University Northridge campus



- Several fires in science buildings allowed to burn because firemen worried about chemical hazards
- Professors and students lost equipment, notes, materials, samples

Images courtesy: P.W. Weigand, California State University Northridge Geology Department,
Image source: Earth Science World Image Bank http://www.earthscienceworld.org/images

Dartmouth College: Dimethylmercury poisoning

- Karen Wetterhahn, professor and founding director of Dartmouth's Toxic Metals Research Program
  - expert in the mechanisms of metal toxicity
- In 1996, spilled a few drops of dimethylmercury on her gloved hand
  - Cleaned up spill immediately
  - Latex glove believed protective
- Six months later, became ill and died of acute mercury poisoning at age 48

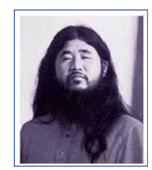
Safety Video: Reactive Hazards

Why worry about chemical security?

- Long history of people deliberately using chemicals to harm others
- Information on how to acquire and deliver them is easy to get:

Aum Shinrikyo: Matsumoto and Tokyo, Japan

- Sarin attack on Judges in Matsumoto, June 1994
  - Sarin sprayed from truck at night
  - 7 deaths, 144 injuries
- Sarin attack on Tokyo subway, March 1995
  - 11 bags with 600 g each on 3 main subway lines
  - 12 deaths, 3938 injuries
- Hydrogen cyanide attacks on Tokyo subway, May 1995
  - Bags of NaCN and sulfuric acid
  - No deaths, 4 injuries



Aum Shinrikyo: Tokyo, Japan

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Aum Shinrikyo: Matsumoto and Tokyo, Japan, cont'd.

- Recruited young scientists from top Japanese universities.
- Produced sarin, tabun, soman, VX.
- Purchased tons of chemicals through cult-owned companies.
- Motives: proof of religious prophecy, kill opponents, interfere with legal proceedings and police investigations.

Cyanide is a Chemical Weapon

- March 2002, an anarchist (called himself "Dr. Chaos") was found at 2 am in a Univ. Illinois, Chicago, building carrying sodium cyanide
- Had chemicals in a storage room at the Chicago subway
  - included containers marked mercuric sulfate, sodium cyanide, potassium cyanide, and potassium chlorate
  - 0.25 pound of potassium cyanide and 0.9 pound of sodium cyanide
  - stolen from an abandoned warehouse, owned by a Chicago-based chemical company
    - 15 drums and 300 jars of various other laboratory chemicals were discovered there

- Sentenced to prison for "possessing a chemical weapon", as well as other charges (Interfering with power, air-traffic control systems, computer systems, broadcast systems and setting fires).

Toxic Industrial Chemicals can be used as Poisons

- **Many incidents in which chlorine gas cylinders are blown up with explosives**
  - Chlorine probably stolen/diverted from water purification plants or oil industry
  - Many civilians and non-combatants injured
- **Chlorine first used in WWI as a chemical weapon**

On March 23, 2007, police in Ramadi's Jazeera district seized a truck filled with "five 1000-gallon barrels filled with chlorine and more than two tons of explosives"

From http://www.longwarjournal.org/archives/2007/03/al_qaedas_chlorine_w.php downloaded Jan 2008.

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Terrorist group recruits science/engineering students

…the squad arrested Kurnia Widodo, a.k.a Ujang, a recent university graduate who majored in chemical engineering. "We believe Kurnia was the technician at the bomb lab," …

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Why worry about chemical security?

- Health and safety of people and environment
- Community relationships
- Reduce chance of accidental chemical release
- Avoid loss and damage to labs and equipment
- Prevent criminals and terrorists from getting dangerous chemicals
  - Wide variety of chemicals have been used
  - Wide variety of motivations for actions
- A deliberate attack on a chemical facility could release a large amount of hazardous chemicals
  - Injure or kill people in nearby areas
  - Eliminate jobs and economic assets

Safety and Security Issues are similar

Variables

- Many different chemicals with:
  - different properties
  - different hazard
  - different applications
- Many different ways to misuse chemicals
  - chemical weapons
  - poisons

Protect

- Workers
- Facility
- Community
- Environment

Government regulations: Chemical security

- Differ from country to country
- Legislation needed to fulfill requirements under the Chemical Weapons Convention
  - Each country passes appropriate laws
  - Each country must declare and track certain chemicals
- UN Resolution 1540
- Other export control legislation

Fundamentals of Chemical Laboratory Safety

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Chemical Laboratory Safety

– *The control of exposure to potentially hazardous substances to attain an acceptably low risk of exposure*

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Chemical Laboratory Safety

Hazard – *the potential to harm*

We want to avoid this.

Risk – *the probability that harm will result*

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Chemical Laboratory Hazards

- Chemical hazards
  - dusts, fumes, mists, vapors, gases
- Physical hazards
  - fire, electrical, radiation, pressure vibration, temperatures, noise
- Ergonomic hazards
  - repetitive motion (pipetting), lifting, work areas (computers, instruments)
- Biological hazards
  - pathogens, blood or body fluids

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Chemical Laboratory Safety

Industrial Hygiene Principles

Anticipation	Chemical hazards
Recognition	Physical hazards
Evaluation	Ergonomic hazards
Control	Biological hazards

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Anticipation

Safety First !

To consider safety in the beginning is:

Easier,

Cheaper,

Safer,

… and it saves you time !

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Anticipation

Risk Analysis

- Which chemicals?
- How much?
- Special equipment needed?
- Who does the work?
- Staff properly trained?
- Can the experiment go wrong?
- Do you have an emergency plan?

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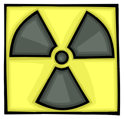
Recognition

Types of lab hazards:

chemical toxicity
fire / explosion
physical hazards
biohazards
radiation
special substances



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Recognition & Evaluation

What are the anticipated risks?

- Are the equipment & facilities adequate?
- Are staff properly and sufficiently trained?
- Risks if experiment goes wrong?
- Is there a plan for this?

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Control

How are the risks controlled?

- **Engineering controls:**
  - enclosure / isolation
  - ventilation / hoods
- **Emergency Plan**
- **Personal Protective Equipment (PPE)**

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Chemical Toxicity

Acute (short term, poisons, asthmagens)
cyanide
strychnine

Chronic (long term, carcinogens, reproductive)
vinyl chloride (liver cancer)
asbestos (mesothelioma, lung cancer)
thalidomide (developmental birth defects)

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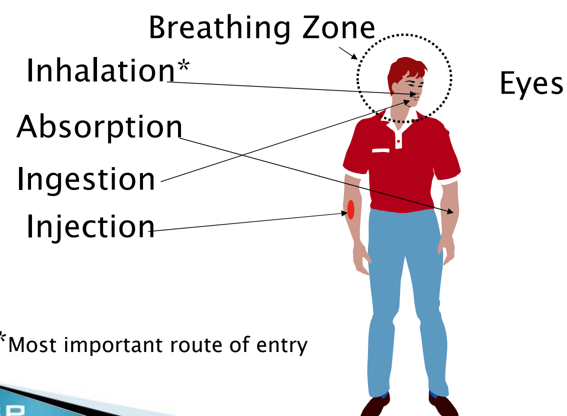
Routes of Exposure



*Most important route of entry

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Fire and Explosion Hazards

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Physical and Ergonomic Hazards

- Moving unguarded parts, pinches vacuum pump belts
- Broken glassware and sharps, cuts
- Pressure apparatus
- Vacuum containers
- Dewar flasks
- High voltage equipment
- Computer workstations
- Slips, trips & falls

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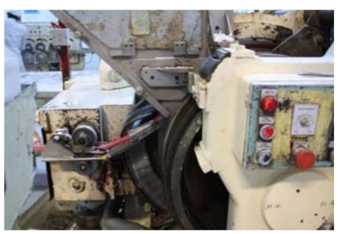
Physical and ergonomic hazards



An industrial assembly line with a fast-moving belt that is unguarded (left) and covered (right).

Photos courtesy of Patrick John Y. Lim.

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Biohazards

- Blood borne pathogens
  - AIDS, HIV, hepatitis, clinical chemistry labs
- Recombinant DNA
  - Genetic engineering, cloning
- Work with animals
  - Zoonoses, diseases from animals

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Radiation Hazards

Ionizing Radiation:
alpha α, beta β, gamma γ,
X-rays, neutrons

Radioactive isotopes:
tritium, H-3, carbon, C-14, sulfur, S-35,phosphorus, P-32/33, iodine, I-135

Radiation Hazards

Non-Ionizing Radiation:
Ultraviolet (UV spectrometers)
Magnetic (NMR, MRI)
Microwave
(Heart pacemaker hazard)
Lasers
(eye protection required)

Special Chemical Substances

Controlled Substances:
regulated drugs, psychotropic (hallucinogenic) substances, heroin

Highly Toxic Chemicals:
nerve gas, phosgene, riot control agents, chemical warfare agents

Evaluation & Control

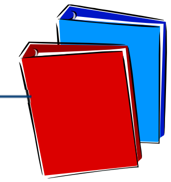
- Administrative practices
  organizational policies
- Operational practices
  work practices
- Engineering controls
  ventilation, barriers

Administrative Practices

organizational *safety policies*

that apply to everyone

Lab Safety Policies



- Have a Safety Manual
  - Never work alone, especially after hours.
  - Specify when eye protection & PPE is required.
  - Specify operations that require hood use.
  - Specify required training.
  - No mouth pipetting.
  - No long hair or dangling attire.

Lab Safety Policies

- No eating, drinking, smoking in laboratories
- Label all chemical containers
- Label refrigerators, No Food
- Label explosion safe refrigerators
- Require periodic fire drills

Operational Practices

Safe Laboratory Procedures:

- Packages opened only in labs, not receiving
- Receiving staff trained to look for signs of breakage and/or leaking shipments
- Receiving area has spill kits
- Mailroom/receiving alert for suspicious shipments

Safe Laboratory Procedures

Use hoods properly:

- Work 15 cm (6”) in from sash
- In center of hood
- Work with hood sash at ~45 cm (18”) high
- Close sash when not in use
- Don’t use for storage

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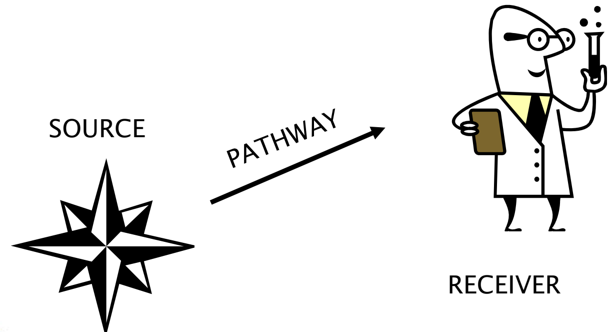
Engineering Controls



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Engineering Controls

1. Change the process

eliminate the hazard

2. Substitution

non-hazardous substance for hazardous

(e.g. – toluene for benzene)

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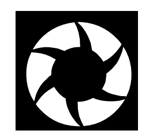
Engineering Controls

3. Isolate or enclose the process or worker

Use a barrier



4. Ventilation

Dilution (general ventilation) – Not good

Local exhaust ventilation (LEV) – Preferred

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Engineering Controls

Properly functioning & used correctly! Laboratory hoods and ventilation are the basis of engineering controls.

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Engineering Controls

Local exhaust ventilation includes:

snorkels

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Engineering Controls

Local exhaust ventilation includes: ***vented enclosures***

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Engineering Controls

Local exhaust includes:

special containment devices

(e.g. – glove boxes, isolation chambers)

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Personal Protective Equipment

PPE includes:

eye protection,
gloves,
laboratory coats. etc.,
respirators,
appropriate foot protection

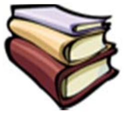
Emergency Planning & Response

- Have routine, unannounced evacuation drills.
- Designate a person for each area to ensure that inner rooms are evacuated.
- Locate outside staging areas at sufficient distance from the building.
- Test and maintain alarms.
- Post a person to meet/direct emergency vehicles.

Emergency Planning & Response

Post each room with:
Emergency phone numbers
After hour phone numbers
Person(s) to be contacted
Alternate person(s)
Unique procedures to be followed

References



"Safety in Academic Laboratories, Vol.1 & 2," American Chemical Society, Washington DC, 2003, also available online:
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=2230&use_sec=false&sec_url_var=region1&__uuid=ef91c89e-8b83-43e6-bcd0-ff5b9ca0ca33

"Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995, also available online:
http://www.nap.edu/catalog.php?record_id=4911

Break

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Aspects of Chemical Security, Dual Use, International Controls, and Chemical Safety and Security

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Chemical dual-use awareness

Dual use chemicals: Chemicals used in industry or everyday life that can also be used in bad ways.

Dual Use Chemicals

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Dual-use chemical example:

- Pseudoephedrine
- Cyanide
- Pesticides
- Fertilizers
- Sodium azide

Dual Use Chemicals

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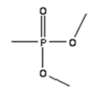
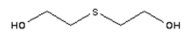
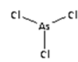
Many lab/industrial chemicals have dual uses

- Dimethyl methyl phosphonate (DMMP)
  - Flame retardant for:
    - building materials, furnishings, transportation equipment, electrical industry, upholstery
  - Nerve agent precursor
- Thiodiglycol
  - Dye carrier, ink solvent, lubricant, cosmetics, anti-arthritic drugs, plastics, stabilizers, antioxidants, photographic, copying, antistatic agent, epoxides, coatings, metal plating
  - Mustard gas precursor
- Arsenic Trichloride
  - Catalyst in CFC manufacture, semiconductor precursor, intermediate for pharmaceuticals, insecticides
  - Lewisite precursor







From: Chemical Weapons Convention: Implementation Assistance Programme Manual (on CD)

Dual Use Chemicals

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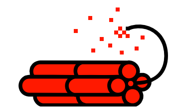
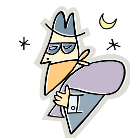
Dual-use Chemicals: Explosives

- Theft of conventional explosives
  - Chemical suppliers
  - Users such as mines or construction sites
- Diversion of industrial or laboratory chemicals
  - Chemical suppliers
  - Chemical factories
  - Academic teaching or research laboratories
  - Disposal sites





Dual Use Chemicals

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Theft / manufacture of explosives: Fertilizer Bomb

Photo: US DOD

- Ammonium nitrate fertilizer and fuel oil (diesel, kerosene)
- Used to bomb Alfred P. Murrah building in Oklahoma City, OK, USA
  - with nitromethane and commercial explosives
  - 168 dead, including children
  - April 1995
- Favored by IRA, FARC, ETA, etc.

Dual Use Chemicals

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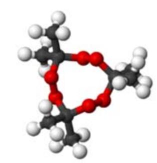
Theft / manufacture of explosives: TATP

- Triacetone triperoxide (TATP)
- Invisible to detectors looking for N-based explosives
- Made using acetone, hydrogen peroxide, strong acid (HCl, sulfuric)
- Favored by terrorists “Mother of Satan”
  - 1997-New York subway suicide bomb plot
  - 2001-Richard Reid “shoe bomber”
  - 2005-London suicide bombs
  - 2009 - Arrest of N. Zazi, NY and Denver



Wikipedia downloaded Oct 2009
http://en.wikipedia.org/wiki/Acetone_peroxide

Dual Use Chemicals

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Diversion of industrial / laboratory chemicals: Sodium azide

- Widely available from older automobile airbags
  - 1980s to 1990s
- Poisonous
- Reacts explosively with metals
  - Biological laboratory drains have exploded from discarded waste solutions containing NaN_3 as a preservative.
- Has been found in possession of terrorists

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Diversion of industrial / laboratory chemicals: Bali bombing

- Amrozi purchased chemicals used to make bombs
- One ton of potassium chlorate* purchased in three transactions from the Toko Tidar Kimia fertilizer and industrial chemicals store in Jalan Tidar, Surabaya, owned by Sylvester Tendean
  - Claimed he was a chemical salesman
  - Obtained a false receipt saying he purchased sodium benzoate
  - Tendean lacked proper permit to sell this chemical, didn't know the chemical would be used to make a bomb
- Details of Aluminum powder purchases not known

* Some press reports state potassium chloride, but this is clearly an error
http://www.smh.com.au/articles/2003/06/09/1055010930128.html
http://www.thejakartapost.com/news/2002/12/18/amrozi-owns-possessing-chemicals.html

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Organization for the prohibition of chemical weapons (OPCW)

- International group headquartered in The Hague, Netherlands
  - https://www.opcw.org/index.html
- Chemical weapons convention (CWC)
  - International treaty which bans the development, production, stockpiling, transfer and use of chemical weapons
- Promotes international cooperation in peaceful uses of chemistry
- Protecting each other

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OPCW: Spiez Laboratory

The Philippines sent delegates to the OPCW CWC conference in Spiez Laboratory.

Photo courtesy of Patrick John Y. Lim.

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CWC: Prevent spread or production of new chemical weapons

- States declare and agree to inspections of many other chemical facilities, depending on chemical type and amount produced
- Over 4,100 inspections have taken place at 200 chemical weapon-related and over 1100 industrial sites on the territory of 81 States Parties since April 1997
- Worldwide, over 5,000 industrial facilities are liable to inspection

International Controls

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Australia Group

- An informal arrangement to minimize the risk of assisting chemical and biological weapon (CBW) proliferation.
  - Harmonizing participating countries' national export licensing measures
  - Started in 1985 when Iraq CW program was found to have diverted chemicals and equipment from legitimate trade
- 40 nations plus European Commission participate

International Controls

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Australia Group: Export Controls

- Controls exports of:
  - 63+ Chemical weapon agent precursor chemicals
  - Dual-use chemical manufacturing facilities and equipment and related technology
  - Dual-use biological equipment and related technology
  - Biological agents
  - Plant pathogens
  - Animal pathogens
- Includes no-undercut policy
  - Countries won't approve an export that another member country denied

International Controls

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UN Security Council Resolution 1540

- Unanimously passed on 28 April 2004
- UN Member States:
  - must **refrain from supporting non-State actors** in developing, acquiring, manufacturing, possessing, transporting, transferring or using nuclear, chemical or biological weapons and their delivery systems.
  - must **establish domestic controls** to prevent the proliferation of nuclear, chemical and biological weapons, and their means of delivery, including by establishing appropriate controls over related materials.
- Enhanced international cooperation is encouraged, promoting universal adherence to existing international non-proliferation treaties.

International Controls

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Chemical Security: Professional Behavior

Chemical professionals

- use their scientific knowledge in a responsible manner.

Chemical Educators

- need to train their students to use their scientific knowledge in a responsible manner.

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Chemical Security Questions

- Is your facility secure?
- How easy would it be for someone to steal chemicals?
- Are the chemistry workrooms, stockrooms, classrooms and labs always locked and secure?
- Is someone always there when these rooms are open?
- Do you check your orders when chemicals arrive to be sure some chemicals are not missing?

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Components of Chemical Security

- Physical security of site
- Personnel management
- Information security
- Management of chemical security activities
- Allocation of chemical security responsibilities
- Development of emergency plans
- Chemical security training

Goal: Ensure that you don't accidently help a criminal or a terrorist get dangerous chemicals

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Chemical Security: Physical Site

LOCK UP!!

Controlled drugs

Chemical Surety Agents

Highly toxic chemicals

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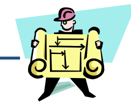
Facility Characterization



Characterize the facility in terms of:

- Site boundary
- Buildings (construction and HVAC systems)
- Room locations
- Access points
- Processes within the facility
- Existing Protection Systems
- Operating conditions (working hours, off-hours, potential emergencies)
- Safety considerations
- Types and numbers of employees
- Legal and regulatory issues

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Threat Definition

Threat classes:

- Outsiders—no authorized access
- Insiders—authorized access
- Collusion—between Outsiders and Insiders

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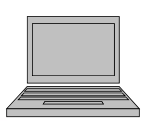
Target Identification

- Determine the possible targets for the following actions
  - Sabotage
    - identify vital areas to protect
  - Theft of chemicals
  - Theft of Information
    - identify location of materials to protect



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Chemical Security: Personnel Management

- Guard against both *Insider and Outsider* threat
- Who checks people entering the building?
- Who has keys? How do they get authorized?
  - Building
  - Stockroom
  - Individual Labs
- When someone leaves, do you make sure they turn in keys?
  - Don't want people making duplicate keys

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Chemical Security: Information Security

- How do you track chemical inventory?
  - Is the information secured so unauthorized people can't read it or alter it?
- Would you know if:
  - some toxic chemicals disappeared overnight?
  - some toxic chemicals didn't arrive?
  - someone has ordered chemicals in the name of your institution but diverted them?

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Chemical Security: Assign Responsibilities

- Identify people responsible for various chemical security activities:
  - physical security, building modifications
  - chemical tracking and reporting
  - personnel and access management
  - information management
  - emergency planning
- Ensure they have the time and resources to do the job.
- Integrate with chemical safety responsibilities.

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Relationships Between Chemical Safety and Security

- Chemical safety:
  - Protection against *accidents*
- Chemical security:
  - Protection against *deliberate* harm

Many practices are the same for chemical safety and security, but there are a few areas of conflict.

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Good Practices for Both Chemical Safety and Security

- Minimize use of hazardous chemicals
  - Replace with less-hazardous chemicals, if possible
  - Reduce scale of experiments
- Minimize supply of hazardous chemicals
- Restrict access to hazardous chemicals
  - Know what you have
  - Know how to store, handle and dispose of what you have
  - Know who has access to materials, knowledge and expertise
- Plan what to do in an emergency.

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Conflicts Between Chemical Safety and Security: Information Sharing

Science generally means sharing information widely, but this may not always be advisable.

- Safety
  - label everything so people recognize hazardous chemicals
  - let community and especially emergency responders know what chemical dangers exist
  - share knowledge about chemical hazards so people know to be alert
- Security
  - labels help identify targets for theft or attack
  - sharing locations of chemicals can publicize targets for theft or attack
  - sharing knowledge of chemical hazards could inspire harmful behavior (copy-cat criminals)

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Conflicts Between Chemical Safety and Security: Facility Exits

- Locking exit doors is secure, but not safe
  - For safety, people need to be able to leave the facility quickly and by many routes
  - For security, you want to control exits as well as entrances so chemicals (or equipment) are not taken.

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Chemical safety and security

USC Chemistry Storeroom before and after installation of steel curtain.

Photo courtesy of Patrick John Y. Lim.

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Setting Priorities

- Labs need to be safe, secure and productive
  - policies and practices need to be flexible enough to allow for the uncertainties of research
  - policies and practices need to align with local laws, regulations, practices and culture. Can't just copy from somewhere else
- Use risk-based security and safety measures
  - can't afford to defend against every imaginable hazard
  - identify threats, characterize facilities, identify alternatives, analyze costs vs. performance
- Be alert for suspicious activities or inquiries.

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All Chemical Facilities Need to be Secured


- Small-scale research laboratories
  - Many different chemicals used in small amounts
- Large-scale manufacturing plants
  - Limited types of chemicals used in large amounts
- Security measures need to match facility and threat
  - Can't afford to defend against all imaginable threat.

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Lunch

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Sandia National Laboratories

CSSP Organization, Responsibilities, and CSSO Duties

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Sandia National Laboratories

Chemical Safety and Security Program Purpose

- Help establish a safe and secure workplace.
- Help safeguard the environment.
- Prevent/reduce release of hazardous chemicals and operations.
- Prevent/reduce exposure to staff.
- Reduce stress.
- Enhance community relations.
- Comply with regulations.
- Crisis management

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Crisis Management: Prevention & Response

- Facility crisis
  - Fire
  - Explosion
  - Chemical release
- Natural disaster
  - Earthquakes
  - Hurricane/typhoon
  - Tsunami
- Disgruntled personnel
  - Employees
  - Ex-workers
  - Students
- Demonstrations, protests
- Evacuation / reoccupancy
- Terrorism

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Crisis Management: Criminal & Terrorism Concerns

- External security
  - Fences
  - Cameras
  - Guards
- Internal security
  - Personnel background checks
  - Employees, contractors, students
- Theft
  - Chemicals, materials
  - Equipment
- Bombing
- Toxic release

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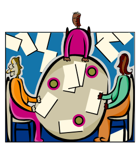
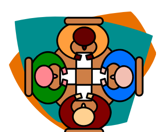
Chemical Safety and Security Applies to Everyone



Administration
Human Resources
Purchasing
Facilities
Construction
Police/Security
Department Administration
Research Administration
Employees
Students
Contractors
All visitors



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Management CSS Responsibilities

POLICY STATEMENT

Documents and describes
the commitment and support
from the highest management level
for the Chemical Safety and Security Program

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Policy Statement Purpose

Establish and provide for maintenance of an effective Chemical Safety and Security Program to protect:

- Employees
- Facility
- Neighbors
- Environment
- Comply with regulations

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Policy Statements

- By senior management
- Typically brief
- Clear goals
- Commitment
- Defines employee role
- Identifies resources and staff
- Signed by person in authority

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Director/President CSS Responsibilities

- Establish an effective CSS Program
- Provide for a budget
- Endorse written Policies, Plans and Manuals
- Appoint CSS Officers
- Ensure CSSO has responsibility, authority and accountability to perform assigned duties
- Establish a CSS Committee
- Maintain support and endorsement
- Timely response to Safety Committee recommendations
- Follow and set example, e.g., wears PPE

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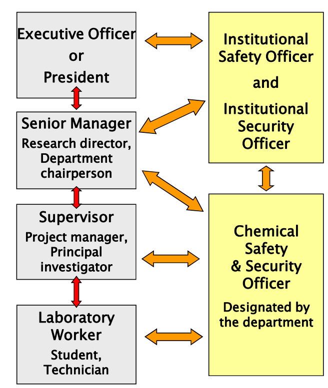
Chemical Safety and Security Program: Ideal Roles

- Culture of Chemical Safety and Security should exist at all levels of the organization.
- Top management sets policy, provides resources.
- Workers, students, researchers must understand and implement.
- Many organizational interactions are important for chemical safety and security
  - After Fig 1-1 in Prudent Practices in the Laboratory, NRC 1995



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Faculty/Principal Investigator

has the responsibility

to *teach*, *model* and *encourage*
good Chemical Safety and Security practices

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Principal Investigator CSS Responsibilities

- Develop procedures with CSSO for unique hazards and chemicals (e.g. carcinogens)
- Develop proper control practices with CSSO
- Participate in developing CSS Plan, CSS Committee, accident investigations
- Ensure CSS documents and records are maintained
- Maintain local chemical inventory for their lab
- Ensure (M)SDS are available in the laboratory
- Facilitate compliance with policies, guidelines and regulations

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Principal Investigator CSS Responsibilities, cont'd.

- Ensure students/workers know and follow policies and practices
- Ensure equipment and controls are properly maintained
- Ensure all students/workers received proper training and refreshers
- Ensure new students/workers receive proper training before starting work
- Inform CSSO of any accidents and incidents
- Follow-up on accidents and incidents

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Employees and students

have a responsibility

to *actively* support and participate
in the CSS Program.

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Employee/Student CSS Responsibilities

- Follow policies/rules
- Wear Personal Protective Equipment (PPE)
- Report accidents, incidents/near misses, problems
- Learn about hazards of specific chemicals
- Suggest changes and improvements
- Work safely
- Do not put others at risk
- Encourage good safety and security
- Behave responsibly

Employee/Student CSS Responsibilities

- Understand and act in accordance with policies and practices
- Wear and maintain proper PPE
- Use engineering controls properly
- Follow good chemical safety practices
- Participate in required training
- Read & understand CSS related documents
- Report accidents, incidents
- Suggest improvements and changes to the CSS Program
- Participate in the CSS Program

Chemical Safety and Security Committee

Has the responsibility to oversee and monitor the CSS Program for management so that a safe and healthy workplace is maintained

Chemical Safety and Security Committee Responsibilities

- Reports directly to senior management
- Endorses policies
- Meets regularly (2 – 4 times/yr) with agendas
- Reviews accidents and incidents, may investigate, write reports with recommendations
- Establishes appropriate subcommittees on specific topics

Chemical Safety and Security Committee Composition

- Chaired by committed staff
- CSSO is ex-officio member
- Includes representatives from:
  - Facilities Management
  - Security
  - Administration
  - Faculty/Staff
  - Teaching Assistants/Graduate Students
  - Shops/Unions
- Representatives should rotate after a few years

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CSS Program Evaluation

- Management leadership
- Employee involvement
- Administrative controls
- Security controls
  - Access to buildings, materials
- Engineering controls
- Accident/incident investigation
- Training
- Use of Personal Protective Equipment (PPE)
- Emergency Response Program
- Medical Surveillance Program
- Work site analysis
  - Inspections, surveys, hazard analysis

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Chemical Safety and Security Officer Duties

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Chemical Safety and Security Officer

- CSSO has the responsibility to provide expertise and information so that a safe and healthy workplace is present
- The Function of the CSSO is to Act as a Co-Worker, *NOT* as a Policeman

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CSSO Duties Include:

- Surveys
- Job Hazard Analysis
- Inspections
- Training
- Medical Monitoring
- Investigations

CSSO Duties

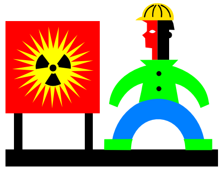
- Oversee procurement, use, storage & disposal of hazardous materials
- Set criteria for exposure levels
- Write and revise CSS Plan
- Train, document and ensure training is performed
- Perform risk assessment and monitoring
- Conduct audits and inspections
- Investigate and report on accidents, incidents
- Interact with staff to correct deficiencies
- *Follow up* to ensure correction and resolution of issues

CSSO Duties

- Consult/advise project management on CSS concerns
- Coordinate with Principal Investigators
- Coordinate and facilitate medical surveillance
- Coordinate record keeping
- Coordinate with BSO, RSO, facilities, administration, security

Hazard Survey

- Baseline
- Periodic (inspections)
- Identify potential job hazards, material hazards, and process hazards

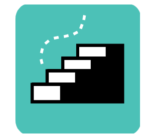


Hazard Survey Process

- Prepare survey form
- Walk-through
- Take measurements
  - – Sample if necessary, monitor exposure formaldehyde, radiation)
- Data analysis
- Write and deliver report

Job Hazard Analysis (JHA)

- Hazards associated with a particular task become apparent from a brief survey:
  - Compile steps needed to complete job.
  - Analyze each step in detail.
    - Could exposure occur?
    - Could an accident occur?
    - Could a change in practice / process could create hazard?
  - Develop recommendations on precautions to eliminate/minimize hazard.



Periodic Lab Inspections

- Done by CSSO
- Coordinate with lab supervisor/PI/occupant s/ safety representative
- Team may include:
  - Peers
  - Facilities representative
- Frequency determined by hazards present and local practices
  - 2 – 4 times/yr
- Look for:
  - Good and bad practices
  - new hazards
  - new security issues

Training Program

- Determine if training is needed, e.g., JHA
- Identify needs
- Identify Goals & objectives
- Develop training activities
- Identify resources
- Conduct training
- Evaluate effectiveness
- Improve program

Employee Training Topics

- New employee orientation
- Specialized laboratory equipment and procedures
- Recognize Occupational Exposure Limits (OEL) for hazardous chemicals; (M)SDS
- PPE use, storage and maintenance (especially respirators)
- Fire safety and fire extinguisher use
- Emergency plans, evacuation procedures & routes
- Ionizing radiation
- Non-ionizing radiation, lasers, microwaves
- Special exposure, e.g., formaldehyde
- Biosafety, Bloodborne pathogens
- Facility security requirements
- Animal Care facilities – use and techniques

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Training Documentation: Sample

- Employee name: ___________________________
- Department: _________________________
- Date: ______

- Training Subject: ______________________________
- Training Date: ___________
- Re-instruction date: _________

- Employee Signature: ______________________________
- Date Signed: __________
- Supervisor's signature: _____________________________
- Date: __________

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Medical Surveillance *vs.* Biological Monitoring

Medical Surveillance

- General program
- Establishes baseline
- Evaluates employees before potential exposure
- Documents past exposure and existing conditions
- Simpler, cheaper, less invasive medical testing
- May be used in conjunction with biological monitoring

Biological Monitoring

- Chemical specific signs and symptoms
- Known exposure levels
- Documented exposure
- Documented amounts of personal exposure
- Documented environmental exposure
- Most specific, most expensive, more invasive

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Guidelines for Incident Investigation

- Description/report of incident
- Review of organizational policy
- Start of investigation
- Cause of incident
  - Emphasis is prevention, *NOT* blame
  - Timely report with recommendations to all responsible parties including senior management
- Timely response to recommendations
  - Correction
  - Follow-up
  - Action taken
  - Training

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Chemical Safety and Security Plan

First step: Collect information

- Writing a good CSS plan requires a lot of information
- Assessment questionnaires can be used to collect such information
- Distribute to:
  - PIs
  - Management
  - Facilities
  - Security
  - Medical

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Assessment Questionnaire

- Who is responsible for CSS compliance?
  - Criteria for exposure control
  - Developing exposure control measures
  - Exposure monitoring
  - Identification of hazardous materials
  - Limited access policy
  - Ventilation maintenance
  - Safety equipment
  - Personal protective equipment
  - Training
  - Hazardous waste management
  - Medical surveillance
  - Emergency response

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Assessment Questionnaire, cont'd.

- List individuals (managers, PIs, professionals, technicians) with Safety & Security responsibilities.
- Who maintains CSS records?
- Is there a Safety/Security Committee?
  - Responsibilities
  - Who are the members?
  - How often do they meet?
- Is there a CSS Manual, Plan?
- Are there CSS policies?
- Is there an Emergency Response Plan?
- Are routine CSS inspections conducted?
  - By whom
  - Details

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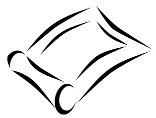
Chemical Safety and Security Plan

- Includes CSS Policy Statements from senior management.
- Describes the entire Program.
- Describes the organization of the Program.
- Explains everyone's responsibilities.
- Describes in general terms policy and who, what, where and why a safety or security task or job is performed.
- Includes references, if necessary.



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Parts of a Chemical Safety and Security Plan

- Policy statement from Senior Management
- Safety & Security Organization
  - Management
  - Responsibilities
    - Management
    - Administration
    - CSSO staff
    - Facilities Management
    - Principal Investigators
    - Staff
    - Contractors

- General housekeeping
- Eating, smoking areas
- Signs & labels
- Emergency procedures
- Chemical storage
- Personal protective equipment
- Respirator protective program

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Parts of a Chemical Safety and Security Plan, cont'd.

- Engineering Controls
  - Ventilation
  - Laboratory hoods
- Waste Management
- Training
- Record keeping
- Fire Protection & Protection
- Location of emergency equipment
- Evacuation plans
- Personal and environmental monitoring
- Inspections
- Medical surveillance
- Administration
  - Purchasing chemicals
  - Purchasing safety equipment

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Standard Operating Procedures (SOPs)

- An SOP explains *concisely and precisely* how, where and who performs a task.
- It does *not* explain why the task is done.
- The Safety and Security Plan explains policy and why a task is performed

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Standard Operating Procedures (SOPs), cont'd.

- SOPs are:
  - Dated
    - When issued
    - When reviewed
    - When revised
  - Have: subject, title and identification code
  - Officially reviewed by management
  - Signed by all responsible parties
  - May include forms
  - Written in a consistent and official format with numbered pages

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Standard Operating Procedures (SOPs)

Consider written SOPs on:

- Security clearance and visitor access
- Employee training
- Medical surveillance
- Respiratory protection and fit
- Eye protection
- Ventilation system maintenance
- Storage, receipt, transport and shipping of hazardous materials
- Accident and emergency response including natural disasters
- Spill cleanup
- Waste management
- Hazardous material handling
- Special operations, radiation, biosafety, lasers, infectious agents

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Plan and SOPs Revision Guidelines

CSS Plan	→ As needed, every 5 years
(M)SDS	→ As received
Laboratory Hoods	→ As needed
Training records	→ Yearly, and as needed
Medical Surveillance records	→ As needed, and every 12-18 months
Exposure monitoring	} As needed
Waste records	} As needed

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Record Retention Recommendations

- Personal records kept by Human Resources for the duration employment + 30 years.
- Medical records are *confidential* and should be kept by the examining physician for duration of employment + 30 years.
- Most other records (e.g., routine monitoring, should be kept for 5 years after date of performance).

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Lab Assessment Exercise : Lab Layout, Hazard Identification

Activity: Laboratory Assessment Exercise

- Form groups of 3-5 people per group
  - Will continue to work with these groups later as well
- Draw the floor plan of a laboratory on a large sheet of paper
  - Identify the main laboratory features such as doors, windows, lab benches, refrigerators, chemical hoods, instruments and other equipment, etc.

Take about 30 minutes to do this

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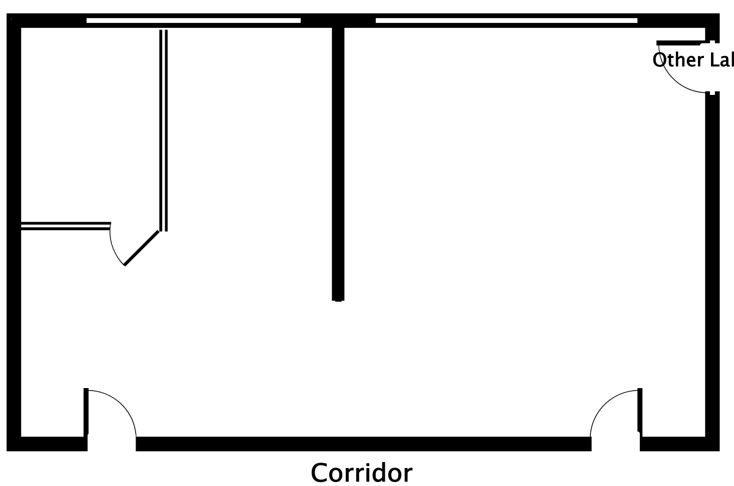
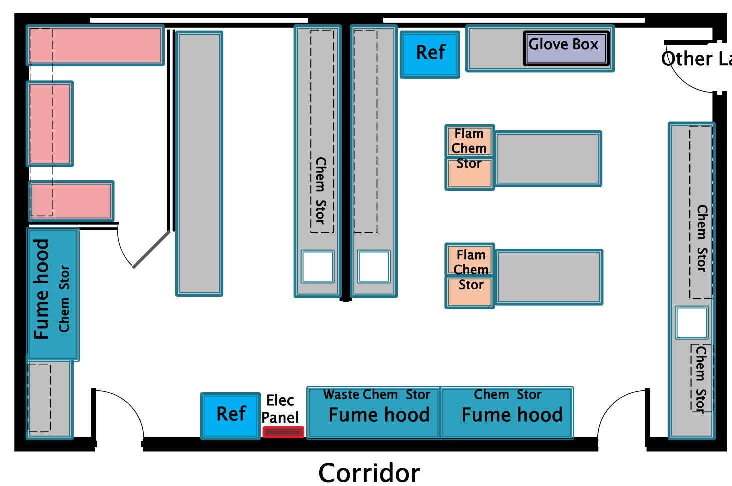
2



Chemical Lab Floor Plan



Chemical Lab Floor Plan

Laboratory Assessment Exercise

- Once the floor plan is done, get hazard and CSS Control stickers from an instructor and apply them to the appropriate places in your laboratory floor plan
- Identify the CSS controls present in your laboratory
- Apply stickers describing the CSS controls to your laboratory floor plan
- Identify any control measures present in your laboratory
  - Even if we don't have stickers for them
- Write down a list of the hazards present
- Keep everything you create in this activity, it will be used later on

Take about 30 minutes to do this

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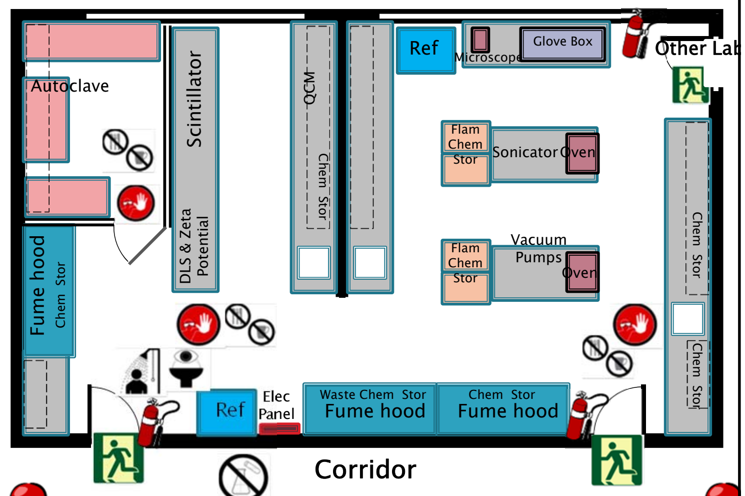


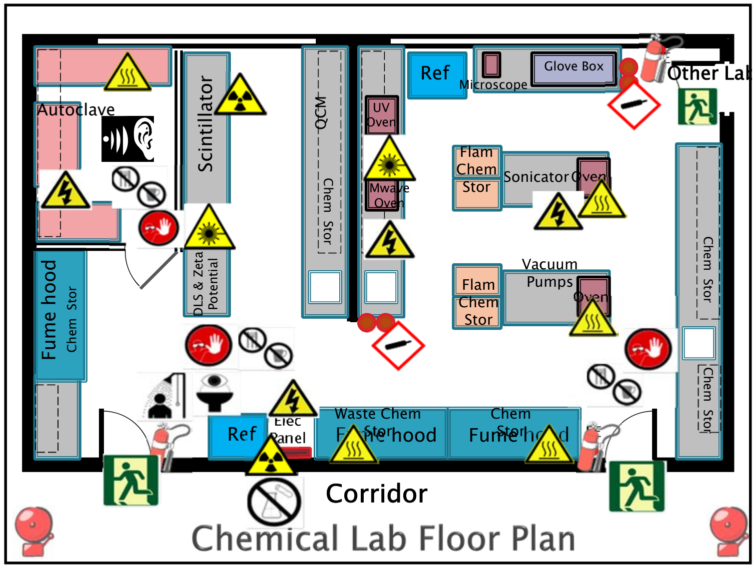
Chemical Lab Floor Plan

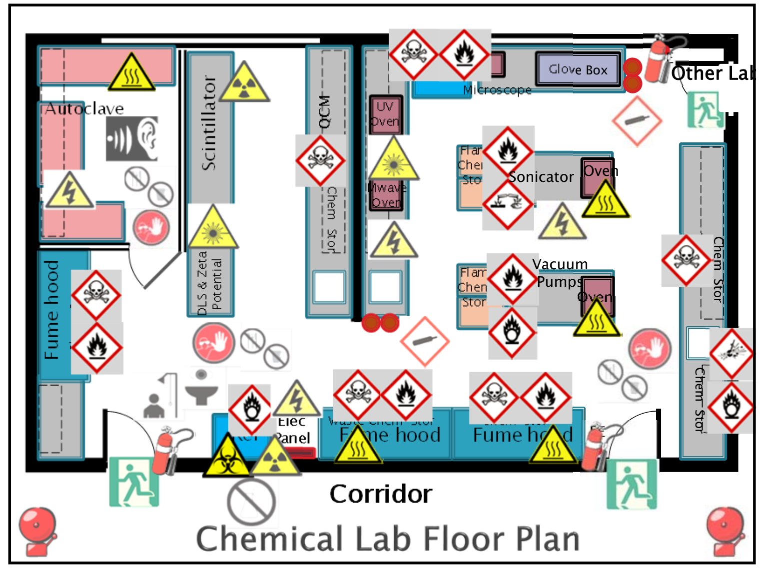
Examples of GHS Pictograms

Corrosive	Irritant	Health Hazard	Acute Toxicity
Flammable	Explosion	Oxidizer	Compressed Gas

Assessment Exercise – Symbols

Hot Surface	UV or IR	Electrical	Laser	Radiation	Biological
Eyewash	Safety Shower	Haz Waste	Exit	Fire Alarm	Fire Exting.





Principles & Concepts of Lab Design

Day 2

Purpose of Laboratory Design

- Protect the Workers
- Enable the Work
- Secure the Facility
- Protect the Environment
- Comply with Regulations

Objectives of Laboratory Design

- Provide a safe/secure workplace
- Facilitate workplace activities
- Efficient
- Cost Effective

Barriers to Good Lab Design


Cost

Poor Communication

Lack of Scientific Knowledge

Complicated Project

Trade-offs

Personalities

Maintenance

Good Laboratory Design

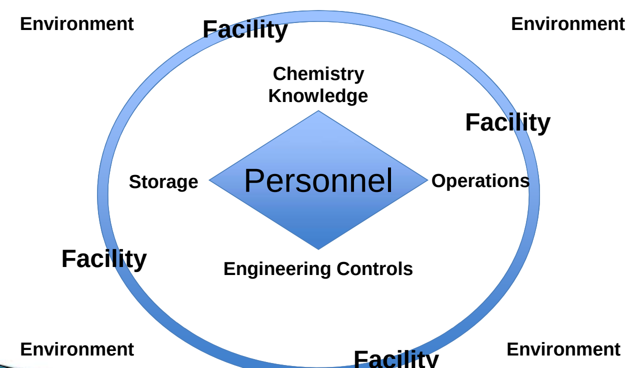
Based on:

Containment

Maximize Containment ⟷ Minimize Contamination

Redundancy is the Key

Chemical Containment Concept



Chemical Protection Depends on:

1
Chemistry Knowledge
Workers must have knowledge and understanding

2
Containment
Safe/Secure Storage
Proper Work Practices
Good Engineering Controls

3
Construction
How well the facility is built

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Key Stakeholders

Architects
Engineers
Administrators
Builders
EHS Professionals
Laboratory Users

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Laboratory Design

is an Iterative Process

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Design Phases

Definition
(problems and needs)
↕ (iterative process)
Interpretation
(of requirements into design criteria)
↕ (iterative process)
Design
(translates specifications into pragmatic reality)
↕
Construction
(to accomplish goal)

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Architectural Features Include:

- Layout of buildings and laboratories
- Space requirements
- Spatial arrangement of equipment and benches
- Emergency egress
- Storage requirements
- Waste requirements
- Access controls
- Security features

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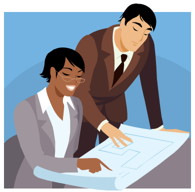
Lab Design Components

- Spatial
  - Floor plan
  - Location of rooms and equipment
  - Traffic flow of people and equipment
  - Access control
- Mechanical
  - Ventilation
  - Utilities
  - Effluent control
  - Control and monitoring
- Safety and Security



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Factors in Laboratory Design

- Architectural
- HVAC
  - heating, ventilation, and air conditioning
- Safety and Security
  - Fire
  - Emergencies
  - Exposures
  - Access/exit control
    - facility, chemicals, equipment

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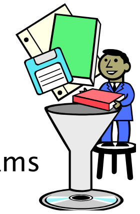
General Information Needed

- Number of occupants and their technical qualifications
- Space and storage requirements
- Utilities needed
- Equipment needs
- Time/duration of occupancy
- Anticipated changes in research/programs
- Sustainability (environmental, green initiatives)
- Security needs



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Safety/Security Information Needed for Lab Design

Type of Work/Research

Type of Hazards

Type of Wastes

Chemical

Biological

Radiation

High Voltage

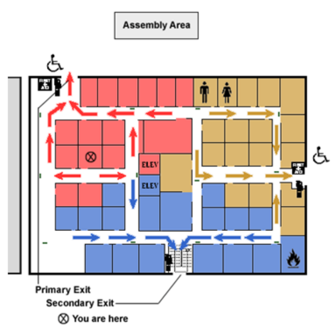
Types of Chemicals

Examples of Lab Design Considerations

- Sample preparation and storage area
- Segregate sample digestion using acid–specialized laboratory hoods
- Segregate solvent extraction to reduce vapor contamination
- Proper eyewash placement
- Adequate egress
- Waste storage area
- Gas bottle storage

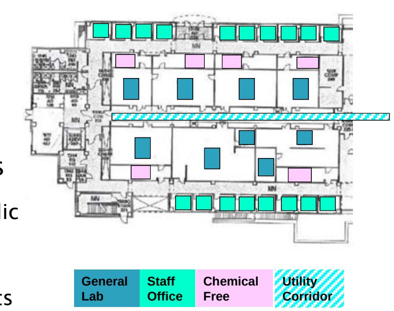
Building Layout: Divide into Zones

- Zones or control areas may have different:
  - Types and degree of hazards
  - Amounts of hazardous chemicals
- Allows better control over:
  - Personnel access
  - Hazards using
    - Equipment
    - PPE
    - Administrative procedures
- Examples: Fire safety zones, HVAC zones, Building floors



Building Layout: Corridors

- Best practice is to separate movement of:
  - General population
  - Laboratory personnel
  - Chemicals and laboratory materials.
- Internal "service corridors" between labs
  - Allow transport of chemicals away from public
  - Provide access to utilities and other support equipment
  - Provide additional lab exits with emergency doors to main corridors



Building Layout: Entrance/Exit Doors

- Good safety: two or more exits from each lab/room/building
- Good security: control who can enter a lab/room/building
- Emergency exit doors:
  - Lack handles, or are locked on outside
  - Have "panic bar" on inside
  - May set off alarm when opened

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Building Layout: Chemical Stockrooms

- Multiple, specialized stockrooms rather than one central storeroom
  - Chemicals dispensed across counter
  - Access restricted to stockroom personnel
  - Locked when unattended

- Teaching stockroom
  - High traffic
  - Only keep ~1 week supply of chemicals needed for student experiments
- Central Stockroom
  - Wide variety of chemicals and materials
  - Additional controls and containment for regulated, attractive, or dual-use chemicals
- Chemicals stored in compatible groups

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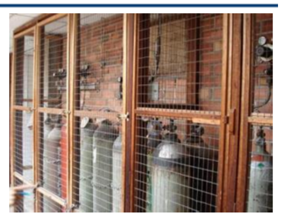
Building Layout: Compressed Gases

- Install tanks outside building and pipe into lab
  - Long-term, frequent use of same gas
  - Restrict access
  - Out-building or outdoors, depending on conditions
- Tanks inside labs
  - Wide variety of gases
  - Low use rates
  - Strap to wall or bench
  - Transport safely



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Building Layout: Chemical Waste

- Waste collection area in teaching/research labs:
  - Convenient student use
  - Emptied/moved frequently
  - Divided into chemically compatible groups
  - Provide safety equipment
- Large volumes of chemical waste should be stored in areas with fewer people
  - Access restricted to responsible personnel
  - Locked when unattended
  - Divided into chemically compatible groups
  - Provide safety equipment and alarms

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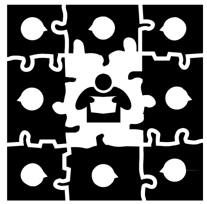
Modular Laboratory Design

- Uses standard size and layout of benches, equipment and utility connections
- Customize layout for specific applications
- Allows for:
  - Cheaper lab design
  - Easier lab modifications
  - Easier lab renovations



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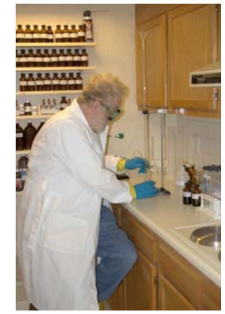
Open vs. Closed Laboratories

Open Laboratory

Closed Laboratory



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Open vs. Closed Laboratories

Consider using both or having connected access:

<u>Closed laboratories</u>

- Specialized, dedicated work
- More expensive
- Less flexible
- Easier to control access
- Needed for specific work
  - NMR
  - Mass spec
  - High hazard materials
  - Dark rooms
  - Lasers

<u>Open laboratories</u>

- Support team work
- Facilitates communication
- Shared:
  - Equipment
  - Bench space
  - Support staff
- Adaptable and flexible
- Easier to monitor
- Cheaper to design, build and operate
- The trend since mid 90's

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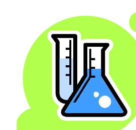
Energy Conservation, Sustainability and Green Chemistry Concerns

- Design leading to increased productivity
- Energy conservation and efficiency
- Centralized heat-generating equipment
- Manifolded hoods and ventilation
- Reduction/elimination of harmful substances and waste
- Efficient use of materials and resources
- Recycling and reuse



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General Lab Layout

- Try to locate hoods, utilities and safety equipment in the same relative position in all labs
- Locate sinks centrally
- Space between benches should allow people to pass each other (≥1.5 m).
- Details on these topics given in later presentations:
  - Lab hoods
  - Safety showers / eyewashes
  - Chemical management

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General Lab Layout

- Construction materials should be appropriate for chemicals
  - Benchtops
  - Cabinets & shelving
  - Flooring
  - Avoid metal drainpipes
- Store chemicals and waste securely – not easily spilled or knocked over.
- Keep bulk chemicals in stockroom – not lab.
- Control access to labs, especially during off-hours

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Teaching Lab Layout

- Higher occupancy than research labs
  - Need easy movement of people around lab
  - Two safe exits
  - Benches in "Islands"
  - 2m distance between benches so students can work "back-to-back"
  - Locate instruments, sinks, supply areas away from hoods to minimize traffic in front of them

- Floor space required per student
  - 3.0 m^2 absolute minimum
  - 6.5 m^2 allowing space for utilities, storage, cleanup, etc.

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Laboratory Modifications or Decommissioning

- When a laboratory is modified or vacated, ensure that:
  - Chemicals have been safely moved to another lab, returned to the stockroom, or properly disposed of.
  - Any contamination has been removed from the:
    - Room (floor, ceiling, walls)
    - Furniture
    - Equipment and fixtures
    - Plumbing system
    - HVAC ductwork

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Conclusion:

Together we can design, build, and operate safe/secure laboratories!

References

- "Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995, ISBN 0-309-05229-7 also available online: http://www.nap.edu/catalog.php?record_id=4911
- "Laboratory Design, Construction, and Renovation: Participants, Process, and Product," National Academies Press, 2000, ISBN 0-309-06633-6, Also available online: http://www.nap.edu/catalog.php?record_id=9799
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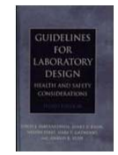
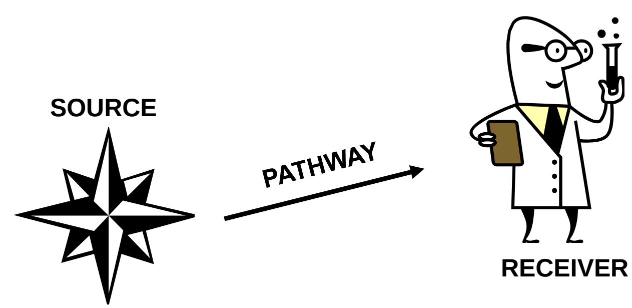
- "Guidelines for Laboratory Design: Health and Safety Considerations, 3rd edition" Louis J. DiBerardinis, et al., Wiley, 2001, ISBN 0-471-25447-9



Principles & Concepts of Lab Ventilation and Chemical Hoods

Hazardous Exposure



Enclose the Source

Hazardous Exposure

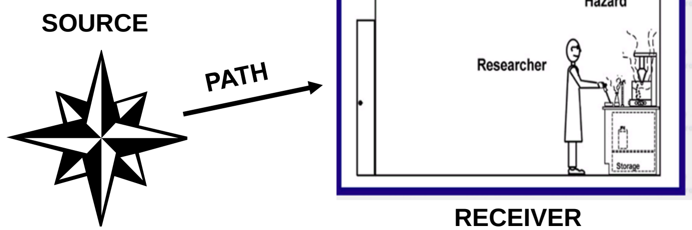


Illustration courtesy, Tom Smith, ECT Technologies, Cary NC USA

Ventilation

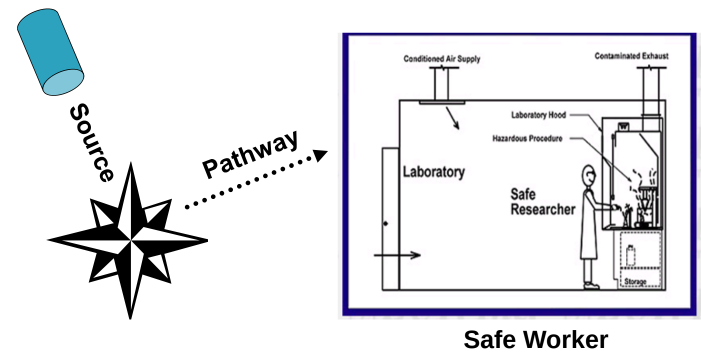


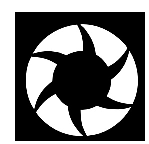
Illustration courtesy, Tom Smith, ECT Technologies, Cary NC USA

Reminder: Prioritization of Controls

- Administrative controls & Operational work practices
- Engineering controls
- Personal protective equipment

Uses of Ventilation

- Keep gas / vapor concentration below OEL
- Air movement to reduce heat stress
- Keep toxic contaminants below OEL
- Confined space entry
- Limit CO_2 buildup
- Control clean room or hospital environments



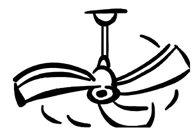
OEL = Occupational Exposure Limit

Definitions

- Hood
  - includes any suction device, regardless of shape, that encloses, captures or removes contaminants
- Dilution Ventilation
  - moves room air around by a fan that is sometimes exhausted to the outside
- Local Ventilation (LEV)
  - ventilation system that captures and removes emitted contaminants

Engineering Ventilation Controls

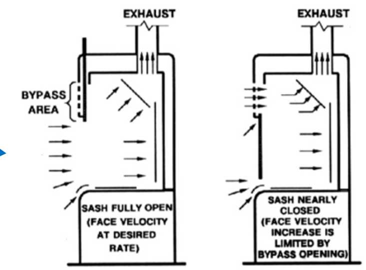
General dilution ventilation



Not good

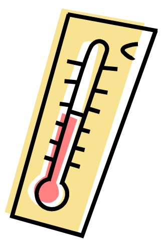
Local exhaust ventilation

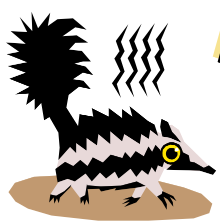
Preferred



Use General Dilution Ventilation

- For Control of:
  - Temperature
  - Harmless Substances
  - Nuisances
  - Odors





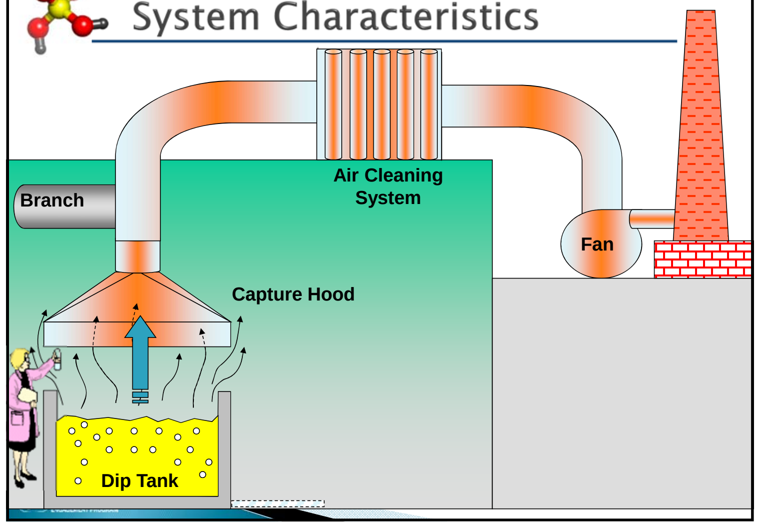
Use Local Exhaust Ventilation (LEV)

- To enclose and contain
- When contaminant is toxic
- Employee works near the contamination
- When complete containment/enclosure is not feasible

LEV Principles

- Enclose source
- Capture contaminant near source
- Keep contaminant out of breathing zone
- Provide adequate make-up air
- Discharge away from air intake

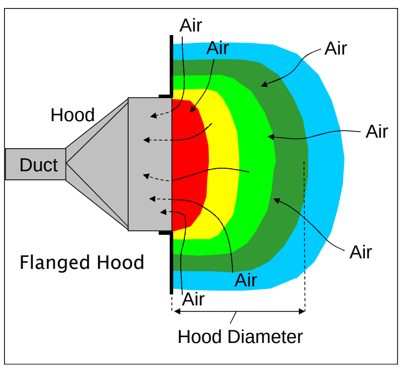
System Characteristics



Hood Capture Velocities

Equal Velocity Zones

% Hood Capture Velocity	
	~100%
	~60%
	~30%
	~15%
	~7.5%

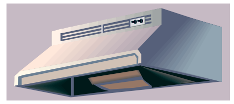


Recommended Capture Velocities

CONDITION	EXAMPLES	CAPTURE VELOCITY m/s (fpm)
No velocity, Quiet air	Evaporation from tanks, degreasers	0.25 – 0.5 (50 – 100)
Low velocity, moderately still air	Spray booths, container filling, welding, plating	0.5 – 1.0 (100 – 200)
Active generation into rapid air motion	Spray painting (shallow booths), crushers	1.0 – 2.5 (200 – 500)
High initial velocity into very rapid air motion	Grinding, abrasive blasting, tumbling	2.5 – 10.1 (500 – 2000)

LEV Capture Ability

- Hood configuration
  - (type of hood)
- Extent of enclosure
  - (e.g., glove boxes completely enclose)
- Air movement in hood
  - (smooth, laminar, non-turbulent)



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Laboratory Hoods

- Laboratory hoods and ventilation are the basis of engineering controls
- But they must be properly: *selected*, *located*, *used*, and *maintained*

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Hood Location Requirements

- As near to contamination source as possible
- So contamination moves away from operator
- Minimize cross-drafts
- Don't place near windows and doors
- Don't place near air conditioning/heater diffuser
- Doesn't interfere with other workers
- Locate out of traffic flow
- Place near rear of laboratory

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A person walking at 0.9-1.3 m/s (2-3 mph) generates cross drafts of 1.3 m/s (250 fpm) that can interfere with hood capture

Principles of Hood Design and Operation

- Enclose as much of the operation as possible
- Place utility controls (gas, electric) outside or as near hood front as possible
- Hood lights should be vapor tight
- Mount hood motor *outside building* and *away from* building *air intakes*
- Don't use hoods for uses not intended (e.g., perchloric acid digestion, radioisotopes)
- Ensure duct material compatible with exhausts
- Don't use without indication it is working properly
- Keep sash fully closed when not in use
- Maintain hood regularly (check fan belt, lubricate motor).
- Regularly evaluate hood (flow rate, mark operating sash height).
- Reports problems, concerns, malfunctions immediately

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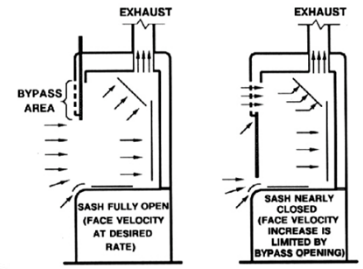
Constant Volume Bypass Hood

- Make up air enters through face and through a bypass
- Bypass opening varies in size as sash is opened or closed
- As sash moves, an almost equivalent area is uncovered to maintain a constant open area, hence, a constant volume of air movement through the face is achieved.



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Specialized Hoods

- Perchloric acid (with water wash down)
- Radiological (with special filters)
- Floor level (improperly called walk-in)
- Distillation/California hoods (0.5m or ~1.5 ft above floor)
- Canopy hoods (not suitable for most lab operations)
- Slot hoods
- Ductless fume hoods
- Vented enclosures or special purpose hoods
- Glove Boxes (complete enclosure)
- Biological Safety Cabinets (BSC)

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Hood Problems and Pitfalls

- Face velocity
  - Recommended 0.4 – 0.5 m/s (80 – 100 fpm)
- Air changes/hour
  - Recommended 6 – 10/hour

Neither of these measurements can guarantee hood capture or containment.

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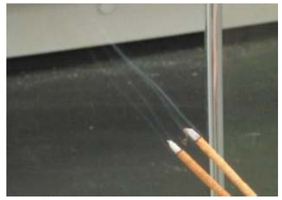
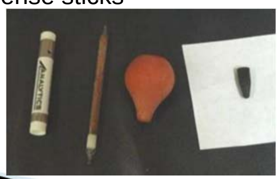
Visual Hood Evaluation

- Smoke sources
  - Visualize air movement
  - Assess capture effectiveness
- Smoke tubes
- Smoke candles
- Theatrical smoke generators
- Incense sticks





Measurable Hood Evaluation

- Velocity measurements
  - Anemometer/velometer
    - m/s or fpm
    - Directional
  - Hot-wire anemometer
    - m/s or fpm
    - Non-directional

Hood Exhaust

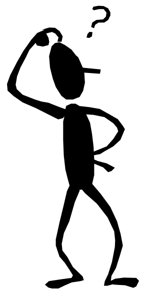
- Height
- Discharge velocity
- Configuration

Weather cap may deflect contaminants downward

Engineering Controls: Avoid Exhaust Recirculation

Potential Issues

- Insufficient air volume
- Too much air flow
- Wrong location
- Wrong configuration
- Bad hood design
- Duct velocity too low
- Insufficient make up air
- Clogged system
- Noise



Improper Hood Use

Improper Hood Use

Place large equipment in a hood on ~5 cm blocks to allow air flow around and under equipment.

Improper Hood Use

Safety shields can block airflow and reduce hood effectiveness.

Conclusions

- Ensuring laboratory hood safety depends on many factors including:
  - Hood design
  - Hood use
  - Lab design
  - System operation

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Break

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Sandia National Laboratories

Other Hazards in the Chemical Laboratory

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Sandia National Laboratories

Physical Hazards

Conditions, besides chemical, biological or radiological conditions or circumstances, that can cause injury, illness and death:

Fire/Asbestos
Centrifuges
Cryogenics
Ergonomic
Office
Physical stress/strain
Construction

Noise
Heat/cold
Sunlight
Non-ionizing radiation
Mechanical
Electrical
Housekeeping
Spills/trips

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Asbestos-Containing Materials

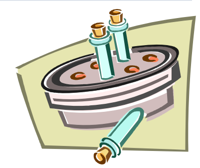
- Gloves
- Lab hoods
- Lab benches

Asbestos-Containing Materials

Asbestos-Containing Materials

Centrifuge Equipment

- Uses
- Hazards
- Control of hazards
  - Only authorized users can use equipment
  - Users must be trained
  - Assign responsibility to lab tech
  - Include in periodic lab inspections



Centrifuge Safety


Don't overload

Check rotor for cracks


Keep rotor and centrifuge clean


Set it upright

221

Cryogens

- What are they?
- Uses
- Hazards
- Control
  - training
  - inspection

222

Chemical Storage: Cryogenics

- Store cryogenics separately from other chemicals
- Store cryogenics (liquid nitrogen) & dry ice in well ventilated areas
- Use proper PPE (including eye protection) when handling & moving cryogenics
- Do not use cryogenics in closed areas

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Chemical Storage: Cryogenics

224

Cryogen Storage

Exploding liquid nitrogen cylinder ruins lab.

Dry Ice

- What is dry ice?
- Uses
- Hazards
- Control measures

Electrical Hazards

- Can be a significant problem
  - Frayed cords, no UL-listing, overloaded circuits
  - Static electricity
- Hazards
  - Fires, electrical shock, power outages
- Control
  - Inspect, act immediately, education

Electrical Hazards

Check to see that all outlets are grounded and that the polarity is correct.

Electrical Hazards

Storage should be at least 1 m from electrical panels, mechanical rooms, air ducts, heaters, light fixtures.

Don't store combustibles in mechanical rooms or electrical closets.

In emergencies it may be necessary to access these panels quickly.

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Electrical Hazards

Multi-outlet strips must be approved and <u>not</u> used for high-amp equipment.
(e.g., ovens, refrigerators)

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Electrical Hazards

231

Heating Mantles

- Uses
- Hazards
- Unshielded rheostats
- Control measures

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Housekeeping- Discussion

Housekeeping- Discussion

Freezers

- Ultra low temperatures
  - -20°C, -80°C
  - Upright vs. walk-in
- Emergency power
- Labels

- Precautions
  - *No dry ice in freezers!*
  - Improper storage
  - PPE

Glassware Handling

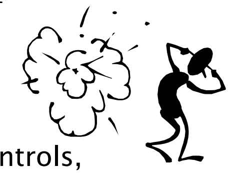
- Potential Hazards
  - Ergonomics
  - High temperature
  - Broken glassware
  - Improper use
- Control
  - Inspection
  - Training

Beware of contaminated Glassware, especially if broken!

Autoclave Explosion

High Pressure Reactions

- Experiments carried out at pressures above 1 atmosphere (~1bar, ~100 kPa, 760 Torr).
  - Use of supercritical fluids (CO_2)
- Hazards
  - Explosions, equipment failure
- Control Measures
  - SOPs, training, engineering controls, inspection
  - Dry runs



Vacuum Work

- **Uses**
  - **Aspiration**
- **Hazards**
  - **Injury due to glass breakage**
  - **Toxicity of chemical contained in vacuum**
  - **Fire following flask breakage**
  - **Contaminated pump oil**
- **Control Measures**
  - **SOPs, inspection, education**

Mechanical Hazard

Mechanical hazards like open drive belts with pinch points must have shields and guards.

Oil pumps need drip pans to contain oil.

Noise

- Elevated noise levels can be a problem.
- Potential Hazards
  - Examples: bone-cutting saws, mechanical water aspirators, sonicators, pumps.
- Control Measures
  - Inspections, PPE, warning labels, training.

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Magnetic Fields

- Uses – NMR, MRI
- Hazards
  - Magnetic field
  - High voltage
  - Cryogenic liquids
    - – e.g., nitrogen, helium
  - Other hazardous materials in lab
- Control Measures
  - Control access to area
  - Training
  - Warning signs

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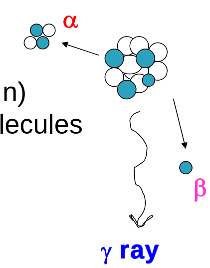
Ionizing vs. Non-ionizing Radiation

❖ **IONIZING RADIATION**
- Particulate or electromagnetic
- Charged (α, β) or uncharged (γ, X, n)
- Causes **ionization** of atoms or molecules

❖ **NON-IONIZING RADIATION**
- Electromagnetic (UV, IR, MW, RF)
- Can not ionize atoms or molecules



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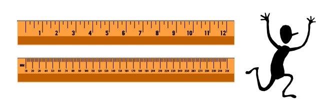
Protect yourself by:

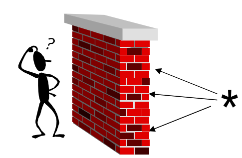
- **TIME** – Limit time near source

- **DISTANCE** – Stay away

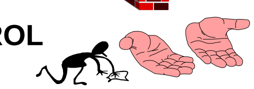
$$I_2 = I_1\left(\frac{d_1}{d_2}\right)^2$$



- **SHIELDING** – Absorb energy



- **CONTAMINATION CONTROL**



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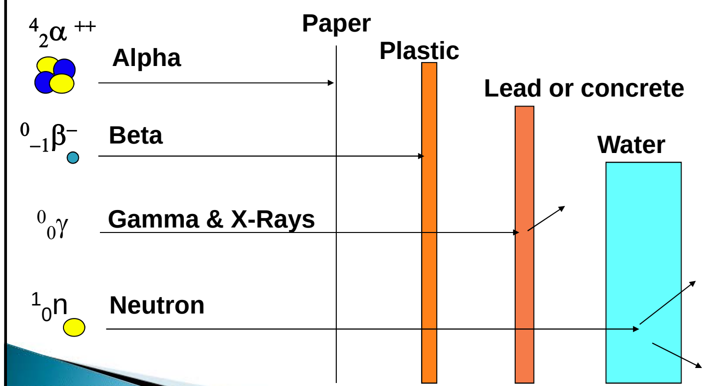
Shielding Materials



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Non-Ionizing Radiation

- UV, Visible, IR, Lasers
- Hazards
  - Skin erythema
  - Eye injuries
- Control Measures
  - Training, PPE, warning signs and labels, interlocks

246

Radio-frequency & Microwaves

- Uses
  - RF ovens and furnaces
- Hazards
  - Cataracts, sterility
  - Arcing – use of metal in microwave
  - Superheating of liquids
  - Explosion of capped vials
- Control Measures
  - SOPs, education, inspection

247

UV Light Reader with Cover Removed

248

Robotics

- Free-moving parts
  - "Struck by" injuries
- Noise
- Lasers
- Aerosol Generation

Sharps, Needles, Blades

Hazards
- Needle sticks
- Cuts
- Contamination

- Control Measures
  - SOPs
  - Training
  - Modify work practices
  - Engineering Controls

Working Alone/ Unattended Operations

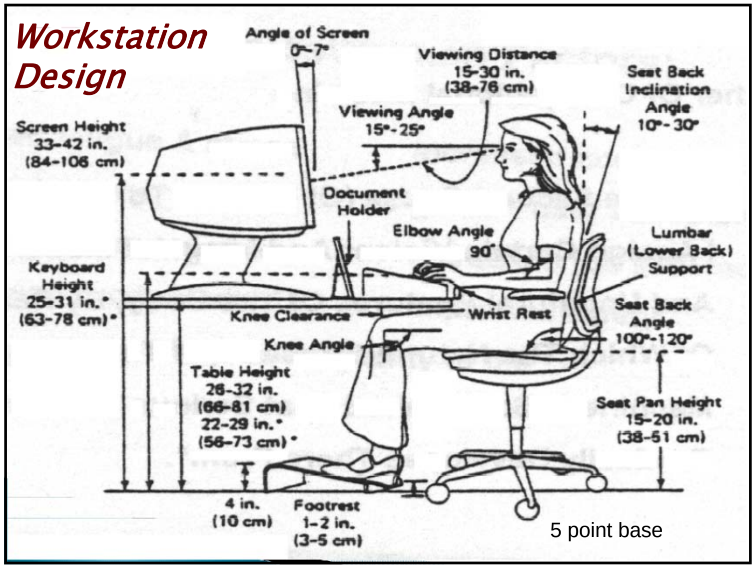
- Working Alone
  - *Avoid!*
  - Murphy's Law will get you! (Anything that can go wrong, will go wrong!)
  - Use the "Buddy System"
- Unattended Operations/Reactions
  - Caution! Prime sources of fires, spills and explosions
  - Check periodically!
  - Fail-safe provisions
  - Leave the lights on to indicate the presence of an unattended activity
  - *Post appropriate signs and emergency phone #'s*
  - Notify those potentially impacted by malfunction

Repetitive Motion Disorders

About 15 to 20% of workers in jobs requiring highly repetitive motion of shoulders, arms, wrists or hands develop repetitive motion disorders.

Disorder	Affected Site
Carpal Tunnel Syndrome	Wrist
Tendonitis	Elbow, wrist, hand
Tenosynovitis	Elbow, wrist, hand
Epicondylitis	Tennis elbow
Reynaud's phenomenon	"White finger"
Ulnar neuropathy	Fingers

Workstation Design



Food is never allowed in laboratories.

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What's Wrong With This Picture?

255

Open-toed shoes should not be allowed in laboratories.

Employees should not wear gloves, lab coats or other PPE outside the lab.

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Slips, Trips, Falls

- Most common injuries
- Causes
  - Chemical spills and leaks
  - Improper work practices
- Control Measures
  - SOPs, proper equipment, effective communication, engineering controls

We want to avoid this.

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Control of Hazards

- Think!
- Develop SOPs, safety manual, policies
  - reviewed and approved by management
- Research protocol review
- Install engineering controls
- Provide PPE
- Provide training
- Conduct inspections, routine & unannounced with lab supervisor
- Document and *follow-up*
- Take action

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Principals of Toxicology

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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

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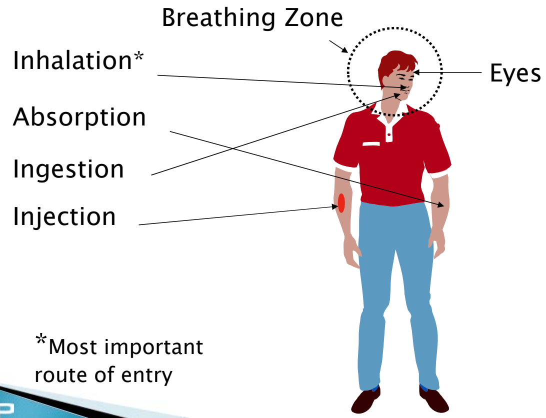
Routes of Exposure



*Most important route of entry

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.

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

Toxicology

- **Poisons** – the adverse effects of substances on living systems
- **Chemical Toxicology** – The potential adverse effects and control of chemicals in the workplace

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

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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

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Factors Influencing Toxicity

Human

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

Chemical

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

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Duration of Exposure

- Acute — 1 to 5 days
- Sub-chronic — 14 to 90 days
- Chronic — 6 months to lifetime

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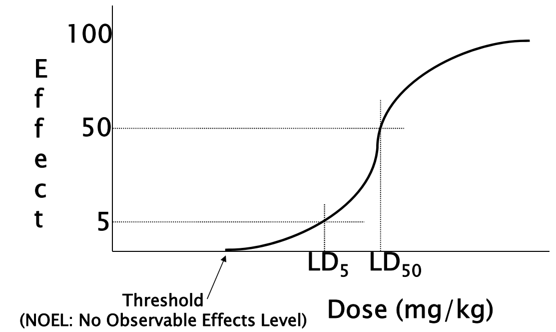
Dose-Response Relationship

- 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
- 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



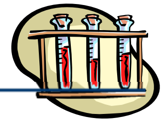
Pharmacokinetics

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

Metabolism

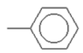
- One purpose of metabolism is to make the chemical more water soluble so it can be excreted
  - Done by adding oxygen molecules in the form of -OH, =O, -COOH, or by conjugation with glutathione, sulfonate, glycine, etc.
- Some chemicals are not directly carcinogenic, but are metabolized to intermediates, e.g, epoxides, which are highly carcinogenic
- Chemicals not metabolized are stored in the body:
  - 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!*

Examples: Metabolites

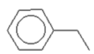


Benzene (C_6H_6)
carcinogenic
phenol, S-phenylmercapturic acid in urine

Toluene
CNS depressant
hippuric acid in urine

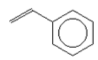


Ethyl benzene
irritant, dermatitis
mandelic acid in urine



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

Styrene
dermatitis
mandelic acid in urine



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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)
- 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)

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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

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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 Organ
- 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)

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Target Organ Effects

Toxins	Target Organ	Signs & Symptoms	Examples
Hepatotoxins	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
Reproductive Toxin	Reproductive System	Birth Defects	Lead, ACN
Cutaneous Agents	Skin	Rashes, Irritation	NaCl, Ketone
Eye Hazards	Eyes	Conjunctivitis	Organic Solvent

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Examples:

Toxic Effects of Solvents and Vapors

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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)

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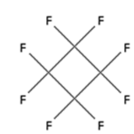
Structure Affects Activity

- 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



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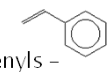
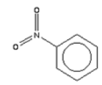
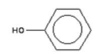
Aromatic Hydrocarbons

- 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)







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Aliphatic Alcohols

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

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Glycol Ethers

- Ethylene glycol monomethyl ether (EGME) $CH_3OCH_2CH_2OH$
  - Disrupts sperm development
  - Developmental toxin – day 7,8-neural tube; day 10-11-digit/paw effects, brain, liver, and kidney
- Ethylene glycol monoethyl ether (EGEE) $CH_3CH_2OCH_2CH_2OH$
  - Testicular degeneration
  - Reproductive/developmental toxins, but less severe
- Propylene glycol monomethyl ether (PGME)
  - Not a reproductive/developmental toxin

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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

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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

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Terminology:

Some slides for your reference

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Terminology

Toxicants	• Substances that produce adverse biological effects of any nature • May be chemical or physical in nature • Effects may be of various types (acute, chronic, etc.)
Toxins	• Specific proteins produced by living organisms (Mushroom toxin or tetanus toxin) • Most exhibit immediate effects
Poisons	• Toxicants that cause immediate death or illness when experienced in very small amounts
Dose	• Quantity (mg, mL)
Dosage	• Frequency (10 mg, 4 times/day)
Exposure dose	• Quantity administered
Absorbed dose	• Actual quantity absorbed

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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

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Lunch

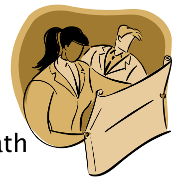
Laboratory Emergency Planning, Response, and Management

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

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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

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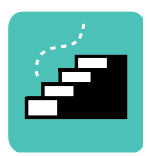
Planning & Preparation

- 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



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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

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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 system
- Training

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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 (PPE)
- Safety Data Sheets (SDS or MSDS)
- Site maps
- Clean up procedures
- Decontamination techniques

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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

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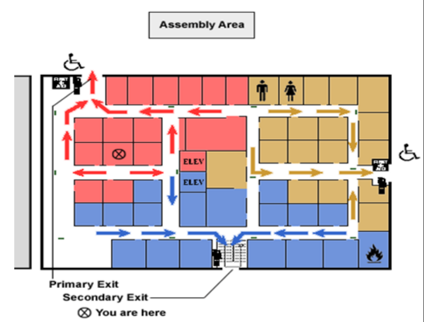
Emergency Planning & Response

Have an evacuation plan for all buildings and areas and POST IT



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Emergency Planning & Response

Don't use hallways for storage

Label and keep all exits clear

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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.

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Emergency Planning & Response

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

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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!

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Emergency Planning & Response

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

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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?

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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):	646-3327

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Emergency Phone Numbers

Clearly post emergency numbers
Do employees know what to do?

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Emergency Planning & Response

Hoods should have low flow alarms.

Chemical specific toxicity alarms may be needed in certain areas.

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Emergency Planning & Response

Centrally locate safety showers and eyewashes.

Schedule routine, periodic maintenance of all safety equipment.

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Teach employees to properly use the Safety Shower

Time can make a difference…

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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

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Transporting Chemicals Safely in the Lab

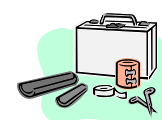
Unsafe Transport of Gas Cylinders

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

Chemical Laboratory First Aid

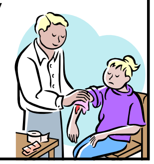
- First aid kits for minor injuries should be centrally located and available in or nearby each laboratory.
- Use for minor accidents/incidents.
- Determine if medical attention is necessary.
- Immediately notify proper authorities, if necessary or in doubt.
- Determine if chemical exposure occurred.
- 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.



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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

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Chemical Spill Response and Cleanup

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Size of Spill Determines Response

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Nuisance Chemical Spill

- **Spills of < 4L of known hazard, that you are comfortable cleaning up**
  - Assess the hazard
  - Alert people in immediate area
  - Post area
  - Wear appropriate PPE
  - Confine spill
  - Absorb excess, surround area with absorbent material
  - 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

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

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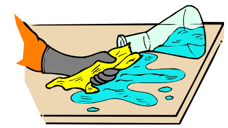
Potentially Hazardous Spills



- 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

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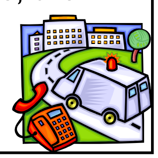
Emergency Notification and Response

- 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.



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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!

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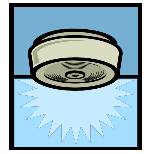
Chemical Laboratory First Aid– Spills

- 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
  - 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

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






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

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Special Considerations for Mercury Spills

- Mercury
  - http://www4.uwm.edu/usa/ep/training.cfm

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.

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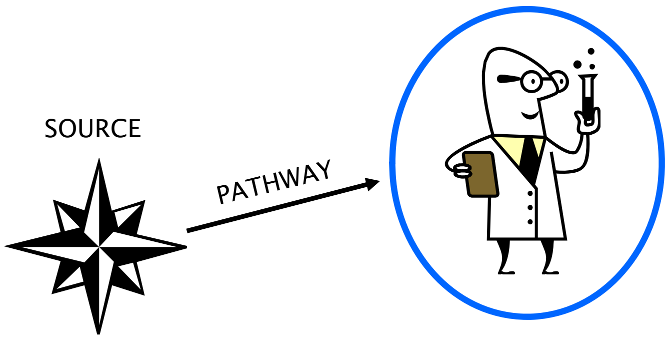
PPE and Safety Equipment Performance Specifications

Worker Protection



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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 …

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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

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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

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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

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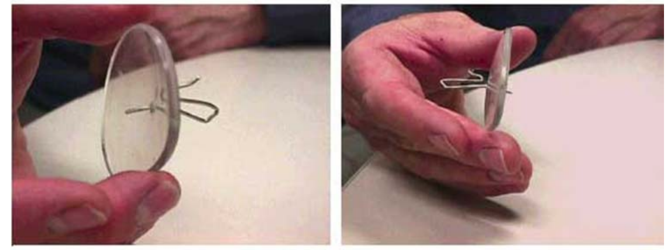
Protective Equipment Works

"Your eyes cannot be replaced"



This staple penetrated the lens but the workers eyes were saved

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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.

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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

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Biohazards and Eye Protection

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

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

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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.

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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
- 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

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Eyewash and Showers

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

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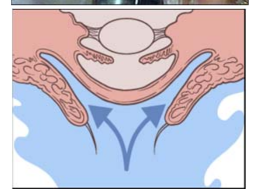
Eyewash and Showers

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

Eyewash Standards

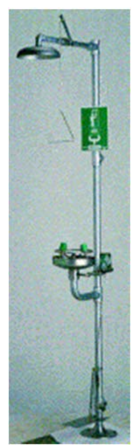


- Eye wash stations
  - Minimum 1.4 – 13.2 L/min (0.4 to 3.5 gal/min)
  - Flush for 15 minutes
- Provide flow for both eyes
  - Hold eyes open
  - Tepid, pH match eye (preferred)
- Easily accessible locations
  - 84-114 cm (33 to 45 in.) from floor
  - 15cm (6 in.) from wall
- Test weekly
  - Portable: 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 17 m (55 ft.) or 10 seconds
  - Normal walking = 6.1 km/hr (3.8 mph)
- Test monthly
- Pull within reach (highly visible)
  - 208 – 244 cm high (82 to 96 in.)
  - Deliver 51 cm (20 in.) column
  - Height: 152 cm (60 in.) above floor
- 76-114 L/min (20-30 gal/min)
- Tepid: 16 – 38ºC (60 to 100 ºF)



Safety Shower Standards cont.

Consider:

- Drains
- Blankets/modesty curtains

Avoid or protect electrical outlets

- ANSI Z358.1-2004

Blocked Eyewash & Safety Shower

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Dirty Eyewash Station

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Glove Selection

- Glove considerations
  - Type glove
    - Dexterity required
    - Chemical & physical
      - material
      - strength
    - Exposure time (splashes vs immersion)
      - breakthrough time
    - Size, comfort, reusable/disposable
    - Thermal (extreme heat/cold)
    - Abrasion; cuts; snags; splinters; punctures
    - Grip: oily, wet, dry
  - **Manufacturer selection charts**

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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).

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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/

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).

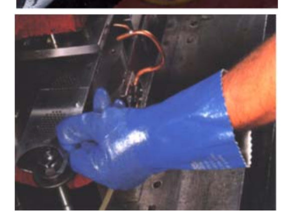
Types of Gloves

Viton®

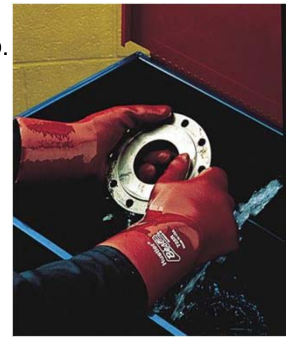
- Highly resistant to permeation by chlorinated and aromatic solvents
- Can be used with water/water based solvents

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.

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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	■	380	E	P	—	—	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	P	—	—	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	P	—	—	P	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	P	—	—	NR	—	—	P	—	—
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	P	—	—	NR	—	—	E	>360	E	NR	—	—	NR	—	—	NR	—	—
17. Benzotrichloride	—	—	—	E	>480	E	NR	—	—	—	—	—	—	—	—	NR	—	—	NR	—	—
18. Benzotrifluoride	—	—	—	E	170	G	F	—	—	E	—	—	G	<10	F	P	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

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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

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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

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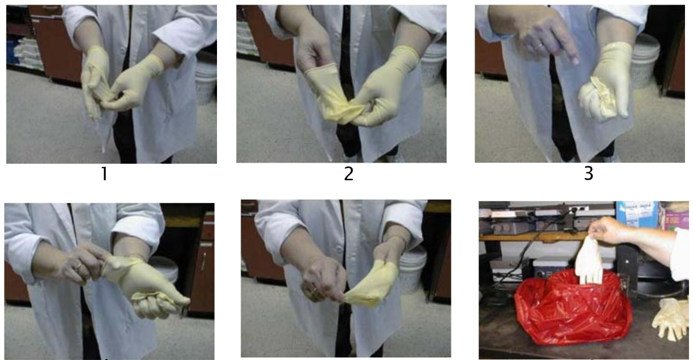
Proper Steps for Removing Gloves



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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)

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Dust Masks vs. Hospital Masks

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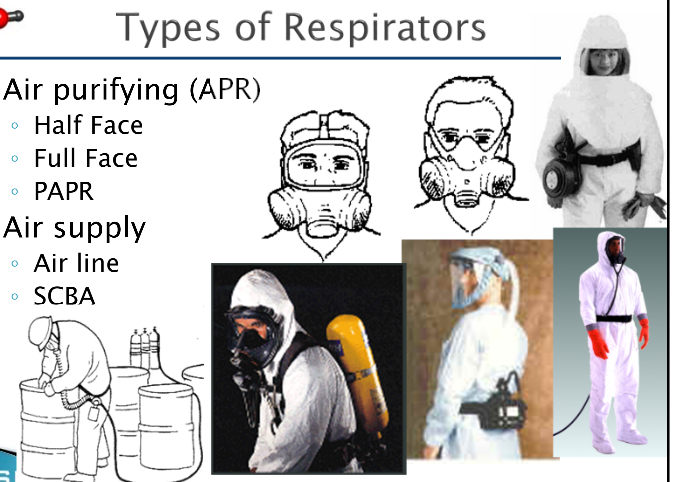
Types of Respirators

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



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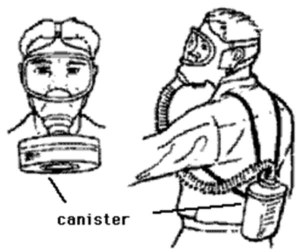
APR Chemical Cartridge Selection

- 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*



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

High Efficiency Particulate Air Filter (HEPA) Respirator

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

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Supplied Air

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

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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
  - $CO \leq 10$ 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.

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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

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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

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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 NOT be worn in labs.

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Tea Break

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Lab Assessment Exercise – Priorities and Action Plan

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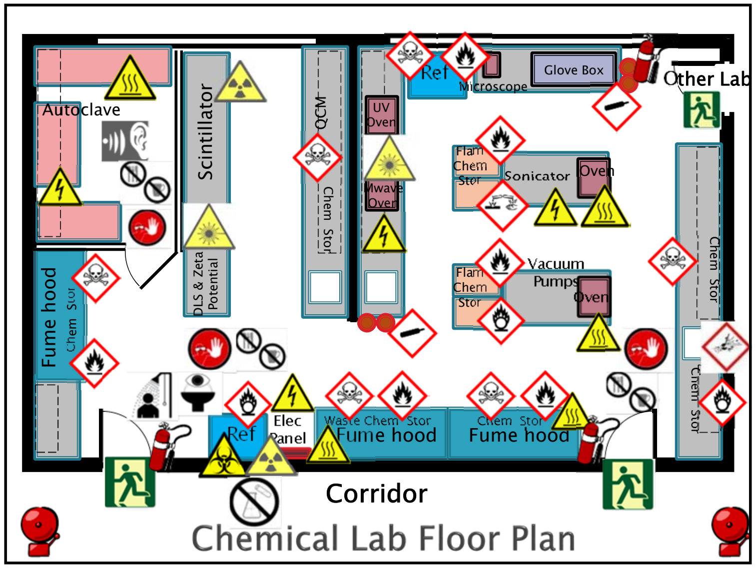

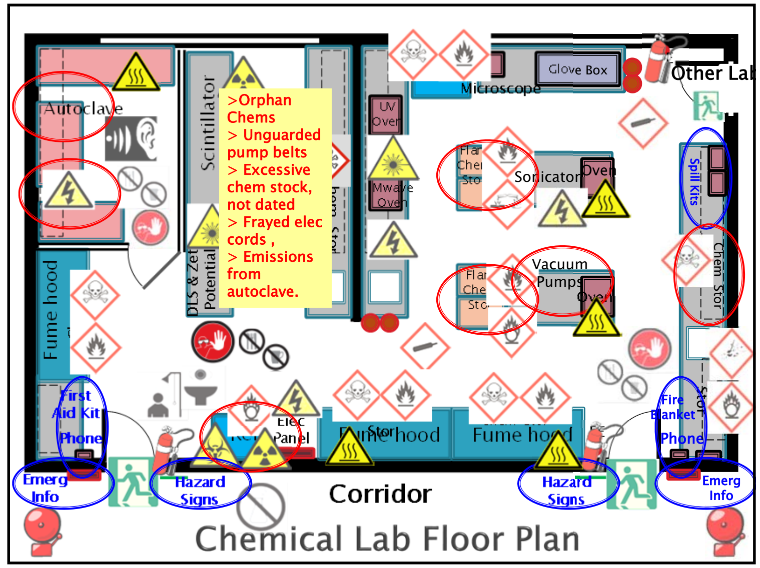

CSS Action Plan

- Prioritization:
  - **Easiest** → **Medium** → **Difficult**
  - **Easiest**
    - inventory
      - check actual
      - remove spent chem.
      - separate groups
      - secondary containment
    - training
    - collect MSDS info
  - **Medium**
    - fire storage cabinets
    - develop SOPs
  - **Difficult**
    - new fume hood
    - proper waste disposal
- CSS leadership team:
  - You, fellow labmate? fellow professor? EHS specialist? department director? others?
- Timeline & commitment:
  - initiate actions, complete actions, ongoing actions, persons responsible

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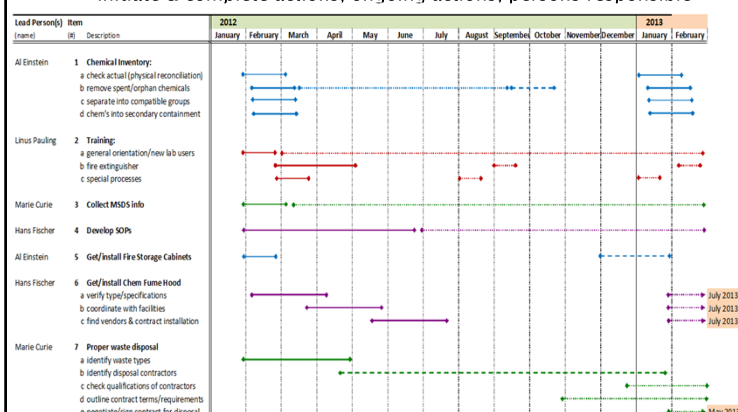
CSS Action Plan

- Timeline & commitment:
  - initiate & complete actions, ongoing actions, persons responsible



Lab Visits and Case Studies and Train-the-Trainer Concepts

Day 3

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Sandia National Laboratories

Chemical Safety and Security Officer

OPEN DISCUSSION
TRAIN-the-TRAINER
CONSIDERATIONS- Techniques

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Fire Prevention and Protection in the Laboratory

Day 4

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Sandia National Laboratories

Fires

- Preventable
- Caused by unsafe practices
  - Electrical safety violations
  - Uncontrolled use of flammable and combustible materials
- Control
  - Inspect, inspect, inspect
    Educate, educate, educate!

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Home Fires

1 million fires and 8,000 deaths annually in the US

Leading causes:
- Cigarettes
- Heating/cooling equipment
- Electrical
- Matches, lighters, candles

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Industrial Fires

- Fifth leading cause of accidental death
  - Vehicles, falls, poison, drowning, fire
- Most dangerous industries from fire hazard:
  - Mines
  - Grain elevators and mills
  - Refineries
  - Chemical plants
- Leading causes:
  - Electrical
  - Smoking
  - Friction
  - Overheating
  - Hot surfaces

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Key Elements of Fire Safety

Get occupants out
Minimize property loss and interruption
Fire Containment/Suppression

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Common Myths

- Fire will light the way out
  - Smoke cloud & soot
- Plenty of time to escape
  - 1 min from small to inescapable fire
- People are killed by the flames
  - #1 killer in fires is CO, not flames
- Wait to be rescued
  - No! Act to save self
  - Ladders can reach to about 6th floor
- Can not prepare for a fire
  - Preparation can save your life

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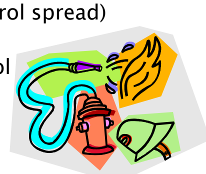
It's the Smoke…

Facial Burns

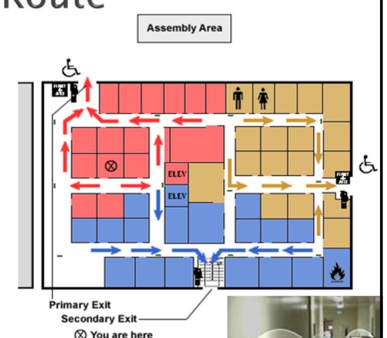
Fire Safety Planning

- **Construction**
  - Building materials
  - Fire-resistive ratings (minutes to hours)
  - Interior finishes (3 classes: A, B, & C)
- **Containing the fire**
  - Stair enclosures and fire walls
  - Separate building units or zones (control spread)
  - Fire doors
  - Smoke, heat and noxious gases control
  - Exits
- **Egress**
  - Two ways out, exit to safe area



Egress – Exit Route

- Continuous and unobstructed path from any point within a workplace
- Consists of three parts:
  - Exit access
  - Exit
  - Exit discharge
- Exit routes must be permanent
  - Unobstructed
- Well marked

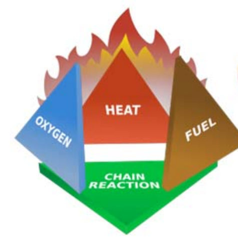


Best Practices: Safety During a Fire…


- Stairs have a bar blocking the steps going down to indicate ground level fire egress
- Keep fire exits and stairwells free from any obstruction .
- Have functioning emergency lights

Fire

- A fire must have four things to ignite and maintain combustion:
  - Fuel
  - Heat
  - Oxygen
  - Chain reaction



Fire Hazards

- **Sources of fuel**
  - Flammable liquids
  - Flammable gases
  - Wood, paper, cardboard
  - Oil soaked rags

Train employees to notice & report fire hazards

Periodic inspections

Drills

- **Sources of heat (ignition)**
  - Electrical circuits:
    - Shorts, sparks
    - Arcs (switches)
    - Heat build-up
  - Hot surfaces
  - Space heaters
  - Hotplates, coffee pots, coffee makers
  - Welding
  - Smoking
  - Open flames
  - Static electricity

Flash Point

- Flash point:
  - The minimum temperature at which a liquid gives off enough vapor to form an ignitable mixture.
  - In general, the lower the flash point, the greater the hazard.
- Flammable liquids:
  - have flash points below 38°C
  - are more dangerous than combustible liquids
  - may be ignited at room temperature
- Combustible liquids:
  - have flash points at or above 38°C
  - Can pose serious fire and/or explosion hazards when heated

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Flammability/Explosive Limits

Above UFL/UEL, mixture is **too rich to burn**

Upper Flammability/Explosive Limit (**UFL/UEL**)

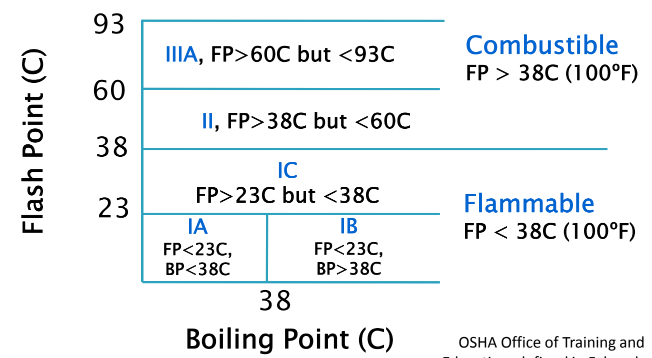
Flammability/Explosive Range

Lower Flammability/ Explosive Limit (**LFL/LEL**)

Below LFL/LEL, mixture is **too lean to burn**

Defined in terms of the amount of fuel in air.

Classes of Flammable and Combustible Liquids



OSHA Office of Training and Education, defined in Fahrenheit

Fire Safety Program Components

A good plan for safe use of flammable and combustible liquids contains at least these components:

- Control of ignition sources
- Proper storage
- Fire control
- Safe handling

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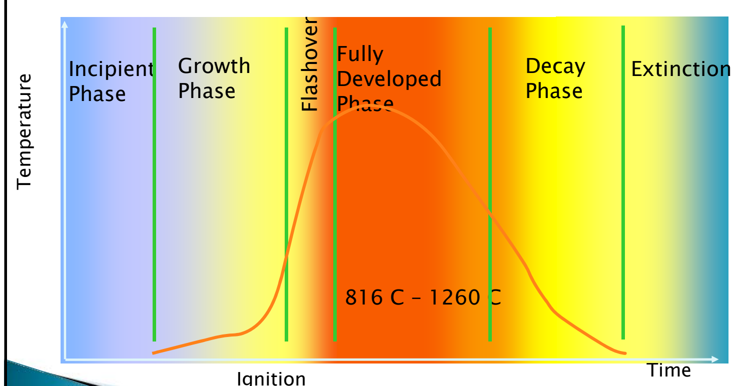
Fire Behavior



Fire Behavior

Stack Effect

- Hot expanding gases move vertically
  - Tightness of construction
  - External winds
  - Internal/external temperature
  - Vertical openings
    - Stairways
    - Elevator shafts
    - Ventilation shafts

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Vapor Volume

Volume of gas formed when a liquid substance evaporates

Computed from specific gravity and vapor density

$$\text{Vapor Volume } (m^3/\text{liter}) = \frac{0.829\ (\text{SpG})}{\text{Vapor density}}$$

Example: What is the vapor volume of a liter of acetone?
[SpG = 0.9, relative to water; Vapor density = 2, relative to air]

$$\text{Vapor Volume } (m^3/l) = \frac{0.829\ (0.9)}{2} = 0.373\ m^3/l$$

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Vapor Volume

What is the probability of forming a combustible mixture if a 4 liter container of acetone is used in a room 3 x 4 x 2.5 m?

[LEL = 2.5%; assume incomplete mixing factor 5]

Volume of the space = 30 m^3

Vapor volume = 0.373 m^3/L

Vapor volume necessary to form a Combustible mixture:

$30\ m^3 \times 0.025 = 0.75\ m^3$

$$\frac{0.75\ m^3}{0.373\ m^3/L} = 2.01\ L$$

Applying the mixing factor of 5:

2.01 L / 5 = 0.40 L

[About = 1 coffee mug]

Since it doesn't take much more than "1 coffee mug" of acetone to form a combustible mixture, the probability appears to be high!

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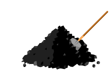
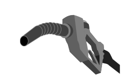
Classification of Fires

With recommended extinguisher distances

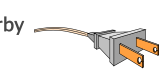
- A Ordinary combustibles – cloth, paper, wood, coal ~23 m
  - Extinguish by cooling or smothering



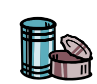
- B Flammable/combustible liquids, gases, greases and oils – gasoline, diesel fuel ~15 m
  - CO_2 or dry powder: monoammonium phosphate



- C Energized Electrical equipment cables, motors nearby
  - Extinguishing agent must *not* be conductive
  - CO_2 or dry powder



- D Combustible metals – sodium, magnesium, titanium ~23 m
  - Extinguishing agents must absorb heat and not react with the metal
  - special dry powder, sand



- K Restaurant grease fires associated with cooking nearby
  - Special liquid chemicals

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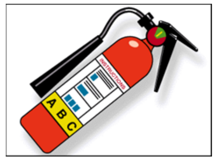
Fire Extinguishers

Dry Chemical



CO_2

Placed within ~15-25 m

Water

Annual & Monthly inspections

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Fire Alarm Systems

- **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

410

Fire Detection & Alarms

- Thermal
- Heat
  - Fixed temp
  - Rate of rise
    - ~6 to 8 C/min (12 to 15°F/min)

Issues:

Testing
Dust, corrosion, hot processes, weather, mechanical damage

- Smoke
  - Photoelectric
    - IR from smoke
  - Ionization
    - Ionize smoke
- Flame Detectors
  - Flames – IR or UV
- Gas Sensors

411

Manual Pull Stations

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

People are reluctant to sound fire alarms!

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Responding To A Fire

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Employee Training

Workshop training in ICCBS, University of Karachi, Pakistan.

Photo courtesy of Patrick John Y. Lim.

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Using a Fire Extinguisher

P	Pull
A	Aim
S	Squeeze
S	Sweep

Video Courtesy of Washington State Emergency Management Division, Public Education Program

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Electrical Fires

- ✓ Pull the plug out or switch off the power at the fuse box. This may stop the fire immediately.
- ✓ Smother the fire with a fire blanket, or use a dry powder.
- ✗ Never use water on it.

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What To Do If Someone Catches On Fire

If *you* should catch on fire:

STOP – where you are
DROP – to the floor
ROLL – around on the floor

This smothers the flames, possibly saving your life.

Remember STOP, DROP and ROLL

If a *co-worker* catches on fire:

Smother flames by grabbing a blanket or rug
Wrap them in it.
Could save them from serious burns or death.

When Not To Fight A Fire

Don't fight a fire, when:

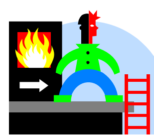
- It is bigger than a waste paper bin
- One extinguisher is not enough
- The fire is spreading beyond the spot where it started
- Smoke is affecting your breathing
- You can't fight the fire with your back to an escape exit
- The fire can block your only escape
- You don't have adequate fire-fighting equipment

DON'T FIGHT THE FIRE YOURSELF

CALL FOR HELP

Remember

When…



- The extinguisher runs out of agent
- Your path of escape is threatened
- The extinguisher proves to be ineffective
- You are no longer be able to safely fight the fire

…LEAVE THE AREA IMMEDIATELY!

Fire Prevention

Fire Prevention Inspections

- Minimize size of fires
  - Control storage of combustible and flammable materials
- Reduce possibility of a fire
  - Control ignition sources
- Ensure fire protection equipment is operational
  - Fire extinguishers not blocked
- Ensure exits are maintained
  - Don't block egress pathways
  - Don't prop open fire doors

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Storage Guidelines

- All storage must be at least 1 m from electrical panels. In some emergency situations it will be necessary to access these panels quickly.
- Maintain at least 1 m clearance from heating surfaces, air ducts, heaters, and lighting fixtures.
- Storage of combustible materials in mechanical rooms is prohibited.

Improper Storage in front of Electrical Panel

Improper Mechanical Room Storage

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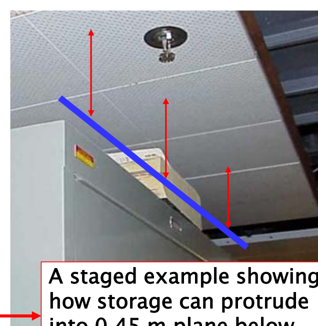
Storage Guidelines

- No storage is allowed in corridors and stairwells. A cluttered hallway could slow down emergency evacuation.
- Storage must not exceed a plane of 0.45 m below sprinkler heads or smoke detectors. Storage that breaks this plane may prevent sprinkler heads from fully covering room during a fire.



A staged example showing how storage can protrude into 0.45 m plane below sprinkler heads.

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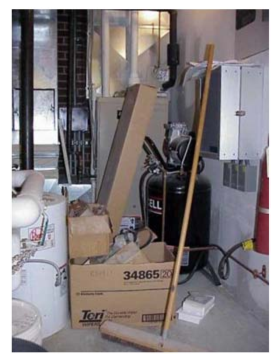
Violations



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Housekeeping…

Storage Areas

Flammables should be stored in an approved cabinet in a cool, well ventilated area to avoid pressure buildup and vaporization

Proper Storage of Flammables is an Important Part of Fire Safety

Limit quantities stored

Safety cans

Secondary Containment

Flammable storage cabinets, rooms or buildings

Storage Containers

- Reduces fire risk
  - Limits oxygen
  - Encourage air circulation to remove heat
  - Limits access to ignition source.
- Containers should be tightly sealed when not in use

Storage Cabinets

- Not more than 225 L of Class I and/or Class II liquids, or not more than 450 L of Class III liquids permitted in a cabinet.
- Must be conspicuously labeled, **"Flammable – Keep Fire Away"**
- Doors on metal cabinets must have a three-point lock (top, side, and bottom), and the door sill must be raised at least 5 cm above the bottom of the cabinet.

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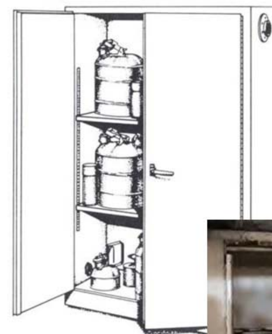
Flammable Storage Cabinets



430

Liquids can develop a static electric charge, which can ignite

Transfer Techniques

- Bond containers
  - Containers are wired together before pouring
  - One container is connected to a good ground point to allow any charge to drain away safely
- Limit use of plastic containers to small volumes (< 4L)
  - No easy way to bond plastic containers

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Lab Assessment Exercise: Preparation for Group Presentations

Lab Assessment Exercise : Group Presentations

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Lunch

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Chemical Management Best Practices

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Cradle-to-grave care of chemicals

Receipt → Storage →

Use → Disposal

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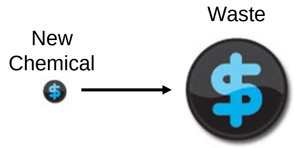
Chemical Management is a Best Practice for Safety *and* Security

- Reduces hazardous waste
- Reduces cost
  - New purchases
  - Waste disposal
  - More efficient
- Improves security
  - Insider threat
  - Outsider threat
- Facilitates environmental compliance
  - Improves quality of research
  - Improves quality of lab instruction



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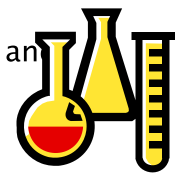
Proper chemical management program has several essential elements

- Chemical Management Elements
- Source reduction
- Procedure for chemical ordering and disposal
- Inventory and tracking
- Storage in stockrooms
- Access control
- Recycling of chemicals, containers and packages



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Chemical Aging

Orphan chemicals donated by industry laboratories included a huge bottle of asbestos (left).

Photo courtesy of Patrick John Y. Lim.

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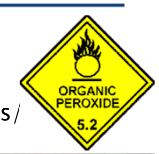
Explosives and Reactives

- Examples:
  - Peroxide-forming
    - Ethers, dioxane, tetrahydrofuran
    - http://www.med.cornell.edu/ehs/updates/peroxide_formers.htm
  - Perchlorate-forming
    - perchloric acid
  - Water/moisture sensitive
    - Na, K, Li, LAlH, flammable metals
- Control measures:
  - Inventory control
  - SOPs, inspections



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Chemical storage: Basic concepts

- Separate incompatible chemicals
- Separate flammables/explosives from ignition sources
- Use flammable storage cabinets for large quantities of flammable solvents
- Separate alkali metals from water
- Separate acids and bases

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Chemical storage: Good practices

- Limit access
  - Label "Authorized Personnel Only"
  - Lock area/room/cabinets when not in use
- Be sure area is cool and well ventilated
- Secure storage shelves to wall or floor
- Shelves should have a ¾" front lip
  - In earthquake territory, have a rod several inches above shelf

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Chemical storage: Basic concepts

- Store nitric acid separately
- Store large containers on bottom shelves
- Lock up drugs, chemical surety agents, highly toxic chemicals
- Do not store food in refrigerators with chemicals

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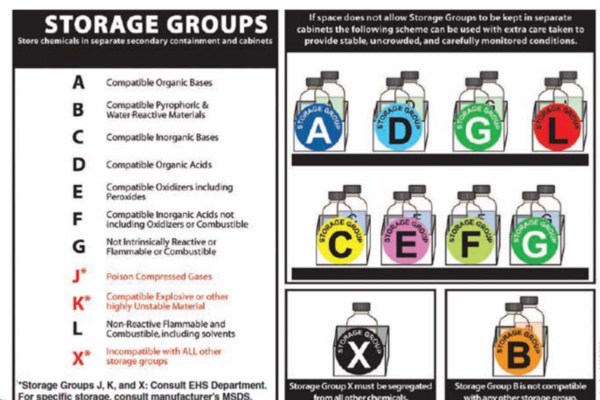
Chemical Storage



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Chemical storage: Gas cylinders

- Secure (chain/clamp) and separate gas cylinders
- Screw down cylinder caps
- Store in well-ventilated area
- Separate & label empty cylinders
- Store empty cylinders separately
- Separate flammable from reactive/oxidizing gases

445

Chemical storage: Bad practices

- **Do Not Store Chemicals**
  - on top of cabinets
  - on floor
  - in hoods
  - with food or drinks
  - in refrigerators used for food
  - where there are wide variations in temperature, humidity or sunlight

446

Chemical storage: Containers

- Don't use chemical containers for food
- Don't use food containers for chemicals
- Be sure all containers are properly closed
- Wipe-off outside of container before returning to storage area
- Transport/carry all containers safely
  - Preferably use outer protective container

447

Improper chemical storage

Never use hallways for storage

Safety Hazard!!

Blocks exit path in emergencies!!!

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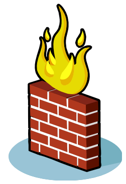
Best practice: access control

- Proper training of chemical handling personnel
- Only trained and approved personnel
  - have access to stock room and keys
  - administrative privileges to inventory and database
- Locked doors and cabinets for controlled substances
  - Radioactive materials
  - Drugs and consumable alcohol
  - Explosives (special handling facility)
  - Dual use chemicals
  - Hazardous waste – high toxicity chemicals



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Chemical Storage Exercise

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Activity: Chemical Storage

- Find one or two partners
- Use the hazard and compatibility information to optimize chemical storage
- Rules:
  - 4 bottles per shelf maximum
  - Note that only one cabinet has a vent
  - Only one cabinet can be secured (padlock)

You may have to make some compromises or hard choices

- When finished, discuss the following and write comments in your workbook:
  - Was there one "perfect" way to store the chemicals?
  - Did you have to make compromises? What were they?
  - In making compromises, what were your main priorities?

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Activity: Chemical Storage

Conclusions

- Can make chemical storage safer and more secure
- Safe and secure chemical storage requires
  - Space
  - Time
  - Training
  - Equipment
- Difficulties may be mitigated by operational controls
  - Substitution
  - Source reduction
- Can get help from a computer/web-based inventory system that tracks hazard classes

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CSB video: Compressed gas fire

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Chemical Inventory System– Dr. Toby Dayrit

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Break

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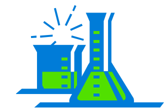
Chemical Waste Management & Disposal

Waste Management

- Nonhazardous waste
- General guidelines– Storage – Packaging
- Special categories
  - Metal waste
  - Radioactive and mixed waste
  - Biological waste
  - Unknown and orphan waste
- Treat on-site



Waste management: nonhazardous waste

- Used oil (uncontaminated) is not considered hazardous waste. Label Containers "USED OIL", not "hazardous waste"

- Uncontaminated PPE (gloves, wipes)
- Triply rinsed glassware (bottles, droppers, pipettes)
- Salts (KCl, NaCl, Na_2CO_3)

- Sugars – Amino acids
- Inert materials (uncontaminated resins and gels)

Waste management: General guidelines

- Secure and lock waste storage area
- Post signs to warn others
- Keep area well ventilated
- Provide fire extinguishers and alarms, spill kits
- Provide suitable PPE
- Provide eye wash, safety showers
- Do not work alone

Waste management: General guidelines

- Insure against leakage; dyke area if possible
- Label all chemicals, containers, vials
- Separate incompatible chemicals
- Keep gas cylinders separate
- Keep radioactive material separate
- Know how long waste can be stored
- Provide for timely pick-up

Waste – Storage guidance

- Container should not react with the waste being stored (e.g. no hydrofluoric acid in glass)
- Similar wastes may be mixed if they are compatible
- Whenever possible, *wastes from incompatible hazard classes should not be mixed* (e.g. organic solvents with oxidizers)
- Containers must be kept closed except during actual transfers. Do not leave a funnel in a hazardous waste container
- Chemical containers that have been triple-rinsed and air-dried in a ventilated area can be placed in the trash or recycled

Waste – General guidance

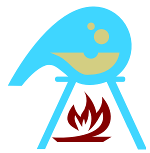
- Certain metals cause disposal problems when mixed with flammable liquids or other organic liquids
- Pressure can build up in a waste vessel
- Corrosion can occur in storage vessel
- Secondary containment is necessary
- Glass waste containers can break

Best practice – Orphan control

- Before moving to new job meet with new lab occupant
  - This can be a new employee or new student
  - Label all chemicals and samples carefully
  - Make notations in common lab book
- Dispose of all unneeded or excess chemicals
  - Put into chemical exchange program
  - Dispose of as hazardous waste
- Do not leave any chemicals behind except by agreement

Waste management

- Recycle, reuse, redistill, if possible
- Dispose by incineration, if possible
- Incineration is NOT the same as open burning



Emissions from incineration vs. open burning

	Open Burn (µg/kg)	Municipal Waste Incinerator (µg/kg)
PCDDs	38	0.002
PCDFs	6	0.002
Chlorobenzenes	424150	1.2
PAHs	66035	17
VOCs	4277500	1.2

Source: EPA/600/SR-97/134 March 1998

Laboratory wastes are packaged in small containers

Lab packs consists of small containers of compatible waste, packed in absorbent materials.

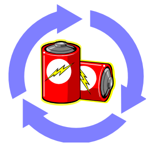
Lab packs segregated at hazardous waste facility

Waste management: Waste disposal service

- Is disposal service licensed?
- How will waste be transported?
- How will waste be packaged?
- Where will material be disposed?
- How will it be disposed?
- Maintain written records

Battery recycling and disposal

- Hazardous waste
  - Lead acid (Pb) – recycle (90% car batteries)
  - Sealed lead (Pb) – recycle
  - Mercury-oxide (HgO) button, silver-oxide (AgO) button – recycled by jewelers
  - Nickel Cadmium (NiCd) recycle



- Nonhazardous waste
  - Nickel Metal Hydride (Ni-MH) recycle
  - Carbon – zinc
  - Alkaline
  - Zinc-air button

Mercury metal disposal

- Collect pure liquid mercury in a sealable container. Label as "MERCURY FOR RECLAMATION"
- Place broken thermometers and mercury debris in a sturdy sealable plastic bag, plastic or glass jar. Label the container "Hazardous Waste – MERCURY SPILL DEBRIS"
- Never use a regular vacuum to clean up a mercury spill – contaminates vacuum, heat evaporates the mercury
- Never use a broom to clean up mercury – spreads smaller beads – contaminates the broom.

Mixed Waste (chemical radioactive)

These wastes must be minimized – heavily regulated

- Universities, hospitals
  - Low level radioactive with chemical
  - Scintillation cocktails
  - Gel electrophoresis waste
- Nuclear energy research
  - Low and high level radioactive with chemical
  - Lead contaminated with radioactivity

Mixed Waste (chemical-biological)

- Medical wastes
  - Blood and tissue
  - Sharps – needles, scalpels
  - Contaminated glassware, PPE
- Autoclave or sterilize
  - Bleach incompatible with autoclave
  - Do not autoclave flammable liquids
- Incinerate

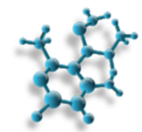
Unknown "orphan" waste

Avoid if at all possible -- requires analysis before disposal!

- Pre-screen
  - Crystals present? (potential peroxide formation)
  - Radioactive (Geiger counter)
  - Bio waste? (interview history)
- Screen
  - Prepare for the worst – wear gloves-goggles-hood
    - Air reactivity
    - Water reactivity
    - Flammability
    - Corrosivity

Unknown waste characterization*

- Physical description – Water reactivity – Water solubility
- pH and neutralization information
- Presence of:
  - ✓ Oxidizer
  - ✓ Sulfides or cyanides
  - ✓ Halogens
  - ✓ Radioactive materials
  - ✓ Biohazards
  - ✓ Toxics



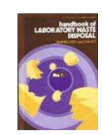
*Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995 Section 7.B.1

Waste management: Down the drain?

- If legally allowed:
  - Deactivate & neutralize some liquid wastes yourself
    - e.g., acids & bases
    - Don't corrode drain pipes
  - Dilute with lots of water while pouring down the drain
  - Be sure that you do not form more hazardous substances
    - Check reference books, scientific literature, internet

Waste management: Treatment in Lab

- References:
  - "Procedures for the Laboratory-Scale Treatment of Surplus and Waste Chemicals, Section 7.D in Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995, available online: http://www.nap.edu/catalog.php?record_id=4911
  - "Destruction of Hazardous Chemicals in the Laboratory, 2nd Edition", George Lunn and Eric B. Sansone, Wiley Interscience, 1994, ISBN 978-0471573999.
  - "Hazardous Laboratory Chemicals Disposal Guide, Third Edition", Margaret-Ann Armour, CRC Press, 2003, ISBN 978-1566705677
  - "Handbook of Laboratory Waste Disposal", Martin Pitt and Eva Pitt, 1986. ISBN 0-85312-634-8



On-site Recycling and Waste Treatment

- Recycling by redistribution
- Recycling of metals
  - Gold-mercury-lead- silver
- Recycling of solvents
  - Clean for reuse-rotovap
  - Distill for purity
- Recycling of oil
- Recycling of E-waste

Chemical recycling

- Reuse by others in the organization or community
- An active chemical exchange program
  - Beware of accepting unusable chemicals
- Reuse in experiments in the laboratory
- Exchange for credit with suppliers by agreement

What should not be recycled

- Gas cylinders past their pressure testing date
- Used disposable pipettes and syringes
- Chemicals and assay kits past their expiration
- Obviously degraded chemicals
- Used tubing, gloves and wipes
- Others?

What should be recycled or redistributed?

- Excess unopened chemicals
- Excess laboratory glassware (unused or clean)
- Consumables with no expiration
- Solvent that can be purified
  - Lower purity suitable for secondary use?
- Precious or toxic metals
  - Hg, Ag, Pt, Pd, Au, Os, Ir, Rh, Ru
- Others?

Solvents recycling – general guidance

- Boiling point must be widely different
- Azeotropes may prevent separation
- Sometimes hazards are created
- Some solvents do not need complete separation
- Hardware for separation

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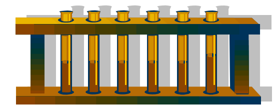
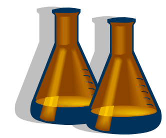
Solvent recycling – general guidance

Solvent recycling requires care and organization

- Keep solvents segregated prior to separation (single product solvent)
- No unnecessary dirt due to careless handling
- Requires good labeling
- A small amount of the wrong chemical can ruin a desired separation
- Care must be taken not to concentrate peroxides





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Solvent recycling – general guidance

Solvent recycling requires care and organization

- Try other purification methods before distillation
  - Convert to precipitate
  - Convert to water soluble
  - Use an adsorbent
- Need BP difference of > 10°C
- Can form azeotrope*
  - water / ethanol (100°C/ 78.3°C)
  - cyclohexane / isobutanol (81°C / 108°C)
- Mixture of 4 solvents not practical
- Distillation can be incorporated into curriculum

* Consult CRC Handbook of Chemistry and Physics for list of azeotropes

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Solvent recycling – low efficiency

Rotovap can be used to pretreat

- Toxic material may be kept from the distillation
- May be sufficient if purity is not crucial
- Separation of solvent from solids

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Solvent recycling – medium efficiency

- Even high efficiency stills are not perfect
- Continuous better than batch for large volumes
- Control reflux
- Monitor head temperature
- Reduce heat loss to get more efficiency
- Do not let still operate to dryness
- Use boiling chips but do not add when solvent is hot

Example: 200mm long column for separating benzene and toluene

Packing	TP
Empty	0.5
Coarse packing	1
Fine packing	5

TP = theoretical plates

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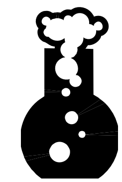
Solvents that should not be recycled by distillation

Accidents have been reported for these distillations

Individual Substances
- Di-isopropyl ether (isopropyl alcohol)
- Nitromethane
- Tetrahydrofuran
- Vinylidene chloride (1,1 dichloroethylene)

Mixtures
- Chloroform + acetone
- Any ether + any ketone
- Isopropyl alcohol + any ketone
- Any nitro compound + any amine



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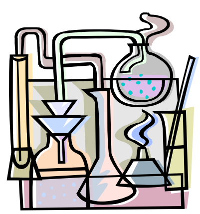
Practical examples of recycling

- Hexane contaminated with small amount of inert solvent used in prep lab
- Chemistry students given a finite quantity of solvent, then had to recycle for subsequent experiments
- Acetone 50% in water for washing. Azeotrope is 88.5% which is then diluted back with water for reuse
- Use rotovap recovery rather than evaporation. Student will redistill; 60% recovery.
- Third wash was captured and used as first wash on next experiment



Source : Handbook of Laboratory Waste Disposal, 1986.
Marion Pitt and Eva Pitt, John Wiley and Sons, ISBN 85312-634-8

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Open Discussion, Next Steps, Workshop Evaluation