Chemical Safety and Security Officer Training

King Saud University, Riyadh, Saudi Arabia
8 –12 December 2012

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.

Sandia National Laboratories

Workshop Overview & Introductions

- CSP Sponsorship
- Purpose of Workshop
- Overview of Workshop
- Introductions

CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

Chemical Security Engagement Program (CSP)

U.S. Department of State: CSP Program Objectives

- Raise awareness about the dual-use nature of chemicals
- Foster collaboration among chemical professionals worldwide
- Provide training opportunities, technical assistance, and conduct risk assessments in academic laboratories and industrial settings
- Support local and regional conferences on chemical security policy and regulation

CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

CSP Activities

- Work with host countries to assess their current needs and priorities in chemical risk management
- Partner with :
  - National and regional chemical organizations (HKI, IKM)
  - Universities
  - International chemical organizations (OPCW, IUPAC, UNFAO)
  - Chemical industry associations (CICM, KN-RCI)
- CSP engages ministries/regulatory agencies in countries with:
  - Regional security concerns
  - Active producers/exporters of industrial chemicals

Institut Teknologi Bandung 1920

HKI Himpunan Kimia Indonesia

CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

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

CSP Website – log in

CSP
CHEMICAL SECURITY ENGAGEMENT PROGRAM

Home | Workshops | Travel Grants | Discussion Board | Resources | Contacts

Grant Application for Travel and Training Support

The Chemical Security Engagement Program travel grants provide short-term travel support to chemical scientists, engineers, technicians, and project managers to attend conferences and seminars for career enhancement and/or to network with other scientists, industry and academic organizations with the intent of developing collaborative projects and/or new research opportunities that improve chemical safety and security.

CSP will consider all eligible proposals that can demonstrate:

- Increased knowledge and/or training on a research topic; and/or
- Impact on the applicants' career and professional development;
- Potential for developing a new research partnership;
- Relevance to the applicant's field of expertise.

Applications must be submitted electronically in English.

Chemical Security Engagement Program is sponsored by the U.S. Department of State.

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Map of Participant Countries

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CSP Website – Discussion Board

CSP
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Discussion Board

Add a comment | Share a document

- Hoods in my laboratory
- Chemical Process Safety Beacon
- Mercury removal from water
- Mercury removal from water by lime softernig
- UN document on mercury reduction
- Process safety education at Ohio State

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Resources

- Chemical Laboratory Safety and Security: A Guide to Prudent Chemical Management," National Academies Press, 2010. (English-French-Arabic-Indonesian translations)
- Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, Revised Edition (2011)
- Chemical Security Engagement Program
- Chemical Safety and Security Officer Training for Laboratory Settings
- Safety and Security Training for the Chemical Industry

Categories

- CSSO Reference Documents
- Laboratory Design
- Chemical Safety
- Chemical Security
- Pesticides
- Orphaned Chemicals

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Map of Participant Countries

Click on image for large, interactive map.

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CSP Website – Photos

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Photo Gallery

Photo Gallery - Saudi Arabia CSSO Dec 2012 (0)

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Workshops

- Photo Gallery

Workshops by year

- 2011
- 2010
- 2009
- 2008

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Sandia National Laboratories

Sandia supports the CSP Program

Sandia National Laboratories
Albuquerque, New Mexico, USA

Welcome to Chemical Safety and Security Officer (CSSO) Training

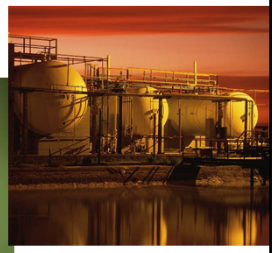
Objectives
- Promote the safe and peaceful use of chemistry
- Encourage the creation of networks of people interested in CSS

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

Chemical Safety and Security Overview

Why worry about chemical safety?

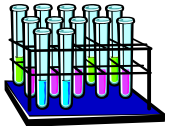
- Chemicals used everyday in labs and factories can be hazardous
- Health of the workers
- Safety of the workers
- Safety of the community
- Safety of the environment



…It's the right thing to do!

But disease depends on many factors…

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



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

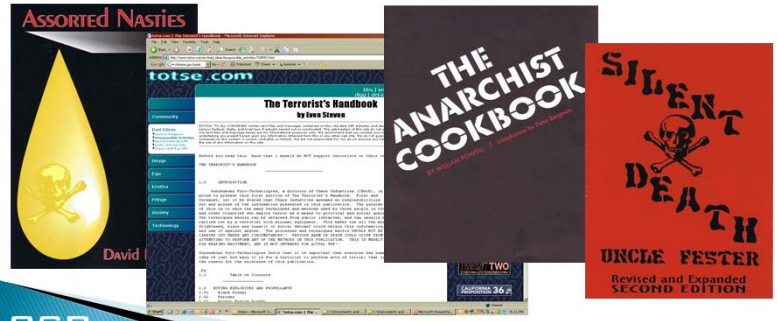
Dartmouth College: Dimethylmercury poisoning

- 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

Photo [illegible]ted poster from Wikipedia commons

Aum Shinrikyo: Tokyo, Japan

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.

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

Important Questions

How does your country regulate and control chemical safety and security?

…Is it effective?

…Could it be improved?

…How?

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

Dual-use Chemicals

Chemical dual-use awareness

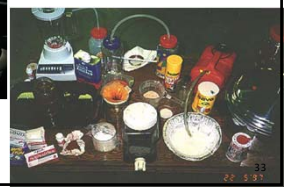
Dual use chemicals: Chemicals used in industry or everyday life that can also be used in bad ways.

Dual-use chemical example:

- Pseudoephedrine
- Cyanide
- Pesticides
- Fertilizers
- Sodium azide

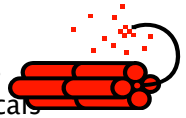
FIGURE. Package of Chinese rodenticide implicated in the poisoning of a female infant aged 15 months — New York City, 2002

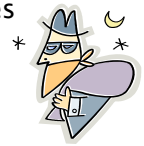
Photo/New York City Poison Control Center



Dual-use Chemicals: Explosives

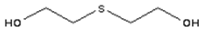
- Theft of conventional explosives
  - Chemical suppliers
  - Users such as mines or construction sites
- Diversion of industrial or laboratory chemicals
  - Chemical suppliers
  - Chemical factories
  - Academic teaching or research laboratories
  - Disposal sites





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)

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

International Chemical Control Groups

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Chemical Weapons Convention

The Australia Group

Export Controls

UN Security Council Resolution 1540

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

Chemical Weapons Convention (CWC)

- International treaty which bans the development, production, stockpiling, transfer and use of chemical weapons
  - Entered into force in April 1997 with 87 State Parties participating
  - Today: 183 nations have joined, 5 others have signed, only 7 have not taken any action.
    - Each nation enacts appropriate laws
    - Each nation agrees to assist other Member States

Australia Group

- An informal arrangement to minimize the risk of assisting chemical and biological weapon (CBW) proliferation.
  - Harmonizing participating countries' national export licensing measures
- 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
- 40 nations plus European Commission participate

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.

Components of Chemical Security

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?

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

Chemical Security: Physical Site

LOCK UP!!

Controlled drugs

Chemical Surety Agents

Highly toxic chemicals

Facility Characterization

- Facility characterization provides important data to:
  - identify assets to be protected and their locations
  - survey the existing physical protection system components at the facility
  - document facility layout for security analysis.

Threat Definition

Threat classes:

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

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

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

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?

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.

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.

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.

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)

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.

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.

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.

CSSP Organization, Responsibilities, and CSSO Duties

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

Crisis Management: Prevention & Response

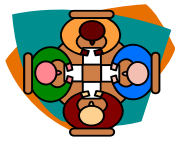
- Facility crisis
  - Fire
  - Explosion
  - Chemical release
- Natural disaster
  - Earthquakes
  - Hurricane/typhoon
  - Tsunami
- Disgruntled personnel
  - Employees
  - Ex-workers
  - Students
- Demonstrations, protests
- Evacuation / reoccupancy
- Terrorism

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

Chemical Safety and Security Applies to Everyone

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



Faculty/Principal Investigator

has the responsibility

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

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

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

Employees and students

have a responsibility

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

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 Officer

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

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

Management CSS Responsibilities

POLICY STATEMENT

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

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

Policy Statements

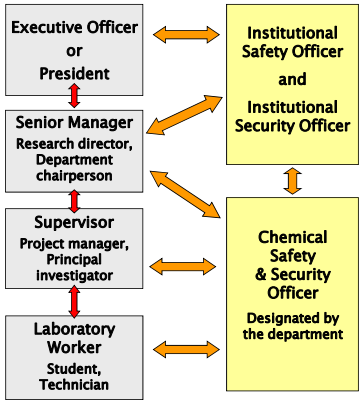
- By senior management
- Typically brief
- Clear goals
- Commitment
- Defines employee role
- Identifies resources and staff
- Signed by person in authority

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 accou 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

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

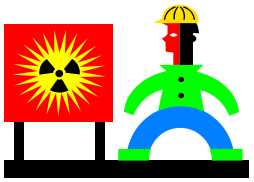


CSSO Duties Include:

- Surveys
- Inspections
- Training
- Medical Monitoring
- Investigations

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 (e.g., formaldehyde, radiation)
- Data analysis
- Write and deliver report

Periodic Lab Inspections

- Done by CSSO
- Coordinate with lab supervisor/PI/occupants/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

Training Documentation: Sample

- Employee name: _____
- Department: _____
- Date: _____

- Training Subject: _____
- Training Date: _____
- Re-instruction date: _____

- Employee Signature: _____
- Date Signed: _____
- Supervisor's signature: _____
- Date: _____

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

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

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

Chemical Hazards and Risks

Overview of Presentation

- Chemical Hazards in Laboratories
- Chemical Hazards in Industrial Processes
  - Identifying Process Hazards
- Sources of Chemical Hazard Data

Laboratory Hazards

- Chemical Hazards
  - Toxic
  - Flammable
  - Reactive
  - Explosive
  - Chemicals of Concern (COCs)
- Physical Hazards
- Biological Hazards
- Radiological Hazards

Chemical Hazards: Principles of Toxicity

Toxicity Depends on Dose & Exposure

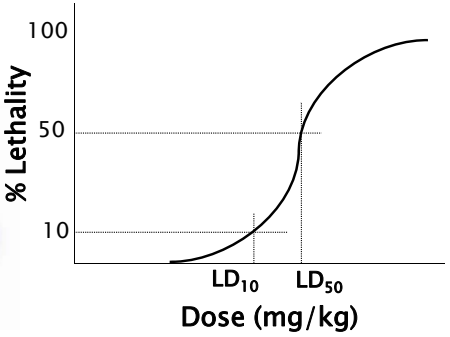
Chemical	Beneficial Dose	Toxic Dose
Aspirin	300–1000 mg	1000–30,000 mg
Vitamin A	500 units/d	50,000 units/d
Oxygen	20% in air	50–100% in air
Water	~1-2 L/day	~13 L

Chemical Hazards: Principles of Toxicity

Toxicity is Measured by Lethality

- LD_{50} (mg/kg)
  - "Lethal Dose 50%"

Dose–Response Curve



Chemical Hazards: Principles of Toxicity

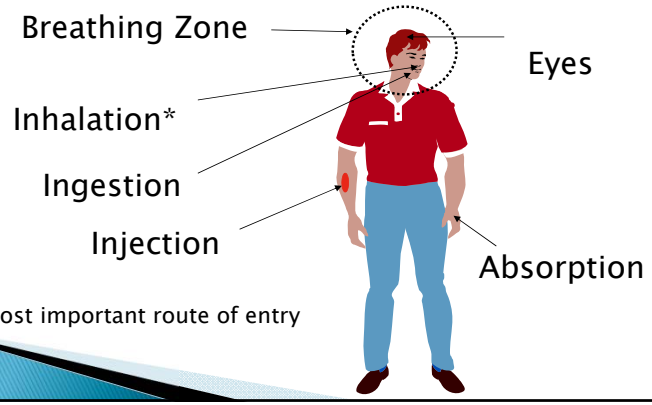
Extremely wide range of toxicities between different substances

Agent	LD_{50} (mg/kg)
Ethanol	7060
NaCl	3000
Formaldehyde	800
Caffeine	192
Nicotine	1
Dioxin	0.0001

Toxicity depends on a variety of factors

Chemical Hazards: Principles of Exposure

Routes of Exposure



*Most important route of entry

Chemical Hazards: Acute Toxins

- Includes highly toxic chemicals/poisons
  - Phosgene
  - Strychnine
- Includes common lab chemicals
  - Cyanides
  - Chlorine gas

Need to ensure safety and security when using and storing acute toxins

Chemical Hazards: Irritants, Allergens, and Corrosives

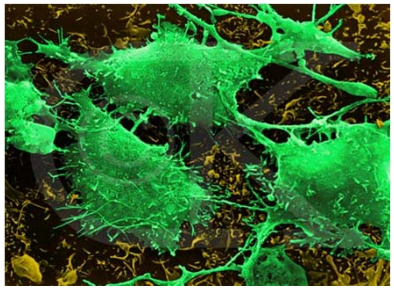
- Irritants
  - Effects are local and reversible
- Corrosives
  - Effects are local
  - Acids and bases
    - pH ≤ 2 or ≥ 12.5
  - React with and damage living tissue
- Allergens (and sensitizers)
  - Cause a reaction of the immune system

Chemical Hazards: Organ-Targeting

- Neurotoxins
  - Ethanol, Hg, CS_2, xylene, *n*-hexane
- Reproductive and Developmental Toxins
  - Harm fertility or reproductive ability
  - Harm fetus
- Other Organs
  - Liver, kidneys, lungs, etc.
  - Chlorinated or aromatic hydrocarbons, some metals

Chemical Hazards: Carcinogens

- Chronically Toxic
  - Vinyl chloride (liver cancer)
  - Asbestos (mesothelioma)
- Carcinogenicity of most chemicals is untested
  - Precautions taken may consider amount and frequency of use
- Treat known carcinogens as particularly hazardous



http://www.alternative-cancer.net/images/Cancer_cell,%20brain.jpg

Chemical Hazards: Flammable

- Fuel: Solids, Liquid, or Gases
  - Compressed or liquefied gases are especially hazardous
- Oxidant
  - Oxygen in air
  - Other oxidants
    - Cl_2, HNO_3
- Ignition
  - Spark
  - Heat

University of California, Santa Cruz, 2002
- Lab fire, cause not determined
- Lost equipment, notes, samples, etc.
- Labs took 2 years to reopen

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.

Example values

	LFL	UFL
Methane	5%	15%
Propane	2.1%	9.5%
Butane	1.6%	8.4%
Hydrogen	4.0%	75%

	Flash point
Methanol	12.2 °C
Benzene	-11.1 °C
Gasoline	-40 °C
Styrene	30.5 °C

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

Chemical Hazards: Reactive

- Water-reactive
- Pyrophoric materials
- Incompatible Chemicals
  - Combination leads to reactive or toxic hazards
    - Concentrated oxidizing or reducing agents

http://science.pixeladdiction.co.uk/?page_id=57

Reactive interactions

Example Compatibility Chart for an Acetic Anhydride Handling Facility

Will These Two Materials React?	Acetic Acid	Acetic Anhydride	Cooling Water	Sulfuric Acid	50% Caustic	Lube Oil	Cleaning Solution
Acetic Acid							
Acetic Anhydride	*Reactive*						
Cooling Water	*Not reactive*	*Reactive*					
Concentrated Sulfuric Acid	*Reactive*	*Reactive*	*Reactive*				
50% Caustic	*Reactive*	*Reactive*	*Reactive*	*Reactive*			
Lube Oil	*Not reactive*	*Not reactive*	*Not reactive*	*Reactive*	*Reactive*		
Cleaning Solution	*Find out what the cleaning solution contains, then determine reactions*						

From CCPS 2001

Chemical Hazards: Explosive

- Initiated by
  - Heat
  - Light
    - $H_2 + Cl_2$
  - Mechanical shock
    - Nitro, peroxo, chlorates
  - Certain catalysts
    - Acid/base catalyzed polymerization
- Dusts
- Peroxide-formers
  - Dialkyl ethers

- Texas Tech University Chemistry Lab, 2010
  - Synthesis of explosive compound
    - Scaled-up without precautions
    - One graduate student severely injured

http://www.csb.gov/investigations/detail.aspx?SID=90&Type=2&pg=1&F_InvestigationId=90

Chemical Hazards: Chemicals of Concern

- Presence or suspected presence of COCs in your laboratory could make you and your institution a target
  - Outsider Threat
  - Insider Threat

Example: Outsider Threat

- Chicago, USA, 2002
  - Joseph Konopka arrested in tunnels under the University of Illinois
  - Had cyanide compounds on him and a stockpile of stolen chemicals including cyanides in subway
  - Sentenced to 13 years in prison for "possessing a chemical weapon" and other charges

http://articles.cnn.com/2002-03-12/us/chicago.cyanide_1_cyanide-in-chicago-subway-sodium-cyanide-chicago-police?_s=PM:US

http://articles.chicagotribune.com/2004-01-04/features/0401040453_1_tunnels-urban-exploration-city-hall

Chemical Hazards: Chemicals of Concern

Example: Insider Threat

- Philadelphia, USA, 2007
  - A microbiologist stole 10-chlorophenoxyarsine from work
  - Attempted to poison her husband's lover
  - Case is still in court

It is important to recognize the safety and security hazards posed by chemicals

http://articles.cnn.com/2011-06-16/justice/us.scotus.poisoned.paramour_1_potassium-dichromate-myrlinda-haynes-carol-anne-bond?_s=PM:CRIME

http://www.chemindustry.com/chemicals/0437452.html

Physical Hazards: Compressed Gases

- Pressure
- Also chemical hazard depending on gas
  - Toxic
  - Reactive
  - Flammable
- Asphyxiation

Physical Hazards: Cryogens, Pressure, and Temperature

- Cryogens
  - Dry ice
  - Liquid nitrogen
    - Contact
    - Oxygen condensation
    - Asphyxiation
    - Pressure
- Pressure
  - High, above ~1 atm
  - Vacuum work
- Temperature

Physical Hazards: Electrical

- Power outages
- Shock
- Fire
- Frayed cords
- Overloaded circuits
- Static electricity

Physical Hazards: Mechanical and Other

- Mechanical
  - Noise
  - Moving parts
    - Yale University, 2011
      - Student dies after getting hair caught in lathe (machine shop of chemistry lab)
- Other
  - Sharps
  - Slips, trips, falls
  - Housekeeping
    - Fire
    - Blocked exits

http://www.waterfront-woods.com/Projects/Lathe/lathe1.JPG

Laboratory Hazards: Biological

Pathogens

- Route of infection
  - Food or water borne
    - Salmonella
  - Blood borne
    - Hepatitis, HIV
  - Airborne
    - Tuberculosis
- Reason for exposure
  - Diagnostic work
  - Research work

Laboratory Hazards: Radiological

- Ionizing Radiation
  - X-rays
  - Gamma rays
  - Alpha particles
  - Beta particles
  - Neutrons
- Ionizing Radiation Sources
  - Radioactive isotopes
    - ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{131}I
  - Instruments
    - Diffractometer
    - Electron microscope
- Nonionizing Radiation
  - Ultraviolet
  - Infrared

- Primarily an eye hazard

Process hazard definition

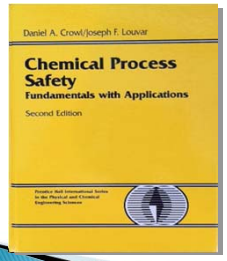
Presence of a stored or connected material or energy with inherent characteristics having the potential for causing loss or harm.

Process Chemical Hazards

- Differ from laboratory chemical hazards
  - Larger scale
  - Environmental conditions: temperature and pressure
- Two types of chemical process hazards:
  - Inherent material hazards
  - Chemical interaction hazards

Process Safety Resources

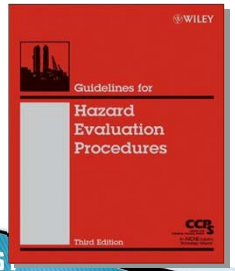
D.A. Crowl and J.F. Louvar 2001.
Chemical Process Safety: Fundamentals with Applications, 2nd Ed., Upper Saddle River, NJ: Prentice Hall.



Chapter
- **2 • Toxicology**
- **4 • Source Models**
- **5 • Toxic Release and Dispersion Models**
- **6 • Fires and Explosions**
- **10 • Hazards Identification**

Process Safety Resources

CCPS 2008a. Center for Chemical Process Safety, *Guidelines for Hazard Evaluation Procedures, Third Edition*, NY: American Institute of Chemical Engineers.



Chapter 3 • Hazard Identification Methods
- 3.1 Analyzing Material Properties and Process Conditions
- 3.2 Using Experience
- 3.3 Developing Interaction Matrixes
- 3.4 Hazard Identification Results
- 3.5 Using Hazard Evaluation Techniques to Identify Hazards
- 3.6 Initial Assessment of Worst-Case Consequences
- 3.7 Hazard Reduction Approaches and Inherent Safety Reviews

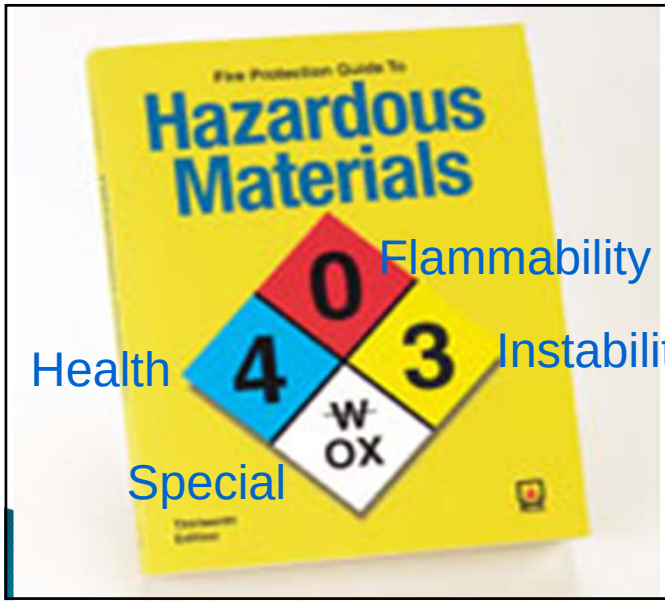
Approaches and methods for identifying process hazards

Some "HAZID" approaches and methods:
- Analyze material properties
- Analyze process conditions
- Use company and industry experience
  - Knowledge of the process chemistry
  - Experience at a smaller scale e.g. pilot plant
  - Examination of relevant previous incidents
  - Use relevant checklists e.g. CCPS 2008a Appx B
- Develop chemical interaction matrices

Chemical hazard data

Some sources of chemical hazardous property data:

- Safety Data Sheets from chemical supplier
- Chemical industry-specific sources (e.g., Chlorine Institute)
- Many books and handbooks (NFPA 704)



NFPA 704
Summary of material hazards for emergency response

Limitations for Identifying Process Hazards

NFPA 704 diamonds and SDSs only give properties of individual hazardous materials

- Hazardous energies not identified
- Some hazardous chemical interactions not identified
- Connected hazards may not be identified

Chemical hazard data

Some internet-accessible data sources:

- **International Chemical Safety Cards**
  www.ilo.org/legacy/english/protection/safework/cis/products/icsc/dtasht/index.htm
- **CAMEO Chemicals**
  cameochemicals.noaa.gov
- **Chemical Reactivity Worksheet**
  response.restoration.noaa.gov/CRW
- **NIOSH Pocket Guide to Chemical Hazards** www.cdc.gov/niosh/npg
- **Wireless Information System for Emergency Responders**
  wiser.nlm.nih.gov

DISCUSSION

- Chemical Hazards in Laboratories
- Chemical Hazards in Processes
- Identifying Process Hazards
- Sources of Chemical Hazard Data

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Globally Harmonized System of Classification

SAND No. 2012-5234C
Sandia is a multiprogram 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.

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Sandia National Laboratories

Labeling Basics

- Proper Labeling of Laboratory Hazards
  - Chemical
  - Physical
  - Biological
  - Radiological

Just ignore the label...
The worst stuff isn't listed anyway.

- Globally Harmonized System (GHS) Hazard Labels

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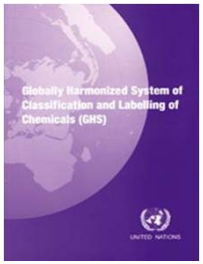
The Globally Harmonized System (GHS) of Classification and Labeling of Chemicals

- A system for standardizing and harmonizing the classification and labeling of chemicals
- Not a regulation or a standard.
  - establishes agreed hazard classification and communication provisions with explanatory information on how to apply the system
- GHS Labels and Safety Data Sheets (SDS)



http://www.osha.gov/dsg/hazcom/ghs.html

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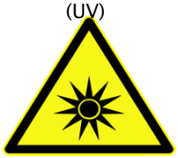
Globally Harmonized System (GHS) Hazard Labels

Corrosive	Irritant	Health Hazard	Acute Toxicity
Flammable	**Explosion**	**Oxidizer**	**Compressed Gas**

Globally Harmonized System (GHS) and Other Hazard Labels

Environmental	Electricity	Hot Surface	Pinch Point
Biohazard	**Radioactive**	**Laser Beam**	**Optical Radiation (UV)**
			

GHS Labels Elements: Example Bottle Label

ToxiFlam (Contains: XYZ)

Danger! Toxic If Swallowed, Flammable Liquid and Vapor

Do not eat, drink or use tobacco when using this product. Wash hands thoroughly after handling. Keep container tightly closed. Keep away from heat/sparks/open flame. - No smoking. Wear protective gloves and eye/face protection. Ground container and receiving equipment. Use explosion-proof electrical equipment. Take precautionary measures against static discharge.
Use only non-sparking tools. Store in cool/well-ventilated place.

IF SWALLOWED: Immediately call a POISON CONTROL CENTER or doctor/physician. Rinse mouth.

In case of fire, use water fog, dry chemical, CO_2, or "alcohol" foam.

See Material Safety Data Sheet for further details regarding safe use of this product.

MyCompany, MyStreet, MyTown NJ 00000, Tel: 444 999 9999

GHS Labels Elements: Example Bottle Label

Symbols (Hazard Pictograms)

ToxiFlam (Contains: XYZ)

Danger! Toxic If Swallowed, Flammable Liquid and Vapor

Do not eat, drink or use tobacco when using this product. Wash hands thoroughly after handling. Keep container tightly closed. Keep away from heat/sparks/open flame. - No smoking. Wear protective gloves and eye/face protection. Ground container and receiving equipment. Use explosion-proof electrical equipment. Take precautionary measures against static discharge.
Use only non-sparking tools. Store in cool/well-ventilated place.

Product Identifier and ingredient disclosure

Signal Word ("Danger" for the more severe hazards, and "Warning" for the less severe hazards)

Hazard Statement

IF SWALLOWED: Immediately call a POISON CONTROL CENTER or doctor/physician. Rinse mouth.

In case of fire, use water fog, dry chemical, CO_2, or "alcohol" foam.

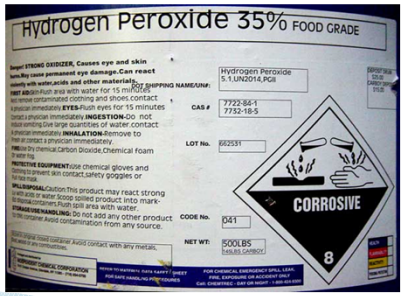
Supplemental Information

Supplier Identification

Precautionary Statement (prevention, response in cases of accidental spillage or exposure, storage, and disposal

Example Labels

- Label Creation



Other Labeling Considerations

- Chemical Resistance
- Environmental Resistance
  - Heat, Fridge, Freezer
- Age
- Size
  - Label
  - Container
- Attachment to Bottle

GHS Safety Data Sheets

- Serve the same function as an MSDS does in ISO, EU and ANSI requirements
- Most comprehensive source of information
  - Hazards, including environmental hazards
  - Advice and safety precautions
    - Transportation, emergency responders, poison centers
- Product related and not specific to workplace or task
  - Written and supplied by manufacturer
- Only for pure substances and some mixtures

http://www.osha.gov/dsg/hazcom/ghs.html

SDS Format

16 Sections

1. Identification
2. Hazard(s) identification
3. Composition/information on ingredients
4. First-aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and Storage
8. Exposure controls/ personal protection
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological information
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information

Section 2: Hazards

- GHS classification of the substance/mixture and any national or regional information
- GHS label elements, including precautionary statements.
  - Pictograms, black and white reproduction of the symbols, or the name of the symbol, e.g., flame, skull and crossbones.
- Other hazards which do not result in classification (e.g., dust explosion hazard) or those not covered by the GHS.

Section 4: First-aid Measures

- Description of necessary measures, subdivided according to the different routes of exposure, i.e., inhalation, skin and eye contact, and ingestion.
- Most important symptoms/effects, acute and delayed.
- Indication of immediate medical attention and special treatment needed, if necessary.

Section 6 and 7

Section 6: Handling and Storage
- Precautions for safe handling.
- Conditions for safe storage, including any incompatibilities.

Section 7: Exposure controls/ personal protection
- Control parameters, e.g., occupational exposure limit values or biological limit values.
- Appropriate engineering controls.
- Individual protection measures, such as personal protective equipment (PPE).

Section 10: Stability and reactivity

- Reactivity
- Chemical stability
- Possibility of hazardous reactions
- Conditions to avoid (e.g., static discharge, shock or vibration)
- Incompatible materials
- Hazardous decomposition products

Section 13 and 15

Section 13: Disposal Considerations

- Description of waste residues and information on their safe handling and methods of disposal, including the disposal of any contaminated packaging.
  - May be region, country specific

Section 15: Regulatory Information

- Safety, health and environmental regulations specific for the product in question.
  - May be region, country specific

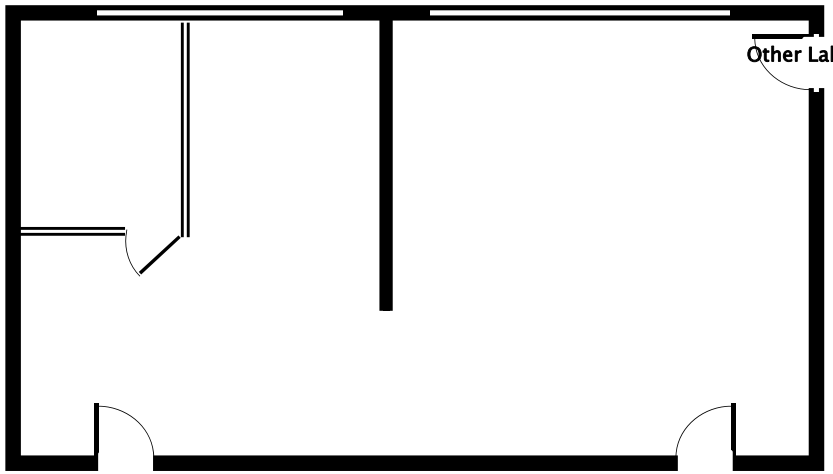
GHS Safety Data Sheets (SDS)

- Benefits of the SDS
  - The SDS contains comprehensive information for chemical management in one place
- Drawbacks
  - Not always current
  - Lack of toxicity information for most chemicals
  - Industry focus, not specific to laboratory scale
  - Sometimes inconsistent
- Keep a SDS for each chemical in your inventory
- Ensure all SDSs are accessible to workers and auditors

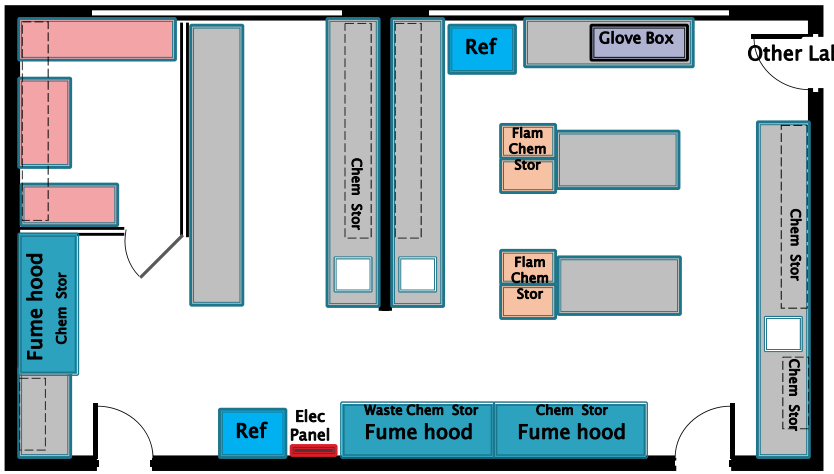
Lab Assessment Exercise Part 1: Lab Layout, Open Discussion

Lab Assessment Exercise

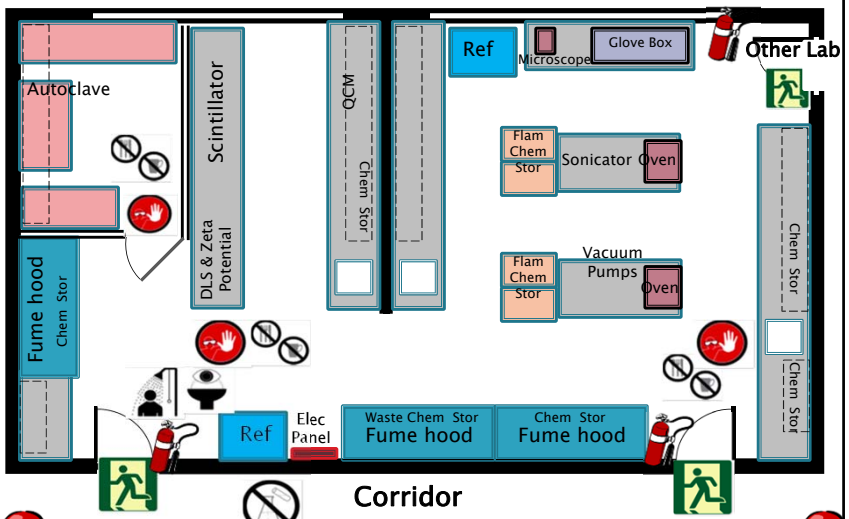
Introduction



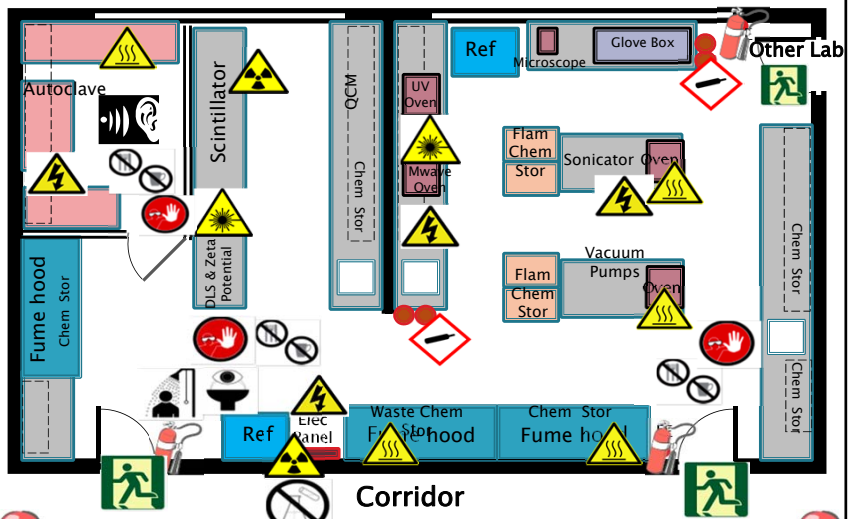
Chemical Lab Floor Plan



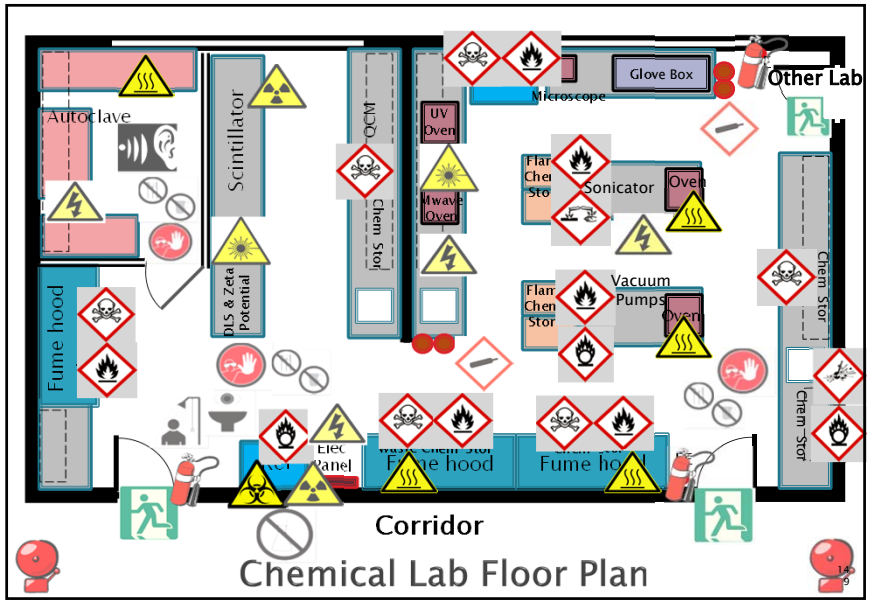
Chemical Lab Floor Plan

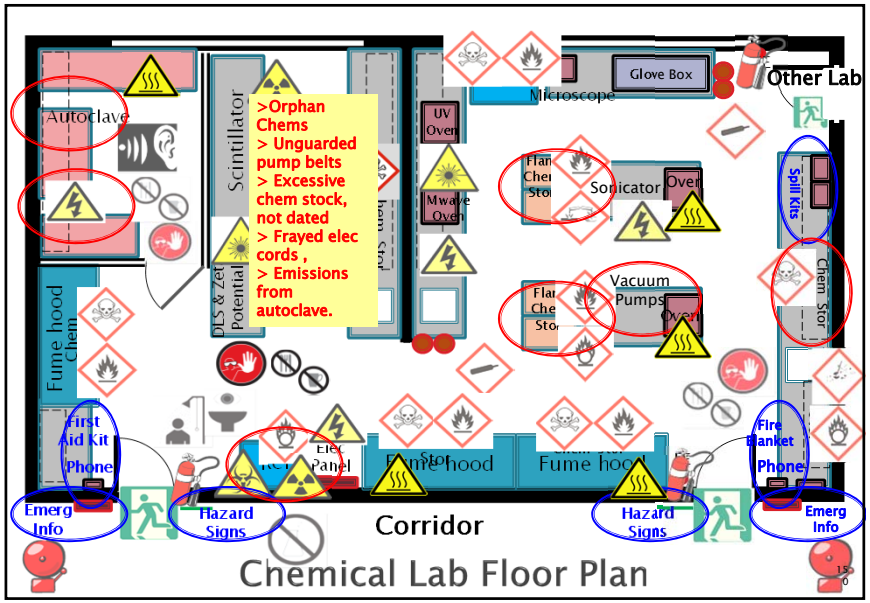


Chemical Lab Floor Plan



Chemical Lab Floor Plan





CSS Action Plan

- Prioritization:
  - **Easiest** → **Medium** → **Difficult**
    - inventory
      - check actual
      - remove spent chem.
      - separate groups
      - secondary containment
    - training
    - collect MSDS info
    - fire storage cabinets
    - develop SOPs
    - 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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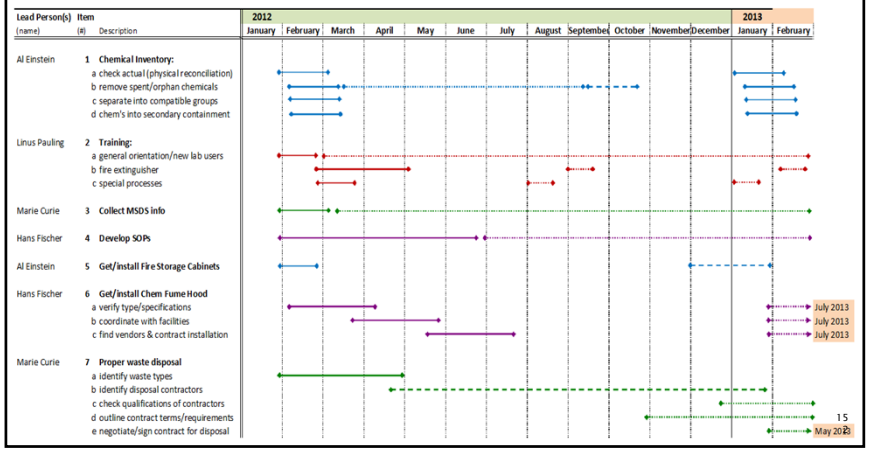
CSS Action Plan

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



Lab Assessment Exercise Part 1: Lab Layout

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
  - Use an actual floor plan of a laboratory that someone in the group works in, if possible
  - Identify the main laboratory features such as doors, windows, lab benches, refrigerators, chemical hoods, instruments and other equipment, etc.

Lab Assessment Exercise Part 2: Lab Hazards and Safety Controls

Part 2: Laboratory Assessment Exercise

- Once the floor plan is done, get hazard stickers from the instructor and apply them to the appropriate places in your laboratory floor plan
- Identify the safety controls present in your laboratory
- Identify the hazards present in your laboratory
- Apply stickers describing the safety controls and hazards to your laboratory floor plan