Why worry about chemical safety?

- Chemicals used everyday in labs and factories can be hazardous.

Studies indicate lab chemists may have:

- Shorter life spans, more disease

- Higher cancer incidence

- Higher suicide rate (females)
Possible chemical health problems

**Chemicals**
- Vinyl chloride
- Asbestos
- Carbon tetrachloride
- Mercury
- Lead
- Thalidomide
- Methanol
- CO, CS₂

**Diseases**
- Liver cancer
- Mesothelioma
- Hepatotoxin (jaundice)
- Neurotoxin, CNS, narcosis
- Reprotoxin, birth defects
- Reprotoxin, developmental defects
- Blindness, death
- Hematopoietic, hemoglobin, cyanosis

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.
- Firefighters responded to alert from heat-detection system in building.
- Controlled by noon.
- Up-to-date inventory of hazardous materials allowed firefighters to enter building and contain fire.
- Building did not have automatic sprinkler system.

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

University of California Santa Cruz: Fire, cont’d.

- 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.
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 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

University lab chemical accidents

Incident – Chemical

- Fire and one death – t-butyl lithium + pentane

- Dartmouth, wrong gloves – methyl mercury

- Wroclaw Poland, explosion – dry perchlorates

- Australia, skin absorption – hydrofluoric acid

- Okazaki Japan, explosion – peroxide by-products in synthesis

- OSU, US cylinder explosion – liquid nitrogen cylinder

- Material science engineering lab explosion – nitric acid + ethanol explosion

Bhopal: Pesticide plant chemical release

- One of the greatest chemical disasters in history, December 1984

- Union Carbide plant making Sevin released ~40 tonnes of methyl isocyanate in the middle of the night

- Low local demand for pesticides meant the plant was only partially running

- Some hardware was broken or turned off, including safety equipment
  - Safety measures and equipment far below US standards

- Plant in heavily populated area

Safety Video: Reactive Hazards

Major industrial chemical disasters

<table>
<thead>
<tr>
<th>Accident/location</th>
<th>Chemical product &amp; exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 1912 Toyama Japan</td>
<td>- itai-itai disease/cadmium</td>
</tr>
<tr>
<td>- 1921 Oppau Germany</td>
<td>- ammonium nitrate</td>
</tr>
<tr>
<td>- 1930 Gauley Bridge WV USA</td>
<td>- silica</td>
</tr>
<tr>
<td>- 1968 Yusho Japan</td>
<td>- rice oil/PCB,PDDF</td>
</tr>
<tr>
<td>- 1974 Flixborough UK</td>
<td>- cyclohexane</td>
</tr>
<tr>
<td>- 1976 Seveso Italy</td>
<td>- herbicide production/TCDD</td>
</tr>
<tr>
<td>- 1984 Bhopal India</td>
<td>- methyl isocyanate</td>
</tr>
<tr>
<td>- 1986 Chernobyl Ukraine</td>
<td>- ionizing radiation</td>
</tr>
<tr>
<td>- 2005 Texas City USA</td>
<td>- hydrocarbon production</td>
</tr>
<tr>
<td>- 2005 Jilin China</td>
<td>- benzene/aniline</td>
</tr>
</tbody>
</table>

Taiwan: Silane fire

- Motech Industries solar cell plant in Tainan Industrial Park
  - 1 death
  - US $1.3 million damage
  - Silane / air explosion
    - Operator responded to gas-cabinet alarm
    - Explosion occurred when he opened gas-cabinet
    - Fire burned for 1 hour before being controlled
      - Caused other SiH₄ and NH₃ cylinders to empty
  - November 2005

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
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!

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
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.

Chicago, Illinois, USA

- 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 0.8 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).
  http://cns.miis.edu/db/wmdt/incidents/1190.htm, accessed 12/07

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Iraq

- 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”

Chemical Security

US Homeland Security Secretary Michael Chertoff told the American Chemistry Council, March 21, 2006:

“Now, the chemical sector certainly stands as one of the principal areas of infrastructure about which we have to be concerned. If you look back at the whole history of the way al Qaeda has conducted its operations, where possible, they have always tried to leverage our own technology against ourselves. They've turned jets, commercial jets, into weapons. They've tried to use our own chemicals and our own products as means of exploding devices against us. And obviously, one of the areas we have to be concerned about are parts of our infrastructure which house chemicals which could, if properly ignited, create a huge amount of havoc in a populated area – whether it be because of a large explosion or whether it's because of toxic inhalation...”
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

Protec

• 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?
BREAK

Fundamentals of Chemical Laboratory Safety

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&useSec=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

Definitions
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)

"Dose makes the poison. All substances have the potential to harm."
– Paracelsus ~1500 AD

300 mg aspirin = safe*
3000 mg = toxic
*normal, healthy, adult

Chemical Toxicity

Toxicity depends on:
- Concentration (dose)
- Frequency
- Duration
- Route of exposure

Routes of Exposure

- Breathing Zone
- Inhalation*
- Absorption
- Ingestion
- Injection

*Most important route of entry
Chemical Laboratory Safety

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

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

Chemical Laboratory Safety

Hazard – the potential to harm

Risk – the probability that harm will result

Chemical Laboratory Safety

based on the principle of

Industrial Hygiene

- The anticipation, recognition, evaluation and control of health hazards in the work environment to protect workers' health and well-being and to safeguard the community and the environment
Industrial Hygiene Principles

- Anticipation
- Recognition
- Evaluation
- Control

Chemical hazards
Physical hazards
Ergonomic hazards
Biological hazards

Anticipation
Safety First!

To consider safety in the beginning is:
- Easier,
- Cheaper,
- Safer,

... and it saves you time!

Anticipation
Advance Experiment Planning:

- Outline proposed experiment
- Acquire safety information (M)SDS, REACH
- Consult with CSSO?

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?
Recognition

Types of lab hazards:
chemical toxicity
fire / explosion
physical hazards
biohazards
radiation
special substances

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?

Control

How are the risks controlled?
• Engineering controls:
  – enclosure / isolation
  – ventilation / hoods
• Emergency Plan
• Personal Protective Equipment (PPE)

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

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

1. Change the process to eliminate the hazard

2. Substitution of a non-hazardous substance for hazardous (e.g., toluene for benzene)

3. Isolate or enclose the process or worker using barriers

4. Ventilation
   - Dilution (general ventilation): Not good
   - Local exhaust ventilation (LEV): Preferred

Lab Containment Principles

Concept

Source → Pathway → Receiver

Control Used

Engineering Control → Operational Practices → PPE
Engineering Controls

Dilution (general) ventilation

Local exhaust ventilation preferred

\[ Q_{in} \rightarrow C \rightarrow V \rightarrow Q_{out} \]

\( Q = \text{flux}, \ C = \text{contaminant conc.} \)

\( V = \text{velocity}, \ G = \text{generation rate} \)

Properly functioning & used correctly!

Laboratory hoods and ventilation are the basis of engineering controls.

Engineering Controls

- Special barrier facilities
  - clean rooms, carcinogen rooms, weighing rooms

- Safety shields
  - radiation shields, hood sashes, splash guards

Personal Protective Equipment

PPE includes:

- eye protection,
- gloves,
- laboratory coats, etc.,
- respirators,
- appropriate foot protection
Personal Protective Equipment

Eye protection - specific to the hazard

Gloves - must be chemical specific

- Laboratory coats
- Aprons
- Other protective clothing

Respiratory Protection

Requires:
- training & fit-testing

Can provide a false sense of security.
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.

Emergency Planning & Response

Have an evacuation plan and POST IT!

Never use hallways for storage

Dangerous!!

Blocks passage and emergency exits

Emergency Planning & Response

Label and keep all exits clear, unlocked or equipped with panic bars.
**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.

**Central location and maintain fire extinguishers and alarms.**

**Chemical Exposures to Eyes or Skin**

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

- **Centrally locate equipment**
  - Remove contaminated clothing
  - Thoroughly flush with water
  - Follow chemical specific procedures (i.e. HF)
  - Seek medical assistance
**Chemical Spills**

Centrally locate spill kits for quick access

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

---

**Emergency Planning & Response**

Centrally locate, inspect and maintain:

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

---

**Any Questions?**

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**Aspects of Chemical 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

- Pseudoephedrine is a common ingredient in cold medicines
- Precursor to crystal methamphetamine
- Recipes for conversion available on web

Clandestine meth labs in US during 2002
- Caused 194 fires, 117 explosions, and 22 deaths
- Cost $23.8 million for cleanup
- Dumped chemicals led to
  - deaths of livestock
  - contaminated streams
  - large areas of dead trees and vegetation


Dual-use chemical example: Cyanide

- Widely used in mining and metal plating industries, but is also a well known poison.
- Product tampering*
  - Tylenol capsules
    - laced with KCN
    - 7 deaths, fall 1982, Chicago, Illinois, USA
    - Led to tamper-proof product packaging
  - Popular with criminals and terrorists because it is relatively easy to obtain
  - HCN is CW agent AC


Therence Koh/AFP/Getty Images

Dual-use chemical example: Pesticides

- Widely used in homes and agriculture, but also used to poison people.

Dushuqiang (Strong Rat Poison)
- Outlawed in China in the mid-1980s, but was still available
- Nanjing, China, Sept. 2002
  - 38 people killed by poison in snack-shop food, +300 sick
  - Jealously by rival shop owner
- Hunan, China, Sept. 2003
  - 241 people poisoned by cakes served by school cafeteria
  - Motive and perpetrator unknown
- Tongchuan City, Shaanxi, China, April 2004
  - 74 people poisoned by scallion pancakes
  - Motive and perpetrator unknown
- 5 other incidents reported between 1991 and 2004

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-arthritis 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

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

Theft / manufacture of explosives: Fertilizer Bomb

- 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.

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”
  - Sept 2009 arrest of N. Zazi, NY and Denver
  - July 2005 London suicide bombs
  - 2001 Richard Reid “shoe bomber”
  - 1997 New York subway suicide bomb plot

Photo: US DOD

Wikipedia downloaded Oct 2009
http://en.wikipedia.org/wiki/Acetone_peroxide
**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 Na$_3$N as a preservative.
- Has been found in possession of terrorists

**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


**Diversion of industrial / laboratory chemicals: Quote from the “Terrorists Handbook”**

2.1 ACQUIRING CHEMICALS

The first section deals with getting chemicals legally. This section deals with "procuring" them. The best place to steal chemicals is a college. Many state schools have all of their chemicals out on the shelves in the labs, and more in their chemical stockrooms. Evening is the best time to enter lab buildings, as there are the least number of people in the buildings, and most of the labs will still be unlocked. One simply takes a bookbag, wears a dress shirt and jeans, and tries to resemble a college freshman. If anyone asks what such a person is doing, the thief can simply say that he is looking for the polymer chemistry lab, or some other chemistry-related department other than the one they are in.

9.0 CHECKLIST FOR RAIDS ON LABS


**Group Discussion**

- What chemicals are of most concern for diversion?
  - Common laboratory/industrial chemicals that would be targeted by someone for illegal reasons such as making explosives, illegal drugs, or chemical weapons.
International Chemical Controls

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
### CWC: Destroy existing stockpiles and facilities

- Twelve States parties have declared CW production facilities.
  - Bosnia and Herzegovina
  - China
  - France
  - India
  - Islamic Republic of Iran
  - Japan
  - Libyan Arab Jamahiriya
  - Russian Federation
  - Serbia
  - United Kingdom of Great Britain and Northern Ireland
  - United States of America
  - another State Party
- As of August 2007, 42 of 65 declared CW production facilities have been certified as destroyed, 19 converted to peaceful purposes.
- As of August 2007, 23,912 metric tonnes of CW agent has been destroyed out of 71,330 metric tonnes declared.
- On 11 July 2007, the OPCW confirmed the destruction of the entire chemical weapons stockpile in Albania.
  - Includes old and abandoned CW munitions

### 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 3,000 inspections have taken place at 200 chemical weapon-related and over 850 industrial sites on the territory of 79 States Parties since April 1997.
- Worldwide, over 5,000 industrial facilities are liable to inspection.

### CWC: Chemicals on schedules subject to verification measures

- **Schedule 1:**
  - Known CW agents
  - Highly toxic, closely related chemicals, or CWA precursors
  - Has little or no peaceful application
- **Schedule 2:**
  - Toxic enough to be used as a CWA
  - Precursor to or important for making a Schedule 1 chemical
  - Not made in large commercial quantities for peaceful purposes
- **Schedule 3:**
  - Has been used as a CWA
  - Precursor to, or important for making a Schedule 1 or 2 chemical
  - Is made in large commercial quantities for peaceful purposes
- **Unscheduled Discrete Organic Chemicals (UDOC)**
- Lists of scheduled chemicals follow: also in documents on CD

### CWC: Reporting requirements

- Use/transfer of these chemicals is allowed for research, medical, or pharmaceutical purposes.
- Reporting requirements depend on facility type, chemical types and amounts.
  - “Other Facility” type, as defined in CWC documents, most relevant here
  - Amounts of chemicals that would require that your National Authority approve the work and report your institution annually to the OPCW
    - Schedule 1: 100 g aggregate
    - Schedule 2: 1 kg for 2A, 100 kg for other 2A, 1 Tonne of 2B
    - Schedule 3: 30 Tonnes
    - UDOC: 30 or 200 Tonnes (lower number if contains P, S, or F)

**Caution:**
Your country might require reporting of lower amounts!
**Schedule 1 Chemicals**

A. Toxic chemicals

- (1) O-Alkyl (C<10, incl. cycloalkyl) alkyl (Me, Et, n-Pr or i-Pr) phosphonofluoridates, e.g.:
  - O-Alkyl: Bis(2-chlorovinyl) phosphonofluoridate
  - Sonon: O-Phenacyl ethylphosphonofluoridate

- (2) O-Alkyl (C<10, incl. cycloalkyl) N,N-dialkyl (Me, Et, n-Pr or i-Pr) phosphoramidocyanidates, e.g. 1-alkyl: O-2-Ethyl N,N-diethyl phosphoramidocyanidate

- (3) O-Alkyl (C<10, incl. cycloalkyl) S-2-dialkyl (Me, Et, n-Pr or i-Pr)-aminoethyl alkyl (Me, Et, n-Pr or i-Pr) phosphoramidocyanidates and corresponding alkylated or protonated salts, e.g. 2-V: O-2-Ethyl 5-dioctylaminoethyl methyl phosphonothiolate

- (4) Dialkyl (Me, Et, n-Pr or i-Pr) N,N-dialkyl phosphoramidocyanidates
  - 2-Chloroethylcholoromethylsulfide
  - Mustard gas: Bis(2-chloroethyl)sulfide
  - Bis(2-chloroethyl)glycine
  - Sexemustard: 1,2-Bis(2-chloroethyl)ethylene
  - Soman: O-Pinacolyl ethylphosphonothiolate
  - 1,4-Bis(2-chloroethyl)thio)ethane
  - 1,5-Bis(2-chloroethyl)thio)pentane
  - Bis(2-chloroethyl)thiobromide
  - O-Mustard: Bis(2-chloroethyl)thiobromide

- (5) Lewisites:
  - Lewisite 1: 2-Chlorovinyl dichloroarsine
  - Lewisite 2: Bis(2-chlorovinyl)chloroarsine
  - Lewisite 3: Tris(2-chlorovinyl)arsine

- (6) Nitrogen mustards:
  - Pr or i-Pr)-phosphonofluoridates, e.g.:
    - TPB: 1,1,2-Trifluoro-2-(dimethylamino)ethyl-2-chloride and corresponding protonated salts
    - HN1: Bis(2-chloroethyl)ethylamine
    - HN2: Bis(2-chloroethyl)methylamine
    - HN3: Tris(2-chloroethyl)amine

- (7) Saxitoxin

- (8) Ricin

- (9) Quinuclidin-3-ol

- (10) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) phosphoramidocyanidates and corresponding alkylated or protonated salts

Exemptions: N,N-Diethylaminoethanol and corresponding protonated salts

**Schedule 2 Chemicals**

A. Toxic chemicals

- (1) Ammon: O,O-Diethyl S-[2-(diethylamino)ethyl] phosphorothiolate and corresponding alkylated or protonated salts
- (2) FPIB: 1,1,3,3,3-Pentafluoro-2-(dimethylamino)ethyl-1-propene
- (3) EZ: 3-Quinuclidinyl benzilate

B. Precursors

- (4) Chemicals, except for those listed in Schedule 1, containing a phosphorus atom to which is bonded one methyl, ethyl or propyl (normal or iso) group but not further carbon atoms, e.g.:
  - Phosphorus oxychloride
  - Phosphorus trichloride
  - Phosphorus pentachloride
  - Trimethyl phosphate
  - Triethyl phosphate

- (5) Lewisites:
  - Lewisite 1: 2-Chlorovinyl dichloroarsine
  - Lewisite 2: Bis(2-chlorovinyl)chloroarsine
  - Lewisite 3: Tris(2-chlorovinyl)arsine

- (6) Nitrogen mustards:
  - Pr or i-Pr)-phosphonofluoridates, e.g.:
    - TPB: 1,1,2-Trifluoro-2-(dimethylamino)ethyl-2-chloride and corresponding protonated salts
    - HN1: Bis(2-chloroethyl)ethylamine
    - HN2: Bis(2-chloroethyl)methylamine
    - HN3: Tris(2-chloroethyl)amine

- (7) Saxitoxin

- (8) Ricin

- (9) Quinuclidin-3-ol

- (10) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) phosphoramidocyanidates and corresponding alkylated or protonated salts

- (11) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) amineethane-2-ols and corresponding protonated salts

- “Discrete Organic Chemical” means any chemical belonging to the class of chemical compounds consisting of all compounds of carbon except for its oxides, sulfides and metal carbonates, identifiable by chemical name, by structural formula, if known, and by Chemical Abstracts Service registry number, if assigned.

**Schedule 3 Chemicals**

A. Toxic chemicals

- (1) Phosgene: Carbonyl dichloride
- (2) Cyanogen chloride
- (3) Hydrogen cyanide
- (4) Chloropicrin: Trichloronitromethane

B. Precursors

- (5) Phosphorus oxychloride
- (6) Phosphorus trichloride
- (7) Phosphorus pentachloride
- (8) Trimethyl phosphate
- (9) Triethyl phosphate
- (10) Dimethyl phosphate
- (11) Diethyl phosphate
- (12) Sulfur monochloride
- (13) Sulfur dichloride
- (14) Thiophosgene: O-Phenacyl ethylphosphonothiolate
- (15) Ethyldithanolamine
- (16) Methylthiobutane
- (17) Triethanolamine

**Unscheduled discrete organic chemicals (UDOC)**

- Also subject to CWC reporting, but only for large amounts.

- “Discrete Organic Chemical” means any chemical belonging to the class of chemical compounds consisting of all compounds of carbon except for its oxides, sulfides and metal carbonates, identifiable by chemical name, by structural formula, if known, and by Chemical Abstracts Service registry number, if assigned.
OPCW: Promotes international cooperation in peaceful uses of chemistry

- Associates program
- Analytical skills development course
- Conference support program
- Research projects program
- Internship Support Program
- Laboratory Assistance Program
- Equipment Exchange Program

OPCW: Protecting each other

- Each member state can request assistance from other member states in the event of a threat or attack, including chemical terrorism
- This can take the form of expertise, training, materials, and/or equipment

Australia Group

- An informal arrangement to minimize the risk of assisting chemical and biological weapon (CBW) proliferation.
  - Harmonising 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

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
UN Security Council Resolution 1540

- Unanimously passed on 28 April 2004
- 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 on such efforts is encouraged, in accord with and 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

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

Facility Characterization

Facility characterization provides important data that:
- Identifies locations and assets to be protected
- Establish what existing Protection System components are already present at the facility
- Documents facility layout for use in analysis

Threat Definition

Threat classes:
- Outsiders—no authorized access
- Insiders—authorized access
- Collusion—between Outsiders and Insiders
What Might Motivate Adversaries?

- **Terrorists**
  - Ideology
- **Criminals**
  - Financial
- **Activists**
  - Ideology
- **Insiders**
  - Ego
  - Ideology
  - Revenge
  - Financial
  - Coercion

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 was 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.

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.

Relationships between Chemical Security and Chemical Safety

- **Chemical safety:** Protect against accidents
- **Chemical security:** Protect 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 can recognize hazardous chemicals.
  - Let community and especially emergency responders know what chemical dangers are there.
  - 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.

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

CSS Responsibilities
Principal Investigator, 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

CSSO Training, Experience, Skills

• Chemistry
  - Nomenclature
  - Physical properties
  - Reactivities
  - Chemical compatibilities
• Health and Safety (industrial hygiene)
• Security
  - Facility
  - Chemicals
  - Equipment
  - Personnel
• Psychology
  - Dealing with people
• Physics
  - Ventilation
  - Radiation (ionizing/non-ionizing)
  - Electrical
• Biology
  - Biosafety
  - Recombinant DNA
  - Blood borne pathogens
• Administration
• Writing
• Speaking/presentations/training

CSSO Responsibilities

• Report directly to higher management
• Provide leadership in safety and security
• Draft a budget
• Ensure Plans and Manuals are written and updated
• Advise administration, staff, employees, students
• Conduct inspections and audits
• Investigate accidents and incidents
• Respond to problems and concerns
• Participate in Chemical Safety and Security Committee(s)
• Ensure documentation, records and metrics are maintained
• Develop CSS Training plans
• Know legal regulations and ensure compliance
The Function of the CSSO is to Act as a Co-Worker, *NOT* as a Policeman.

The Chemical Safety and Security Committee (CSSC) 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

**Commitment:**
- Establish a formal CSS Program
- Announce formation of a CSS Program
- Create a written policy statement
- Designate a Chemical Safety and Security Officer
- Endorse a written CSS Plan (Manual)
- Participate and intervene as needed

**Support:**
- Financial support (budget)
- Staffing
- Response/resolution of problems by
  - Establishing a CSS Committee
- Stipulates CSS is part of everyone’s job
  - CSS applies to everyone
  - Specifies CSS orientation for new employees
- Supports CSS staff

**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 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

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

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

Chemical Safety and Security Officer
Duties
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
• Trains, documents and ensures training is performed
• Performs risk assessment and monitoring
• Conducts audits and inspections
• Investigates and reports on accidents, incidents
• Interacts with staff to correct deficiencies
• Follows 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 (e.g., 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 create hazard?
- Develop recommendations on precautions to eliminate/minimize hazard.

**Periodic Lab Inspections**

- Done by CSSO
- Coordinate with lab supervisor/Chief/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

**Sample Laboratory Survey/Inspection Checklist**

- Date of Inspection:_______
- Conducted by:__________
- Location (room and building):_______
- Principal Investigator/supervisor:_______

**Laboratory Work Practices**

- Smoking observed?
- Food observed/stored. In refrigerators?
- Mechanical pipetting devices present/used?
- Hazardous chemicals present/used in designated areas?
- Lab surfaces cleaned/decontaminated after use?
- PPE available/properly used, stored, maintained?
Survey/Inspection Checklist, cont’d.

• Hazard Communication
  – Warning signs, required PPE *posted*.
  – (M)SDS available.
  – Signs for storage areas, refrigerators, waste, designated work areas’ specific hazards.
  – Label all containers.
  – Access controlled.

• Personal Protective Equipment
  – Available for each specific hazard.
  – Eye protection available, when & where required & *posted*.
  – Other PPE available as necessary.
  – Visitor PPE available.
  – Visitor requirements for PPE *posted*.

Survey/Inspection Checklist, cont’d.

• Chemical Storage
  – Area secured
  – Chemicals with special security needs present?
  – Chemicals inventoried
  – Incompatible chemicals segregated.
  – Volatile, flammable material keep away from heat.
  – Corrosives, flammables keep below eye level.
  – Limited quantities of flammable, or other hazardous chemicals, stored in lab.
  – Unnecessary, outdated chemicals discarded.
  – Safety carriers available for bottle transport.

Survey/Inspection Checklist, cont’d.

• Compressed Gas Cylinders
  – Properly chained or secured
  – Caps in place, if available
  – Stored away from heat
  – Cylinders properly marked with contents
  – Empty and full separated
  – Flammables separated from non-flammables
  – Lines labeled and in good condition
  – Proper valves used
  – Toxic gases stored securely

Survey/Inspection Checklist, cont’d.

• Safety Equipment
  – Eyewashes & safety showers present, unobstructed, in good working order, routinely tested and maintained.
  – Fire alarms & telephones appropriately placed and labeled.
  – Adequate number and type of unobstructed, routinely inspected fire extinguishers.
  – Spill kits available, maintained, labeled.
  – Adequate number of fire alarm/ detection devices.
  – Flammable storage cabinets available.

• General Facility
  – Benches are water/chemical heat resistant.
  – Sturdy furniture.
  – Sinks for hand washing.
  – Exits marked
  – Access controls
Survey/Inspection Checklist, cont’d.

• Ventilation
  – Hoods available and in good working order.
  – All hoods marked with proper operating height and restrictions for use.
  – Hoods not cluttered with chemical and equipment storage.

• Housekeeping
  – Lab areas uncluttered.
  – Aisles & exits unobstructed.
  – Work surfaces free from contamination.
  – Spills cleaned up.
  – Electrical cords in good condition, equipment grounded.
  – Heavy objects on lower shelves.
  – Glassware free from defects.

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 Program

- Baseline screening
  - Medical history
  - Past illnesses, exposures and diseases
  - Comprehensive physical exam
  - Assessment of limitations
    - Respirator use and other PPE
- Treatment
  - Emergency
  - Non-emergency (e.g., first aid)
- Periodic Medical exam
- Termination exam
- Confidential record keeping
  - Physician, employee

Biological Monitoring Program

- Identify employees with potential exposure to specific hazardous chemicals, biological agents, working conditions.
  - Specific signs and symptoms of chemical exposure.
  - Use of respirators.
    - Cardiovascular, hearing (perforated tympanic membrane), neurological (e.g., epilepsy), psychological disorders
    - Working in noisy areas.
  - Working in Biosafety risk areas.
    - Bloodborne pathogens
      - e.g., Human blood and body fluids, hepatitis B (HBV), HIV, AIDS
    - Infectious agents
      - e.g., Zoonosis, animal care, recombinant DNA
- Determine extent of personal and environmental exposure.
- Take actions to eliminate/minimize exposure.
- Confidential record keeping.

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
### Incident Investigation Form: Sample

- Date of accident/incident: 
- Time reported: 
- Location: 
- Type of incident: fire, explosion, spill, employee exposure, theft, intruder, near-miss: 
- Date of investigation: 
- Investigation team members: 

**Nature of Incident**

- Incident description, include people, task, chemicals, etc. involved
- Nature of injuries, exposures, illnesses, damages, losses
- Determination of potential causes
- PPE worn at the time
- Hazard control or access control measures in use

### Incident Investigation Form, cont’d.

- Organizational policies, procedures, etc. that apply
- Was training proper and up-to-date?
- How could incident been prevented?
- Has similar incident occurred in past, when, where, circumstances?

Team recommendations to prevent reoccurrence of such incidents:

- [ ]
- [ ]
- [ ]

### 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
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

Assessment Questionnaire, cont’d.

- List individuals (managers, PIs, professionals, technicians) with Safety & Security responsibilities; indicate SO, CSSO, BSO, RSO, etc.
- 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

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.

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
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

Standard Operating Procedures (SOP)

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

Standard Operating Procedures (SOP), 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

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
Plan and SOP 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

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).

Principles and Concepts of Laboratory Design
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

Chemical Protection Depends on, cont’d:

3. Construction
   How well the facility is built

Key Stakeholders

- Architects
- Engineers
- Administrators
- Builders
- EHS Professionals
- Laboratory Users
Laboratory Design is an Iterative Process

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)

Major US Standards & Guidelines
- ANSI Z9.5 American National Standards Institute, Z 9.5 Laboratory Ventilation Standard
- NFPA National Fire Protection Association
- BOCA Building Officials Code Association
- ASHRAE 110 American Society of Heating, Refrigeration and Air Conditioning Engineers, Standard 110 for Testing and Evaluating Laboratory Hoods
- Others
  - National Electrical Code
  - American Chemical Society, Green Chemistry Institute
  - www.acs.org/greenchemistry

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
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**

Factors in Laboratory Design

- **Architectural**
- **HVAC**
- **Safety and Security**
  - Fire
  - Emergencies
  - Exposures
  - Access/exit control (facility, chemicals, equipment)

(* heating, ventilation, and air conditioning)

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

Safety/Security Information Needed Before Design can Begin

- Type of Work/Research
- Type of Hazards
  - Chemical
  - Biological
  - Radiation
  - High Voltage
- Type of Wastes
Safety/Security Information Needed for Lab Design, cont’d.

Types of Chemicals (based on physical state and properties)
- Flammable
- Corrosive (acid or base)
- Reactive
- Acutely Toxic (poisons)
- Chronically Toxic (e.g., carcinogens, repro-toxins)
- Regulated
- Acutely Toxic (poisons)
- Chronically Toxic (e.g., carcinogens, repro-toxins)
- Regulations
- Emergency preparedness
- Waste management

Specific Chemical Laboratory Safety/Security Concerns

Include:
- Fire detection, alarms, and suppression systems
- Safety equipment (i.e. emergency showers, eyewash and contaminant control)
- Ventilation (i.e. laboratory hoods, glove boxes, ventilated enclosures)
- Management of chemicals and waste
- Access controls for facility and laboratories

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

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

Building Layout: Compressed Gases

- Install tanks outside building and pipe into lab
  - Long-term, frequent use of same gas
  - Highly hazardous gases
  - Restrict access
  - Out-building or outdoors, depending on conditions
Building Layout: Compressed Gases

- Tanks inside labs
  - Wide variety of gases
  - Low use rates
  - Strap to wall or bench
  - Transport safely

Building Layout: Chemical Waste

- 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

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

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
Current Trends in Laboratory Design of Safety/Security Concern

- Open Laboratories
- Energy Conservation
- Ventilation Concerns
- Hood Designs
- Hood Manifold systems
- Effluent Modeling from Exhaust Stacks
- Lab Decommissioning

Open vs. Closed Laboratories

Open Laboratory
- 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

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

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

Consider using both or having connected access:
Energy Conservation Issues

- Vented Enclosures
- Ductless Hoods
- Diversity
- Manifolded Systems
- Recirculation of Room Exhaust Air
- Variable Air Volume Systems
- Automatic Sash Closers
- Air Change per Hour
- Low Flow Hoods

Ventilation Considerations Include

- Heating and cooling needs
- Maintaining directional airflow
- Type of hoods
- Single vs. manifolded hoods

General Laboratory Hood Considerations

- Determine minimum exhaust requirements.
- Communicate hood limitations to users.
- Label restrictions e.g., no perchloric acid.
- Alarm systems
- Consider future needs.

Laboratory hood design and ventilation are discussed in detail in later presentations.
Hood Manifold Considerations

**Single Hood - Single Fan**

0.5 m³/s 0.5 m³/s 0.5 m³/s

H H H

Hood Manifold Considerations

**Manifold: 3 Hoods, 1 Fan**

1.5 m³/s

H1 H2 H3

Hood Manifold Considerations

**Hood Diversity = 33%**

0.5 m³/s

H1 H2 H3

Ventilation Design

Hood exhaust should not be blocked or deflected downward, but should exhaust straight up
Avoid re-entrainment
Disperse emissions straight upward and downwind!

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

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 m² absolute minimum
  - 6.5 m² allowing space for utilities, storage, cleanup, etc.
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

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

Conclusion

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

References