Chemical
SAFETY AND SECURITY TRAINING

Chemical Industry Safety and Security

Penang and Johor Bahru, Malaysia
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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Sandia National Laboratories

Fundamentals of Laboratory Chemical Safety

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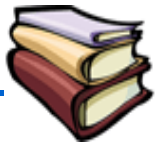
Environmental & Chemical Safety Educational Institute

Chemical SAFETY AND SECURITY TRAINING

Fundamentals of

Chemical Laboratory Safety

References



"Safety in Academic Laboratories, Vol.1 & 2," American Chemical Society, Washington DC, 2003, handouts and available online:
http://membership.acs.org/c/ccs/publications.htm

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Why worry about chemical safety and 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

Chemical Laboratory Safety

Hazard---the potential to harm

We want to avoid this.

Risk---the probability that harm will result

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

Based on Industrial Hygiene Principles

- Anticipation
- Recognition
- Evaluation
- Control

chemical hazards
physical hazards
ergonomic hazards
biological hazards

Anticipation

- **Plan Experiment in Advance**
  - Outline proposed experiment
    - What chemicals? How much?
    - What equipment?
  - Acquire safety information
    - MSDS (Material Safety Data Sheet)
    - REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)
    - ICSCs (International Chemical Safety Cards)
    - Reference textbooks
  - Consult with Safety Office?

Recognition & Evaluation

- **What are the anticipated risks?**
  - Are the equipment & facilities adequate?
    - Is special equipment needed?
  - Are staff properly and sufficiently trained?
    - Who will do the experiment?
    - What kind of training do they need?
  - Can the experiment go wrong?
    - What would go wrong?
    - Is there a plan for this?

Control

- How are the risks controlled?

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

Recognition

- Types of lab hazards

Chemical toxicity
Fire / explosion
Physical hazards
Biohazards
Radiation
Special substances

Chemical Toxicity

Acute (short term, poisons, asthmagens)

cyanide
Strychnine

Chronic (long term, carcinogens, reproductive)

vinyl chloride (liver cancer)
asbestos (mesotheloma, lung cancer)
thalidomide (developmental birth defects)

Chemical Toxicity

- Toxicity depends on
  - concentration (dose)
  - frequency
  - duration
  - route of exposure

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

300 mg aspirin = safe

3000 mg aspirin = toxic

Routes of Exposure

Breathing Zone

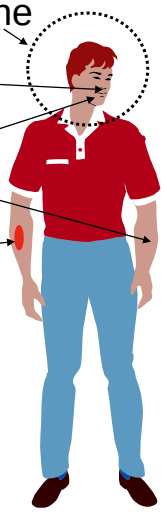
Inhalation*

Absorption

Ingestion

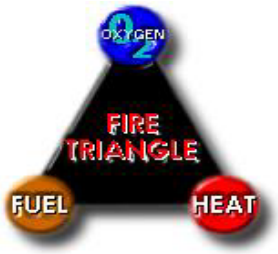
Injection

Eyes



*Most important route of entry

Fire and Explosion Hazards



- **Flammable solvents**
- **Pyrophorics**
- **Spontaneous combustion**

Physical and Ergonomic Hazards

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

BioHazards

- ❑ **Blood borne pathogens**
  AIDS, HIV, Hepatitis, clinical chemistry labs
- ❑ **Recombinant DNA**
  Genetic engineering, cloning
- ❑ **Work with animals**
  Zoonosis, diseases from animals

Radiation Hazards

- **Ionizing Radiation**
  - alpha α, beta β, gamma γ, X-rays, neutrons
- **Radioactive isotopes**
  - tritium (H-3), carbon (C-14), sulfur (S-35), phosphorus (P-32/33), iodine (I-135)

Radiation Hazards

- ***Non-Ionizing Radiation***

Ultraviolet (UV spectrometers)

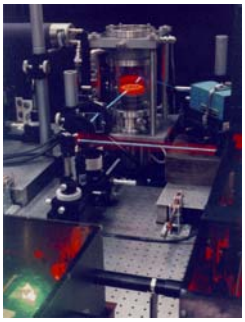
Magnetic (NMR, MRI)

Microwave

(Heart pacemaker hazard)

Lasers

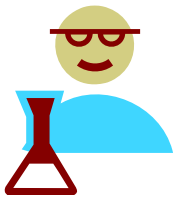
(eye protection required)



Special Chemical Substances

- ❑ **Controlled Substances**
  - regulated drugs, psychotropic (hallucinogenic) substances, heroin
- ❑ **Chemical Surety (Warfare) Agents**
  - nerve gas, phosgene, riot control agents

Evaluation & Control



- ❑ **Administrative practices**
  - organizational policies
- ❑ **Operational practices**
  - work practices
- ❑ **Engineering controls**
  - Hardware (ventilation, barriers)

Administrative Practices: Lab Safety Policies

- ❖ Have organizational safety practices
  - Apply to everybody
  - Don't work alone after hours
  - Specify when eye protection & PPE is required
  - Specify operations that require hood use
  - Specify required training
  - No mouth pipetting
  - No loose long hair or dangling attire
- ❖ Have a Safety Manual

Administrative Practices: Lab Safety Policies

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

Administrative Practices: Lab Safety Policies

- Schedule routine, periodic maintenance and inspection of fume hoods
- Schedule routine, periodic maintenance of safety showers and eye wash stations
- Schedule routine, periodic maintenance of fire suppression/fighting equipment
- Post restricted areas with proper signs
  - radiation, biosafety, carcinogen, high voltage, lasers, authorized personnel only, etc.

Operational Practices: Safe Chemical Handling Procedures

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

Operational Practices: Safe Laboratory Procedures

- Schedule routine maintenance, calibration and inspection of all hoods, fire and safety equipment
- Schedule and participate in routine fire drills
- Train personnel in emergency response
- Wear PPE properly, don't just have it

Operational Practices: Safe Laboratory Procedures

- Use hoods properly
  - 6" in from sash
  - in center of hood
  - work with hood sash at 12-18"
  - close sash when not in use
  - don't use for storage

Operational Practices: Safe Laboratory Procedures

❖ **Safely transport chemicals**

- use container in a container concept
- label all containers
- inform driver of hazards
- provide contact names, phone numbers
- provide MSDS

Operational Practices: Transfer Chemicals Properly

- **Some flammable liquids accumulate a static electric charge**
  - **This can release a spark that ignites the liquid**
- **Bond metal dispensing and receiving containers together before pouring such liquids**

benzene

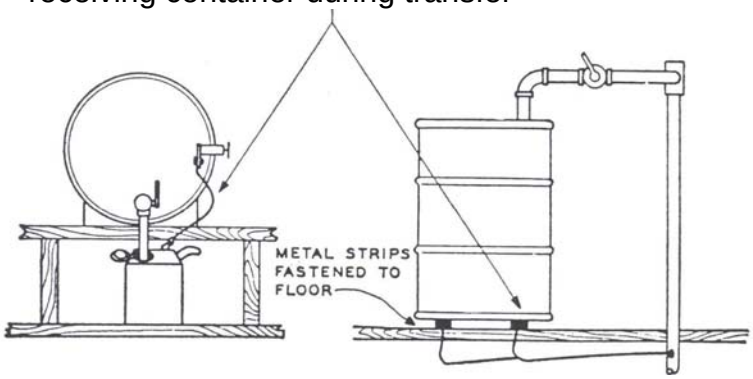
toluene

gasoline

xylene

Operational Practices: Control of Static

Wire needed unless containers are already bonded together, or fill stem is always in metallic contact with receiving container during transfer



Operational Practices: Safe Laboratory Procedures

- **Housekeeping**
  - **label all containers**
  - **clean-up spills**
  - **eliminate trips hazards**
  - **proper storage**

Engineering Controls: Laboratory Containment Principles

Concept

Source → **Path** → **Receiver**

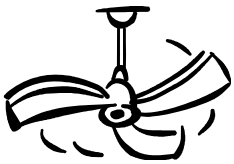
Control Used

Engineering Control → **Operational Practices** → **PPE**

Engineering Controls

1. **Change the process**
   - eliminate the hazard
2. **Substitution**
   - Use non-hazardous substance instead of hazardous, such as toluene for benzene
3. **Isolate or enclose the process or worker**
   - use a barrier
4. **Ventilation**
   - dilution (general ventilation) - not good
   - local exhaust ventilation (LEV) - Preferred

Engineering Controls



Dilution / general ventilation

not good

Local exhaust ventilation

Preferred

Engineering Controls

Laboratory hoods and ventilation are the basis of engineering controls.
But they must be properly: functioning, maintained and used!

Engineering Controls: Local exhaust

Local exhaust ventilation options include:

Snorkels

Vented enclosures

Engineering Controls: Local exhaust

Local exhaust ventilation options include:

Glove boxes

Isolation chambers

Engineering Controls: Local exhaust

- **Special barrier facilities:**
  clean rooms, carcinogen rooms, weighing rooms
- **Safety shields:**
  radiation shields, hood sashes, splash guards

Engineering Controls: Exhaust vents

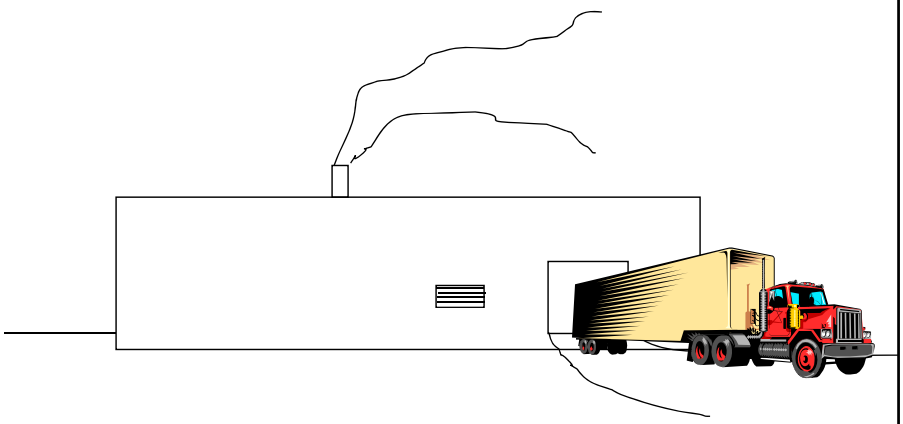
Hood exhaust should not be blocked or deflected downward, but should exhaust straight up

Engineering Controls: Exhaust vents

Avoid exhaust re-entrainment

Disperse emissions straight upward and downwind!

Engineering Controls: Avoid Exhaust Recirculation

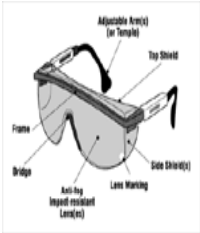


Engineering Controls:
Personal Protective Equipment (PPE)

PPE includes:
eye protection,
gloves,
laboratory coats. etc.,
respirators,
appropriate foot protection

Engineering Controls:
Personal Protective Equipment

Eye protection
specific to the hazard



Engineering Controls: Personal Protective Equipment

Gloves

must be chemical specific

Engineering Controls: Personal Protective Equipment

- Laboratory coats
- aprons
- other protective clothing

Engineering Controls: Respiratory Protection

requires:

training

fit-testing

can provide a false sense of security

Emergency Planning and Response

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Emergency planning and response is based on safety principles of

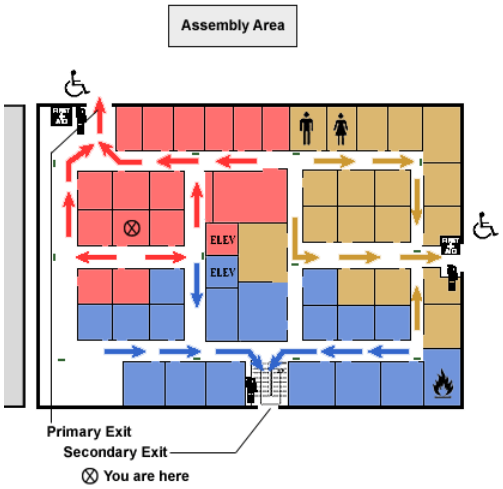
- Anticipation
- Recognition
- Evaluation
- Control

Emergency Planning & Response

Have an evacuation plan

and

POST IT



Emergency Planning & Response

Don't use hallways for storage

Dangerous!!

Blocks passage and emergency exit path

Emergency Planning & Response

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

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

Emergency Planning & Response

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

Emergency Planning & Response

Centrally locate and maintain fire extinguishers and alarms

Emergency Planning & Response

If people are expected to use extinguishers

they must be trained

Emergency Planning & Response

Post each room with:

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

Location	
Hazards Within:	
Primary Contact:	
Second Contact:	
Building Monitor/Safety:	
Department Head:	
Fire/Police/Ambulance:	**911**
Envir. Health & Safety (or RSO, if needed):	646-3327

Emergency Planning & Response

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

Chemical Exposures to Eyes or Skin

Centrally locate safety showers and eyewashes

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

Chemical Spills

Centrally locate spill clean-up kits

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

- alert colleagues and secure area
- assess ability to clean-up spill
- find spill kit
- use appropriate PPE and sorbent material
- protect sinks and floor drains
- clean-up spill, collect/label waste for disposal
- report all spills

Chemical Management Best Practices

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Chemical and Waste Management

Best Practices

References

"Less is Better," American Chemical Society, Washington DC, 2003, available online: http://membership.acs.org/c/ccs/publications.htm

"School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107, Cincinnati, OH, 2006, available on-line: http://www.cpsc.gov/CPSCPUB/PUBS/NIOSH2007107.pdf

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

Chemical Management

Institute a Safety Program

- Have a Safety Manual
- Appoint a chemical safety officer for each major area/section/group/building
- Form a Safety Committee
- Have periodic safety training (films, etc)
- Have safety inspections
- Investigate serious accidents/incidents
- Follow-up!

Cradle - to - grave care of chemicals

Receipt → **Storage** →

Use → **Disposal**

Plan experiments in advance!

What chemicals are needed?

How much is needed?

How will the chemicals be handled?

What are the reaction products?

How will the chemical be stored?

How will disposal take place?

Inventory management

Less is Better !

- Order only what you need
- Reduce size of experiment
  - It cost less to store
  - It cost less to dispose

"Less is Better: Guide to minimizing waste in laboratories", Task Force on Laboratory Environment, Health and Safety, American Chemical Society, 2002. http://membership.acs.org/C/CCS/pub_9.htm

Inventory management

Less is Better !

It's Safer!

It may be cheaper to order diethyl ether in large containers

But, if it's opened for a long time—peroxides can form!

Inventory management

-R-O-O-R-

Peroxide Forming Chemicals

Even with inhibitors they can become dangerous over time

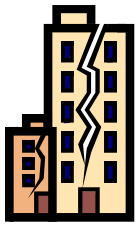
Examples: ethers, dioxane, tetrahydrofuran

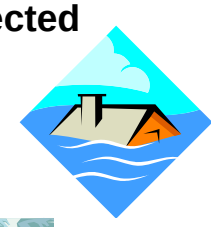
- **discard or test if unsure**
- **label & date when received, when opened, and provide expiration date**

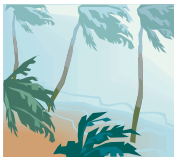
References: See for example, http://www.med.cornell.edu/ehs/updates/peroxide_formers.htm

Chemical storage

- Protect chemicals during normal operations
- Protect chemicals during unexpected events
  - Floods
  - Tidal waves
  - Earthquakes
  - Typhoons
  - Hurricanes







Chemical storage: Basic concepts

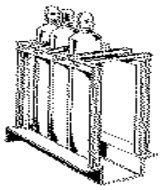
- Separate incompatible chemicals
- Separate flammables/explosives from ignition sources
- Use flammable storage cabinets for large quantities of flammable solvents
- Separate alkali metals from water
- Separate acids and bases

Use flammables storage cabinets

Chemical storage: Basic concepts

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

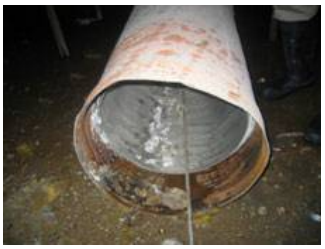
Chemical storage: Gas cylinders



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

Improper gas cylinder storage/handling

Gas Cylinders



Exploded nitrogen cylinder

Chemical storage: Cryogenics

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

Chemical storage: Good practices

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

- Separate incompatible chemicals
  - Organize chemicals by compatible groups
  - Alphabetize chemicals only within compatible groups

Chemical storage: Bad practices

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

Chemical storage: Containers

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

Improper chemical storage

Never use hallways for storage

Safety Hazard!!

Blocks exit path in emergencies!!!

Suggested shelf storage groups: Organics

- Acids, anhydrides
- Alcohols, amides, amines
- Aldehydes, esters, hydrocarbons
- Ethers, ketones, halogenated hydrocarbons
- Epoxies, isocyanates
- Azides, peroxides
- Nitriles, sulfides, sulfoxides
- Cresols, phenols

Suggested shelf storage groups: Inorganics

- Metals, hydrides
- Halides, halogens, phosphates, sulfates, sulfides
- Amides, azides, nitrates, nitrites
- Carbonates, hydroxides, oxides, silicates
- Chlorates, chlorites, perchlorates, peroxides
- Arsenates, cyanides, cyanates
- Borates, chromates, manganates
- Acids
- Arsenics, phosphorus, sulfur

Waste management: General guidelines

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

Waste management: General guidelines

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

Dangerous waste management

Waste management

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

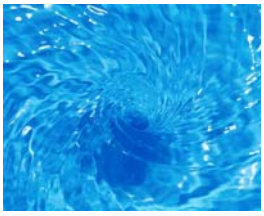
Waste management: Waste disposal service

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

Waste management: Down the drain?

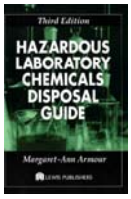
If legally allowed:

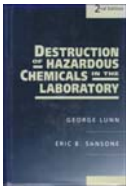
- Deactivate & neutralize some liquid wastes yourself
  - e.g., acids & bases
  - Don't corrode drain pipes
- Dilute with lots of water while pouring down the drain
- Be sure that you do not form more hazardous substances



Waste management: Treatment in Lab?

- **Destruction / neutralization of hazardous chemicals**
  - **May or may not be allowed by regulations**
  - **Must be done by trained chemist**
  - **Specific to each chemical**
- References:
  - "Procedures for the Laboratory-Scale Treatment of Surplus and Waste Chemicals, Section 7.D in Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995, available online: http://www.nap.edu/catalog.php?record_id=4911
  - "Destruction of Hazardous Chemicals in the Laboratory, 2nd Edition", George Lunn and Eric. B. Sansone, Wiley Interscience, 1994, ISBN 978-0471573999
  - "Hazardous Laboratory Chemicals Disposal Guide, Third Edition", Margaret-Ann Armour, CRC Press, ISBN 978-1566705677
  - "Handbook of laboratory Waste Disposal", Martin J. Pitt and Eva Pitt, Ellis Horwood, 1985, ISBN 0-85312-634-8 (out of print)





Chemical management

- **Proper chemical management is an important part of laboratory safety and security**
- **Helps protect people, laboratories and the environment**
- **Can save money by avoiding duplicate chemical purchases**

Lab Safety Activity:

What's Wrong With These Pictures?

What's Wrong With This Picture?

What's Wrong With This Picture?

What's Wrong With This Picture?

What's Wrong With This Picture?

What's Wrong With This Picture?

What's Wrong With This Picture?

Break