Chemical Safety and Security Officer Training

Egypt
26-27 October, 2011

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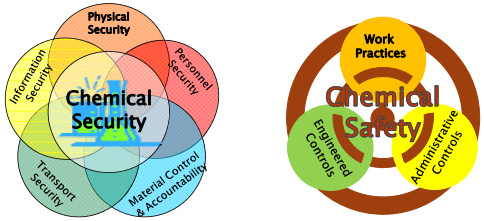
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Risk Assessments



Consequences, Mitigations, Prioritization

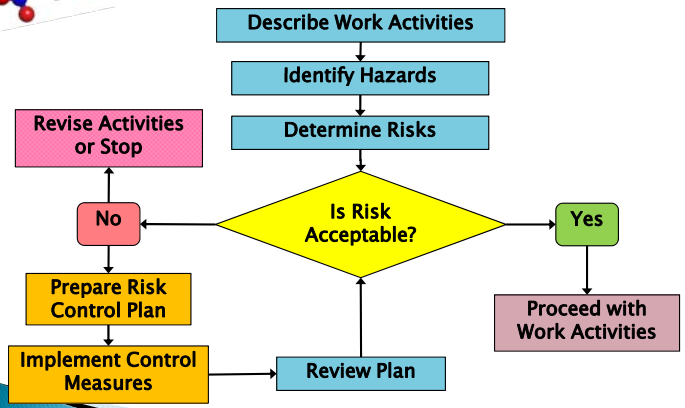
Why Risk Assessment?

- Laboratory Chemical Safety
  - preventive measures designed to reduce the risk of accidental exposure to or release of a chemical hazard
- Laboratory Chemical Security
  - preventive measures designed to reduce the risk of intentional removal (theft) and misuse of a chemical hazard – intent to cause harm
- Identification of preventive measures is determined by the RISK ASSESSMENT

CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

Chemical SAFETY AND SECURITY TRAINING

Risk Governance Strategy

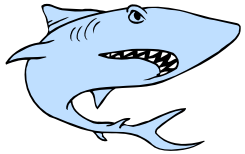


CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

Chemical SAFETY AND SECURITY TRAINING

What is a Hazard?

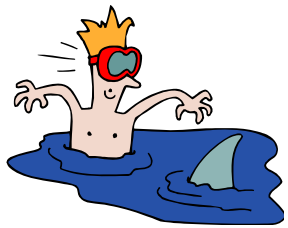
- Hazard is a source or object that can cause harm



- Hazard is *not* a risk without a specific environment or situation

How do you Determine Risk?

- Risk is the likelihood of an event that has consequences



Work activity: Snorkeling

Describe Work Activities:
Snorkeling

↓

Identify Hazards:
Shark

↓

Determine Risks:
Shark bite, drowning

↓

Work activity: Reactive Chemicals

Describe Work Activities:
mixing reactive chemicals

↓

Identify Hazards:
reactive/incompatible chemicals

↓

Determine Risks:
explosion, fire

↓

Is The Risk Acceptable?

Is The Risk Acceptable?

Risk = *f* (Likelihood, Consequence)

- Likelihood
  - the probability of harm from a given hazard and the likelihood of exposure *based on the procedures and work practices*
- Consequences
  - degree of harm from accidents
- Risks
  - exposure to hazard

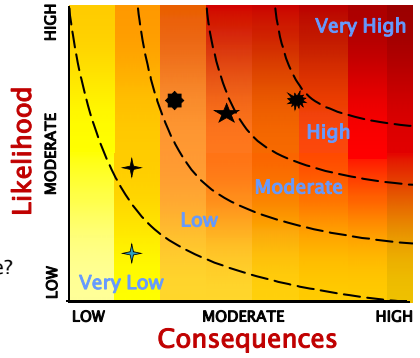
Is The Risk Acceptable?

Risk = *f* (Likelihood, Consequence)

- Likelihood
  - The likelihood of harm by the agent and the likelihood of exposure through an infectious route based on the procedures and work practices
- Consequences
  - of disease/harm from accidental exposure
  - of explosion from reaction
  - of fire from heat/spark
- Risks
  - accidental exposure to laboratory workers
  - accidental exposure to community
  - accidental exposure to environment

Risk Evaluation

- Value-based judgement:
  - what is acceptable,
  - what is tolerable,
  - what is intolerable?
- Based on:
  - consequence:
    - severity of harm/damage?
  - likelihood:
    - frequency of exposure?

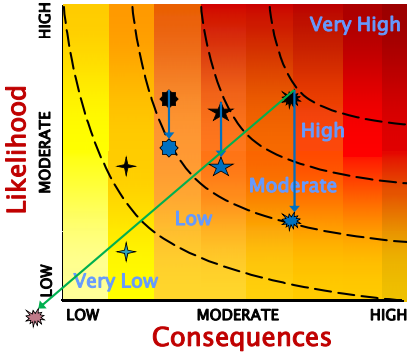


Risk Evaluation

- Identify factors that influence likelihood:
  - for each risk
  - what are routes of exposure?
  - what engineered controls are in place?
  - what work practices are expected?
- Identify factors that influence consequences:
  - for each risk
  - what harm/damage may occur?
  - how severe of a consequence?
  - harm and damage to whom?
- Is the risk high, moderate, or low?
  - why?
  - can it be reduced?

Risk Evaluation for Risk Reduction

- Reducing risk:
  - can we eliminate hazard?
  - can we reduce likelihood?
- Risk-hazard reduction:
  - **eliminating** hazard *WILL* eliminate risk
    - best strategy
    - may not be possible
  - **reducing** hazard *MAY* reduce risk
    - good strategy
    - may be best option



Risk Evaluation

What would be **different** if the activity was a laboratory's work or chemicals being stolen?

by an outsider?

by an outsider with insider help?

Does the hazard change?
Does the risk change?
To whom?

Hazard, Threat and Risk

- A **hazard** is a source or object that can cause harm
- *A **threat** is a person who has intent to cause harm to other people, the community, the environment, or the institution*
- A **risk** can be based on either a hazard, or a hazard and a threat

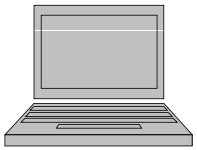
Is The Risk or Threat Acceptable?

Chemical Security Assessment

1. Characterize chemicals and threats
   a. evaluate chemical compounds at a facility (Asset Assessment)
   b. evaluate adversaries who might attempt to steal those chemicals or equipment (Threat Assessment)
2. Characterize the facility
   a. evaluate the likelihood the facility will be targeted
   b. evaluate the likelihood of a successful theft (Vulnerability Assessment)
3. Characterize the risk
   a. evaluate the overall likelihood and consequences of each scenario
   b. determine acceptable and unacceptable risks; develop risk statement

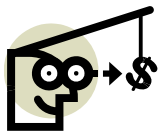
Characterize Chemicals (Assets)

- Chemical Properties:
  - flammability
  - vapor pressure
  - toxicity
  - routes of exposure
  - environmental hazard
- Equipment:
  - special uses (unique)
  - expensive/hard to purchase
- Availability:
  - sources
  - waste disposal/treatment
  - transportability
  - identifiable



Characterize Threats

- Possible adversaries:
  - criminals
    - use for drugs
    - sell to others
  - terrorists
  - extremists
  - angry worker/employee
- Motivations:
  - profit / money
  - social and economic disruption
  - malicious damage/revenge
  - ideology

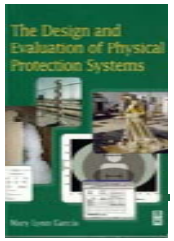


Characterize Facilities

- Characterize the facility considering:
  - mission
  - operations
  - budget
  - safety
  - legal issues
  - regulatory issues

Characterize Facilities

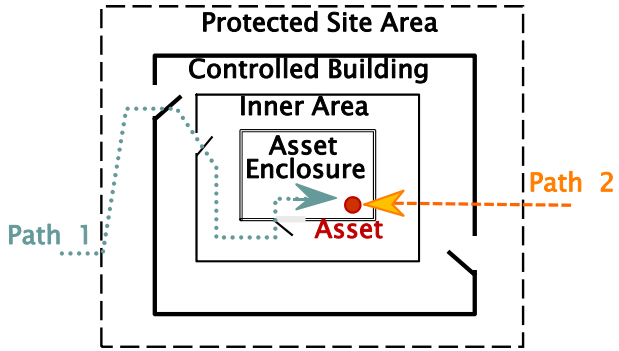
- **Characterize the facility in terms of:**
  - site boundary
  - buildings (construction and HVAC systems)
  - room locations
  - access points
  - processes within the facility
  - existing protection systems
  - operating conditions (working hours, off-hours, potential emergencies)
  - safety considerations
  - types and numbers of employees



Characterize Facilities

- Facility access control:
  - site controls
  - keyed building access
    - key issuing and controls
    - electronic monitoring
  - guard stations
    - detection, assessment and response
- Chemical/equipment protection:
  - locked cabinets for chemicals of concern
  - computer access controls (passwords, etc)
  - inventory tracking
  - equipment/chemical ownership/responsibility
  - procurement approvals required

Characterize Facilities: Adversary Paths to Asset

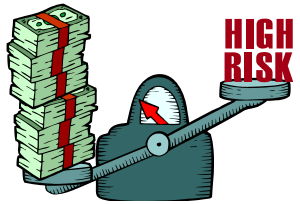


Characterize exposure/release consequences

- Health consequences:
  - disease
  - mortality
  - burns, etc
- Property damage:
  - fire losses
  - explosion damage
  - contamination losses
- Community & Environment:
  - social disruption
  - resource loss/damage
  - economic consequences

The Main Question

- How much risk is acceptable versus the cost of reducing that risk?
- Must manage multiple risks in a holistic manner
  - financial
  - liability
  - health and safety
  - business/mission
  - security



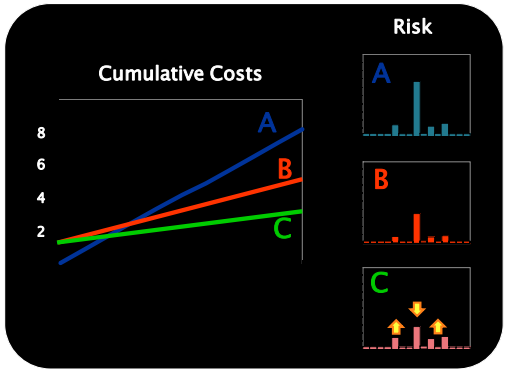
Chemical Security and Risk/Threat Prioritization

- Same concepts as Safety Risk Evaluation:
  - likelihood of theft/misuse
  - consequence of intentional misuse
  - must now consider the adversary
- Value judgement:
  - what is acceptable, tolerable, unacceptable?
- Controls & Mitigation:
  - facility access
  - education and training
  - employee screening
  - site/facility monitoring
  - security personnel
  - emergency response

Chemical Security and Risk/Threat Prioritization

- Balance of risk and resources:
  - consequence versus likelihood
  - cost versus performance (risk reduction)
- Consider mitigation and prevention steps
  - can we afford the loss and damage?
  - how do we prevent it?
  - can we afford to prevent it?
- Lab/institution needs to be productive
- Work culture of being alert is best for security *and* safety

Cost Versus Risk



Risk Assessments: Summary

- Assess the risk by determining likelihood and consequence to allow for strategic decisions on control measures.
- Ideally we consider elimination or substitution first, to remove the hazard.
- A combination of measures might be used based on their effectiveness and our ability to use them and maintain them.
- Cost versus performance (risk reduction)

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Laboratory Emergency Planning, Response, and Management

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Video: Explosion at T2 Lab

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Emergency Planning and Response is based on principles of:

- Anticipation
- Recognition
- Evaluation
- Control

Preparing For Emergencies

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

Emergency Management

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

Planning & Preparation

Anticipate types of emergencies:

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

Emergency Response Plan

Include all situations and conditions:

- Weather emergencies:
  - Flood
  - Tidal waves
  - Cyclones
  - Heavy rains
  - High winds
- Fire
- Earthquakes

- **Security breaches**
- **Distraught employees**
- **Medical Emergencies**
- **Student unrest**
- **Political unrest**
- **Explosion**
- **Evacuation**
- **Terrorism**

Prepare for and expect the unexpected

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

Emergency Action Plan

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

Emergency Response Plan

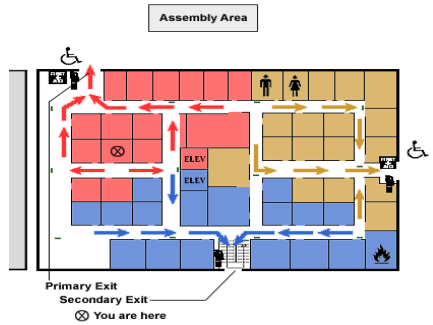
- **Comprehensive employee training**
  - **General employee training**
  - **Specialized & emergency responders**
  - **Annual refresher training or drills**
  - **Untrained personnel should not participate**
- **Spill & emergency response plans**
- **Contingency plans**
- **Medical response/first aid**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

Include:
Fire Prevention Plan

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

Emergency Planning & Response

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



Emergency Planning & Response

Don't use hallways for storage

Dangerous!!

Blocks passage and emergency exit path

Emergency Planning & Response

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

Emergency Planning & Response

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

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

Emergency Planning & Response

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

Alarm Systems: Reminder

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

Manual Pull Stations: Reminder

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

Remember:
People are reluctant to sound fire alarms!

Emergency Planning & Response

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

Emergency Planning & Response

Backup power

Does switch-over automatically?

How long will it run?

How much fuel do you have?

What areas will it support?

How often is it tested and maintained?

Emergency Planning & Response

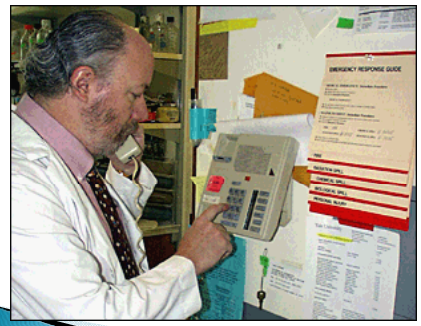
Post each room with:

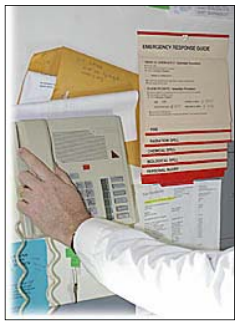
- Emergency phone numbers
- After hours phone numbers
- Person(s) to be contacted
- Alternate person(s)
- Unique procedures to be followed

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

Emergency Phone Numbers

Clearly post emergency numbers
Do employees know what to do?





Emergency Planning & Response

Hoods should have low flow alarms.



Chemical specific toxicity alarms may be needed in certain areas.

Emergency Planning & Response

Centrally locate safety showers and eyewashes.

Schedule routine, periodic maintenance of all safety equipment.

Teach employees to properly use the Safety Shower

Time can make a difference…


Chemical Spills

Centrally locate spill clean-up kits

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

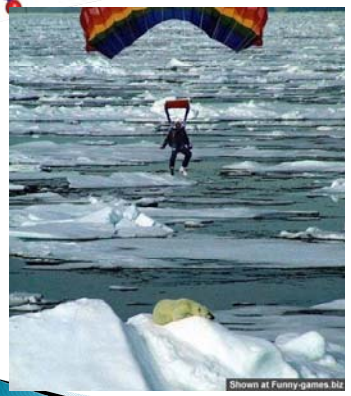
- **Alert colleagues and secure area**
- **Assess ability to clean-up spill**
- **Find spill kit**
- **Use appropriate PPE and sorbent material**
- **Protect sinks and floor drains**
- **Clean-up spill, collect/label waste for disposal**
- **Report all spills**

Centrally locate, inspect and maintain:

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



Always Expect the Unexpected




Tea Break

Principles and Concepts of Laboratory Design

Objectives of Laboratory Design

- Provide a safe/secure workplace
- Facilitate workplace activities
- Efficient
- Cost Effective
- Secure the Facility
- Protect the Environment
- Comply with Regulations

Barriers to Good Lab Design

Cost

Poor Communication

Lack of Scientific Knowledge

Complicated Project

Trade-offs

Personalities

Maintenance

Good Laboratory Design

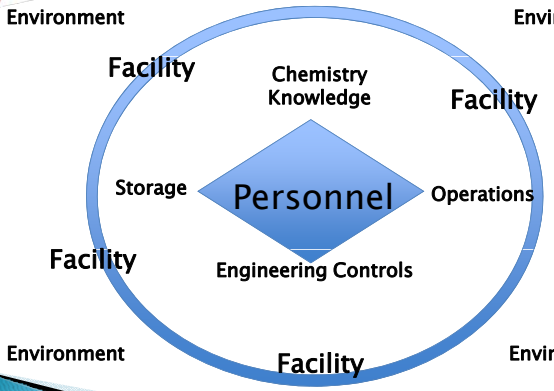
Based on:

Containment

Maximize Containment ⟷ Minimize Contamination

Redundancy is the Key

Chemical Containment Concept



Chemical Protection Depends on:

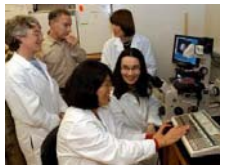
1
Chemistry Knowledge
Workers must have knowledge and understanding

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

Chemical Protection Depends on:

3
Construction
How well the facility is built

Key Stakeholders



Architects
Engineers
Administrators
Builders

EHS Professionals
Laboratory Users

Design Phases

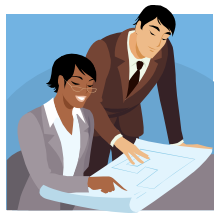
Definition
(problems and needs)
(iterative process)
Interpretation
(of requirements into design criteria)
(iterative process)
Design
(translates specifications into pragmatic reality)
Construction
(to accomplish goal)

Architectural Features

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



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 for Lab Design

Types of Chemicals
(based on physical state and properties)

Flammable
Corrosive (acid or base)
Reactive
Acutely Toxic (poisons)
Regulated
Chronically Toxic (e.g.,carcinogens, repro-toxins)
Chemicals of security concern
Controlled Drugs
Wastes

Specific Chemical Laboratory Safety/Security Concerns

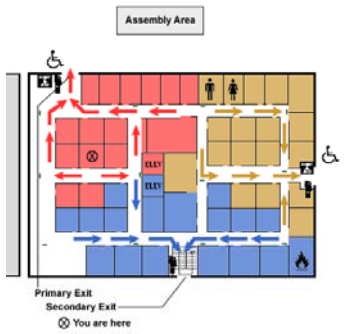
Include:

- **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: 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

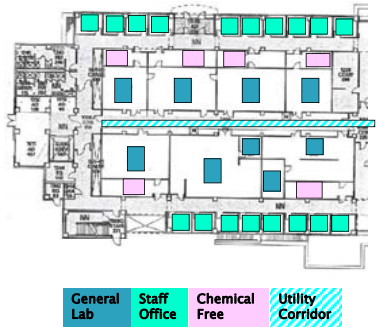
Building Layout: Divide into Zones



- 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 lab materials
- Internal "service corridors" between labs
  - Allow transport of chemicals away from public
  - Provide access to utilities and 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, 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 (pipe into lab):
  - Long-term, frequent use of same gas
  - Highly hazardous gases
  - Restrict access
  - Out-building or outdoors, depending on conditions
- Tanks inside labs
  - Wide variety of gases
  - Low use rates
  - Strap to wall or bench
  - Transport safely

Building Layout: Chemical Waste

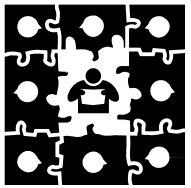
- Large volumes of chemical waste should be stored in areas with fewer people
  - Access restricted to responsible personnel
  - Locked when unattended
  - Divided into chemically compatible groups
  - Provide safety equipment and alarms

Building Layout: Chemical Waste

- Waste collection in lab:
  - 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



Open *vs.* Closed Laboratories

Open Laboratory

Closed Laboratory

Open *vs.* Closed Laboratories

Consider using both or having connected access:

Open laboratories

- 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 laboratories

- 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

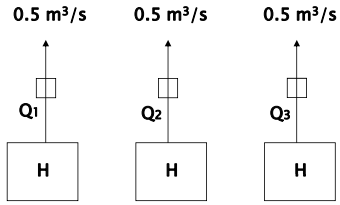
- Design leading to increased productivity
- Energy conservation and efficiency
- Centralized heat-generating equipment
- Manifolded hoods and ventilation
- Reduction/elimination of harmful substances and waste
- Efficient use of materials and resources
- Recycling and reuse

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.

Hood Manifold Considerations

Single Hood – Single Fan



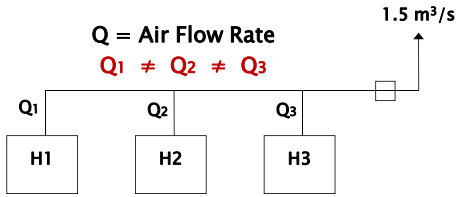
Q = Air Flow Rate

$Q_1 = Q_2 = Q_3$

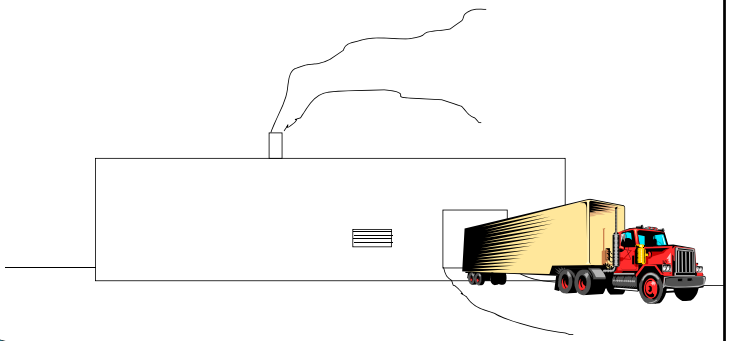
Hood Manifold Considerations

Manifold: 3 Hoods, 1 Fan

Hood Diversity = 33%



Ventilation Design: Avoid Exhaust Recirculation



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

Lab Layout

- Locate hoods, utilities and safety equipment in the same relative position in all labs.
- Locate sinks centrally
- Space between benches to allow people to pass each other (≥1.5 m).
- Details on other 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 m^2 absolute minimum
  - 6.5 m^2 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

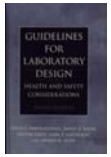
Laboratory Modifications or Decommissioning

- 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



- "Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995, ISBN 0-309-05229-7 also available online: http://www.nap.edu/catalog.php?record_id=4911
- "Laboratory Design, Construction, and Renovation: Participants, Process, and Product," National Academies Press, 2000, ISBN 0-309-06633-6, Also available online: http://www.nap.edu/catalog.php?record_id=9799
- "Handbook of Chemical Health and Safety", Robert J. Alaimo, Ed., Oxford University Press, 2001, ISBN 0-8412-3670-4
- "Guidelines for Laboratory Design: Health and Safety Considerations, 3rd edition" Louis J. DiBerardinis, et al., Wiley, 2001, ISBN 0-471-25447-9

Laboratory Chemical Hoods:

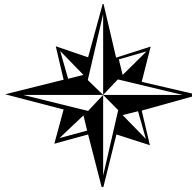
How they work & when they don't

Improper Hood Use

Laboratory Chemical Hood

- Also called a fume hood or fume cupboard
- Designed to limit exposure to hazardous or unpleasant aerosols
- First used by alchemists 500 years ago

Control Concept



PATH

SOURCE

RECEIVER

LEV Objectives

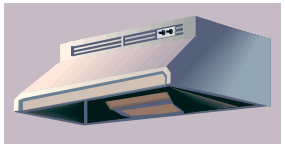
- Maximize Containment
- Minimize Contamination
- Redundancy is the Key

LEV Implementation

- Identify/Characterize Contaminant
- Characterize Air Movement
- Identify Alternative Controls
- Choose Most Effective Control
- Implement Control
- Evaluate Control
- Maintain Control

LEV Capture Ability

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

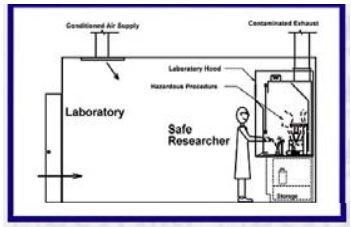


Duct Design

- Provide adequate capture velocity
  - Usually 80-120 fpm (0.4 - 0.6 m/s)
- Maintain duct transport velocity
  - For chemical laboratories ~ 2500 cfm (1.2 m^3/s)

Duct Design

- Keep system balanced,
  - ie, equalize supply & return air
  - match airflows among manifolded hoods
- Minimize power consumption
  - i.e., conserve energy
  - save money



http://www.clf.rl.ac.uk/facilities/AstraWeb/images/Photo7/Air_duct_TA3.JPG

Laboratory Hoods

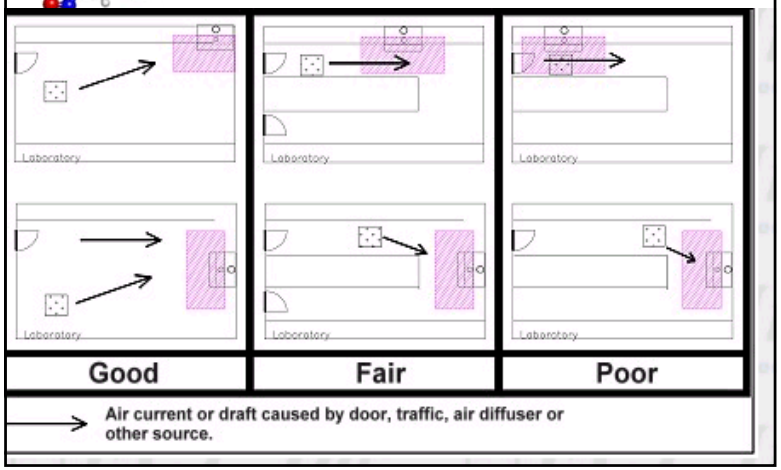
Laboratory hoods and ventilation are the basis of engineering controls.

They must be properly:
selected, *located*, *used*, and *maintained*.

Hood Location Requirements

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

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



Principles of Hood Design and Operation

- Enclose as much of the operation as possible
- Place utility controls (gas, electric) outside or as near hood front as possible
- Hood lights should be vapor tight
- Mount hood motor *outside building* and *away from* building *air intakes*
- Don't use hoods for uses not intended (e.g., perchloric acid digestion, radioisotopes)
- Ensure duct material compatible with exhausts
- Don't use without indication it is working properly

Hood Design & Operation, continued

- Don't put your head in the hood.
- Use proper PPE (gloves, eyewear, etc)
- Place large equipment above surface on 5 cm blocks to allow uniform air flow
- Lower sash height to 30 – 50 cm during operation
- Keep sash fully closed when not in use
- Use liner or tray inside hood to contain spills

http://www.news.harvard.edu/gazette/daily/0403/photos/03-meltonstem_1.jpg

Hood Design & Operation, continued

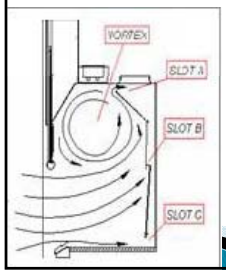
- Work in the center of hood and 15 cm in from hood sash.
- Don't store chemicals or equipment in hood.
- Don't block baffles (slots).
- Maintain hood regularly (check fan belt, lubricate motor).
- Regularly evaluate hood (flow rate, mark operating sash height).
- Reports problems, concerns, malfunctions immediately.

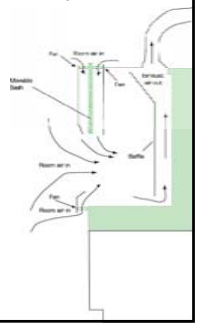
Laboratory Hood Types

- Constant Air Volume (CAV)
  - Traditional/Standard/Conventional
  - Bypass
  - HOPEC (horizontal/vertical sash)
  - Auxiliary Air (not recommended for Lab operations)
- Variable Air Volume (VAV)

Traditional Constant Volume Hood

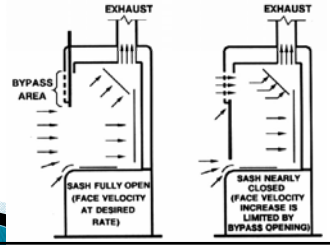
- All make up air enters through hood face.
- Air exhausted is constant regardless of size of face opening or sash height.
- Volume of air movement is constant but velocity varies with sash height.





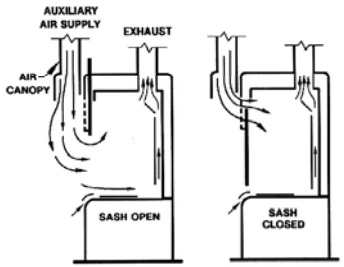
Constant Volume Bypass Hood

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



Auxiliary Air Hood
(not recommended for Labs*)

- Designed to reduce energy consumption.
- Discharges unconditioned make-up/auxiliary air from outside directly above and over user in front of hood.
- Uncomfortable to use and can produce turbulence at hood face.



* According to ANSI Z9.5

HOPEC Hood
(Hand Operated Positive Energy Control)

Combination Horizontal/vertical sash limits sash opening to no more that 50%.

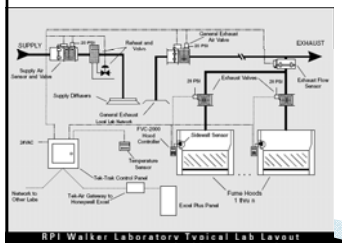
Maintains constant air volume and limits energy consumption.

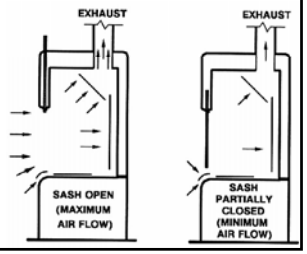
Variable Air Volume (VAV) Hood

Uses mechanical and electronic controls to maintain constant air velocity.

Interfaces with room supply air to conserve energy by maintaining constant face velocity.

Uses complicated electronic components that require special training to maintain.

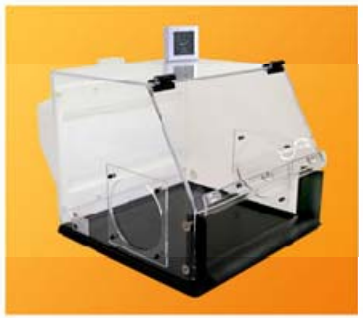




Specialized Hoods

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

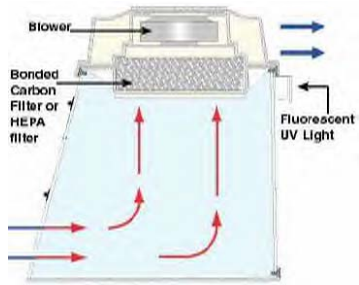
Special purpose vented hood



Chemical weighing station

Bulk powder transfer station

Ductless Hoods



Ductless Hoods

Should only be used in laboratories with:

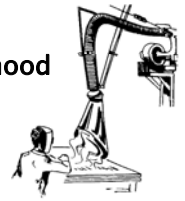
- Small quantities of known non-volatile substances.
- Only with HEPA filters
- Never with volatile substances
- Unless breakthrough time for the specific chemical being used is known, carbon filters are unreliable.

Specialized Hoods

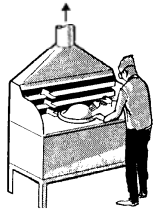
Dust hood, Animal feed

Downdraft table

Snorkel hood



Slot H



Biological Safety Cabinets (BSC)

Several types/classes and configurations.

Designed to protect the sample, and sometimes the worker, from biological contamination.

Most types not suitable for hazardous, volatile chemicals.

Often not vented to the outside.

Reference: http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm

Hood Problems and Pitfalls

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

Neither of these measurements can guarantee hood capture or containment.

Hood Evaluation

- Face Velocity
  - necessary but not sufficient condition
- Smoke Tubes
- Smoke Candles
- Incense
- ASHRAE 110-1995 Test (SF_6)
- Protection Factors (300-10,000):

$$PF = \frac{\text{Contaminant Concentration in Exhaust Air}}{\text{Contaminant Concentration in Breathing Zone}}$$

Ventilation System Evaluation

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

Ventilation System Evaluation

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

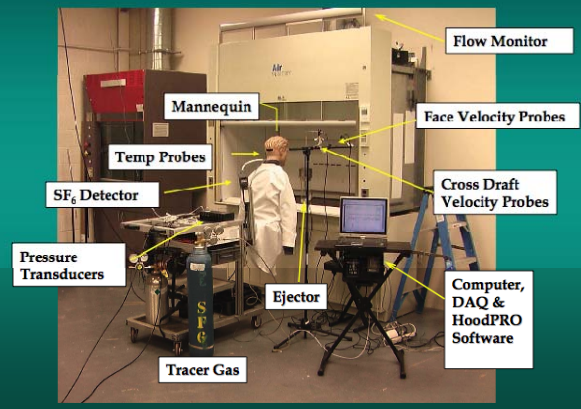
Hood Smoke Evaluation
Face velocity *vs.* Containment

- Lab hood performance = containment of contamination. How do we determine containment?
- Is face velocity the right measurement?
  - 30% – 50% of hoods that leak excessive levels of contaminants still pass the face velocity tests.
  - hoods with face velocities of 50 fpm (0.25 m/s) *can* provide protection factors 2,200 times *greater* than hoods with face velocities of 150 fpm (0.76 m/s).

ASHRAE 110 Containment Test

- Measures containment using SF_6 as a tracer gas
- SF_6 is generated inside the hood at 4L/min.
- A mannequin with a detector in the breathing zone (mouth) is placed outside the hood
- The detector is connected to a recorder
- The hood is also tested with smoke
- The hood is subjected to a walk-by test
- Effect of opening & closing sash is determined

Fume Hood Test Apparatus

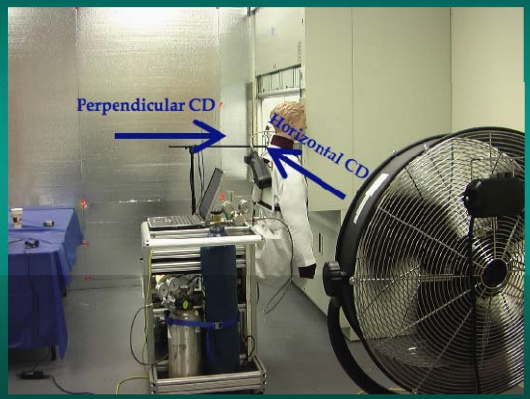


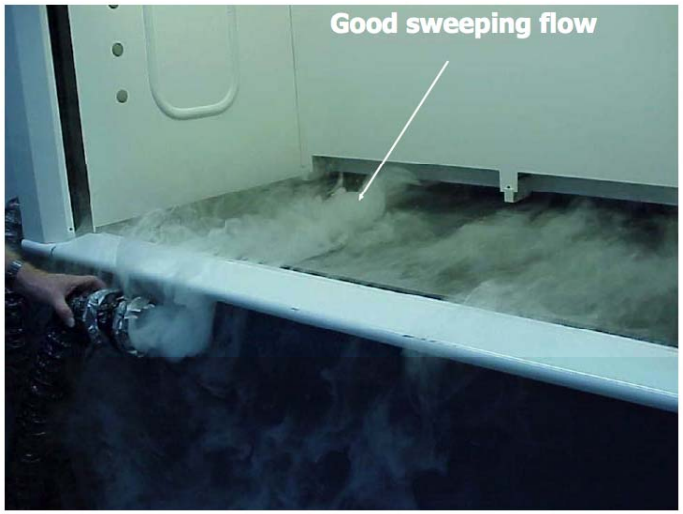
Gas Cylinder Inside Hood

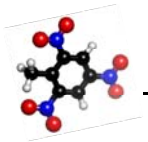
Hood Loading Challenge Test

Walk-By Challenge Test

Cross Draft Challenge Tests







Conclusions

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

Acknowledgements

- Tom Smith ECT, Inc., Cary NC USA
- University of North Carolina, Chapel Hill NC USA
- Texas A & M University
- Flow Sciences Inc, Leland NC USA
- Knutson Ventilation, Edina MN USA
- AirClean Inc, Raleigh NC USA

Lunch

Chemical Waste Management and Disposal

Waste Management

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

Waste management: nonhazardous waste

- Used oil (uncontaminated) is not considered hazardous waste. Label Containers "USED OIL", not "hazardous waste."
- Uncontaminated PPE (gloves, wipes)
- Triply rinsed glassware (bottles, droppers, pipettes)
- Salts (KCl, NaCl, Na_2CO_3)
- Sugars – Amino acids
- Inert materials (uncontaminated resins and gels)

Waste management: General guidelines

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

Waste management: General guidelines

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

Waste – Storage guidance

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

Waste – General guidance

Certain metals cause disposal problems when mixed with flammable liquids or other organic liquids

Pressure can build up in a waste vessel

Corrosion can occur in storage vessel

Secondary containment is necessary

Glass waste containers can break

Dangerous waste management

Video – Fire at Apex Waste Facility

Best practice – Orphan control

Before moving to new job meet with new lab occupant

- This can be a new employee or new student
- Label all chemicals and samples carefully
- Make notations in common lab book

Dispose of all unneeded or excess chemicals

- Put into chemical exchange program
- Dispose of as hazardous waste

Do not leave chemicals behind except by agreement

Waste management

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

Emissions from incineration vs. open burning

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

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

Lab wastes are packaged in small containers

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

Lab packs segregated at hazardous waste facility

Waste management: Waste disposal service

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

Battery recycling and disposal

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

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

Mercury metal disposal

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

Mixed Waste (chemical radioactive)

These wastes must be minimized – heavily regulated

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

Mixed Waste (chemical-biological)

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

Mixed Waste (radioactive-biological)

Medical wastes

- Often disinfect high biohazard to minimize handling risk
- Let short-lived isotopes decay and then use sanitary sewer
- Refrigerated storage for putrescible waste (carcasses-tissue)
- Autoclave or disinfect labware and treat as low level radioactive
- On-site incineration of low level rad waste if allowed (sharps also)

Unknown "orphan" waste

Avoid if at all possible – requires analysis before disposal!

Pre-screen:

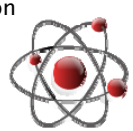
- Crystals present ?
  (potential peroxide formation)
- Radioactive (Geiger counter)
- Bio waste? (interview history)

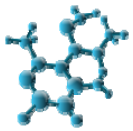
Screen:

- Prepare for the worst:
  wear gloves-goggles-hood
- Air reactivity
- Water reactivity
- Flammability
- Corrosivity

Unknown waste characterization*

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



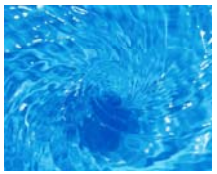


*Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 1995 Section 7.B.1

Waste management: Down the drain?

If legally allowed:

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



Treating on site – volume reduction

Evaporation – if not excessive
- Roto evaporation for recovery
- Do not evaporate corrosives or radioactives
- Only in laboratory hood
- Beware toxics and flammables

Adsorption
- Activated carbon
- Ion exchange resin
- Activated alumina

Precipitation – Extraction

Handbook of Laboratory Waste Disposal, Martin Pitt and Eva Pitt, 1986. ISBN 0-85312-634-8

Treating on site – chemical conversion

Requires chemical expertise:
- may not be allowed by regulations
- specific to each chemical

- Dilution to reduce hazard
  - H_2O_2, $HClO_4$, HNO_3
  - Never add water to concentrated acid
  - Neutralization acid base –gentle
- Hydrolysis (acid and base)
  - Active halogen compounds with NaOH
  - Carboxamides with HCl
- Oxidation–reduction

Handbook of Laboratory Waste Disposal, Martin Pitt and Eva Pitt, 1986. ISBN 0-85312-634-8

Waste management: Treatment in Lab

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

Other Hazards in a Chemical Laboratory

Physical Hazards

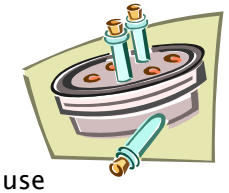
Conditions, besides chemical, biological or radiological conditions or circumstances, that can cause injury, illness and death:

- Fire / Asbestos
- Centrifuges
- Cryogenics
- Ergonomic
- Office
- Physical stress/strain
- Construction
- Noise
- Heat/cold
- Sunlight
- Non-ionizing radiation
- Mechanical
- Electrical
- Housekeeping
- Spills/trips

Asbestos-Containing Materials

- Gloves
- Lab hoods
- Lab benches

Centrifuge Equipment



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

CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

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Chemical SAFETY AND SECURITY TRAINING

Centrifuge Safety

Don't overload …

Check rotor for cracks

Keep rotor and centrifuge clean …

Set it up right…

CSP CHEMICAL SECURITY ENGAGEMENT PROGRAM

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Chemical SAFETY AND SECURITY TRAINING

Chemical storage: Cryogenics

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

Cyrogen Storage

Exploding liquid nitrogen cylinder ruins lab.

Dry Ice

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

Housekeeping

- Do not use hoods for storage!

- Don't block hood air flow:
  - Place large equipment in a hood on 5 cm blocks to allow air flow around and under equipment.
  - Safety shields can block airflow and reduce hood effectiveness.

Open-toed shoes should not be allowed in laboratories.

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

Working Alone Unattended Operations

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

Electrical Hazards

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

Electrical Hazards

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

Electrical Hazards

Multi-outlet strips must be approved and not used for high-amp equipment.

(e.g., ovens, refrigerators)

Electrical Hazards

•Storage should be >1 m from:

- electrical panels, mechanical rooms, air ducts, heaters, light fixtures.

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

• In emergencies, you may need to access these panels quickly.

Freezers

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

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

Glassware Handling

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

Beware of contaminated Glassware, especially if broken!

Autoclave Explosion

- Caution:
  - *No flammables/solvents in autoclaves!*
- Emissions:
  - No toxic compounds
  - breakdown of polymers
    - polystyrene, etc

High Pressure Reactions

- Experiments carried out at pressures above 1 atm (~1bar, 760 Torr, ~100,000 Pa).
  - Use of supercritical fluids (CO_2)
- Hazards
  - Explosions, equipment failure
- Control Measures
  - SOPs, training, engineering controls, inspection
  - Dry runs

Vacuum Work

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

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

Oil pumps need drip pans to contain oil.

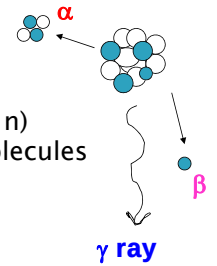
Noise

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

Magnetic Fields

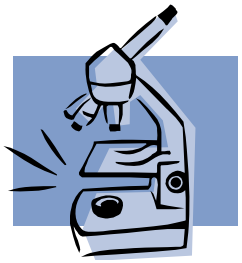
- Uses – NMR, MRI
- Hazards
  - Magnetic field
  - High voltage
  - Cryogenic liquids
    - e.g., nitrogen, helium
  - Other hazardous materials in lab
- Control Measures
  - Control access to area
  - Training
  - Warning signs

Ionizing vs. Non-ionizing Radiation



- **IONIZING RADIATION**
  - Particulate or electromagnetic
  - Charged (α, β) or uncharged (γ, X, n)
  - Causes **ionization** of atoms or molecules
- **NON-IONIZING RADIATION**
  - Electromagnetic (UV, IR, MW, RF)
  - Can not ionize atoms or molecules

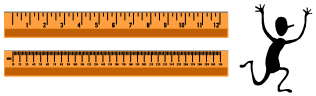
Electron Microscopes



- Types
  - SEM, TEM
- Hazards
  - X-rays
- Control of hazard
  - Periodic maintenance
  - Conduct radiation survey
  - Include in personnel radiation safety program

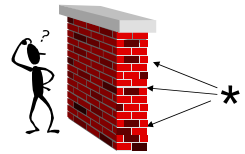
Protect yourself by:

- **TIME** – Limit time near source

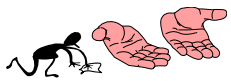


- **DISTANCE** – Stay away

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

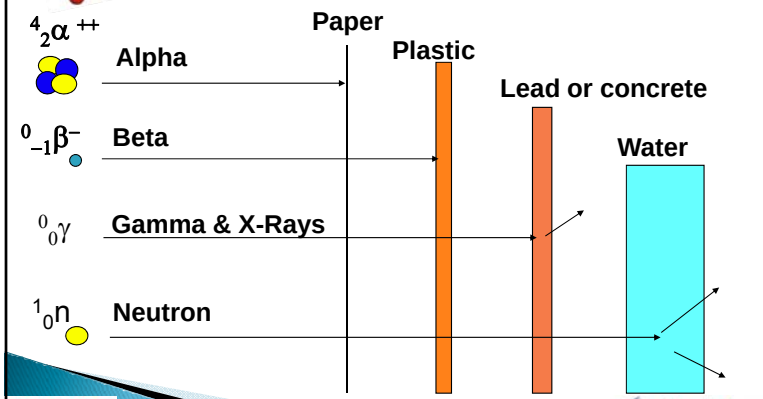


- **SHIELDING** – Absorb energy



- **CONTAMINATION CONTROL**

Shielding Materials



Non-Ionizing Radiation

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

Radio-frequency & Microwaves

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

Sharps, Needles, Blades

- **Hazards:**
  - Needlesticks
  - Cuts
  - Contamination
- **Control Measures**
  - SOPs
  - Training
  - Modify work practices
  - Engineering Controls

Slips, Trips, Falls

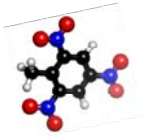
- Most common injuries
- Causes
  - Chemical spills and leaks
  - Improper work practices
- Control Measures
  - SOPs, proper equipment, effective communication, engineering controls


We want to avoid this.

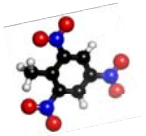
Control of Hazards

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

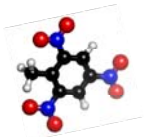
Any Questions?



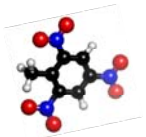
Tea Break



Questions, Open Discussion and Breakout/Next Steps



Feedback Form and Closing



Thank You!

Congratulations!

Adjourn