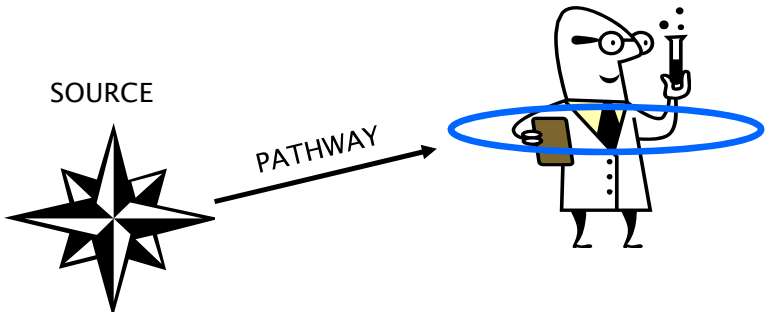
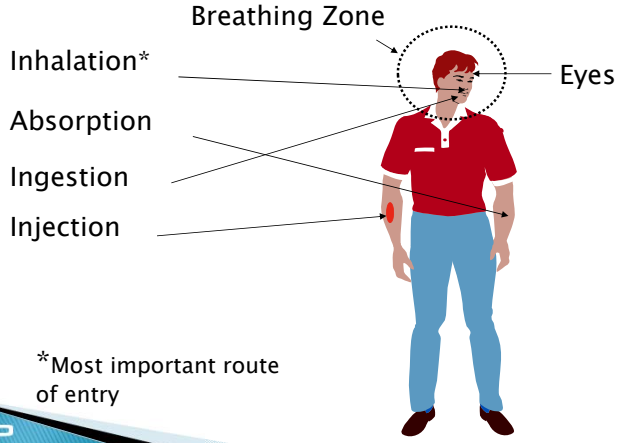
PPE and Safety Equipment Performance Specifications

Worker Protection



Routes of Exposure



*Most important route of entry

Personal Protective Equipment (PPE)

- Should be a last resort, but may be necessary if:
  - engineering controls inadequate or being installed
  - administrative controls don't do the job
  - emergency response or spill cleanup
  - supplement other control techniques if can't achieve required level
- Depends upon human behavior
  - proper selection, fit and comfort issues
- Hazard is still present with PPE …

Training and Qualification

Employees should be trained to know:

- When PPE is necessary?
- What PPE is necessary?
- How to properly don, doff, adjust and wear PPE
- Limitations of PPE
- Proper care, storage, maintenance, useful life, and disposal of PPE.

www.free-training.com/osha/ppe/ppemenu.htm

Personal Protective Clothing (PPE)

- Evaluate task, select appropriate type and train to use it properly
  - lab coats, gowns, aprons
  - safety glasses (with side shields), goggles, face shields
  - gloves
- Remove PPE before leaving the lab

Protective Equipment Works

"It's a hot day, why wear a lab coat?"

An experiment reacted unexpectedly and a flammable solvent from a hood splashed out and landed on the bottom of the lab coat

Eye and Face Protection

Eye protection shields eyes by:

- Primary protection:
  - Safety glasses with side shields protec from flying objects.
  - Goggles prevent objects from enterin under or around the eyewear.
- Secondary protection:
  - Face shields
    - Combine with safety glasses or goggles
    - Do not protect from impact hazards

Eye and Face Protection

Optical Hazards

- Welding helmets are secondary protection to shield from UV, heat, and impact.
- Exposure to laser beams requires suitable laser safety goggles with protection for the specific wavelength.

Eye and Face Protection Requirements

- Ensure employees who wear prescription lenses or contact lenses:
  - Use safety eyewear that incorporates the prescription
  - Use eye protection that can be worn over prescription lenses

Glove Selection

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

Chemical Protective Gloves/Clothing

- Permeation ("silent killer")
  - Substances pass through intact material on a molecular level.
- Penetration
  - Substances pass through seams, zippers, stitches, pinholes, or damaged material.
- Degradation
  - Substance damages material making it less resist or resulting in physical breakdown.
- Contamination
  - Substances transferred inside material (improper doffing or decontamination).

Permeation Rate (PR)	Permeation Breakthrough (PB)	Permeation Degradation rate (DR)
E- Excellent; permeation rate of less than 0.9 mg/cm²/min	>Greater than (time - minutes)	**E** - Excellent; fluid has very little degrading effect.
VG - Very Good; permeation rate of less than 9 mg/cm²/min	< Less than (time - minutes)	**G** - Good; fluid has minor degrading effect.
G - Good; permeation rate of less than 90 mg/cm²/min		**F** - Fair; fluid has moderate degrading effect.
F - Fair; permeation rate of less than 900 mg/cm²/min		**P** - Poor; fluid has pronounced degrading effect.
P - Poor; permeation rate of less than 9000 mg/cm²/min		**NR** - Fluid is not recommended with this material.
NR - Not recommended; permeation rate greater than 9000 mg/cm²/min		† Not tested, but breakthrough time > 480 min DR expected to be Good to Excellent
		†† Not tested, but expected to be Good to Excellent based on similar tested materials

The first square in each column for each glove type is color coded. This is an easy-to-read indication of how we rate this type of glove in relation to its applicability for each chemical listed. The color represents an overall rating for both degradation and permeation. The letter in each square is for Degradation alone...

GREEN: The glove is very well suited for application with that chemical.

YELLOW: The glove is suitable for that application under careful control of its use.

RED: Avoid use of the glove with this chemical.

CHEMICAL	LAMINATE FILM BARRIER			NITRILE SOL-VEX			UNSUPPORTED NEOPRENE 29-865			SUPPORTED POLYVINYL ALCOHOL PVA			POLYVINYL CHLORIDE (Vinyl) SNORKEL			NATURAL RUBBER CANNERS AND HANDLERS*			NEOPRENE/ NATURAL RUBBER BLEND CHEMI-PRO*		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
1. Acetaldehyde	■	380	E	P	—	—	E	10	F	NR	—	—	NR	—	—	E	7	F	E	10	F
2. Acetic Acid	■	150	—	G	270	—	E	60	—	NR	—	—	F	180	—	E	110	—	E	260	—
3. Acetone	▲	>480	E	NR	—	—	E	10	F	P	—	—	NR	—	—	E	10	F	G	10	G
4. Acetonitrile	▲	>480	E	F	30	F	E	20	G	■	150	G	NR	—	—	E	4	VG	E	10	VG
5. Acrylic Acid	—	—	—	G	120	—	E	390	—	NR	—	—	NR	—	—	E	80	—	E	65	—
6. Acrylonitrile	E	>480	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7. Allyl Alcohol	▲	>480	E	F	140	F	E	140	VG	P	—	—	P	60	G	E	>10	VG	E	20	VG
8. Ammonia Gas	■	19	E	▲	>480	—	▲	>480	—	—	—	—	■	6	VG	—	—	—	■	27	VG
9. Ammonium Fluoride, 40%	—	—	—	E	>360	—	E	>480	—	NR	—	—	E	>360	—	E	>360	—	E	>360	—
10. Ammonium Hydroxide	E	30	—	E	>360	—	E	250	—	NR	—	—	E	240	—	E	90	—	E	240	—
11. Amyl Acetate	▲	>480	E	E	60	G	NR	—	—	G	>360	E	P	—	—	NR	—	—	P	—	—
12. Amyl Alcohol	—	—	—	E	30	E	E	290	VG	G	180	G	G	12	E	E	25	VG	E	45	VG
13. Aniline	▲	>480	E	NR	—	—	E	100	P	F	>360	E	F	180	VG	E	25	VG	E	50	G
14. Aqua Regia	—	—	—	F	>360	—	G	>480	—	NR	—	—	G	120	—	NR	—	—	G	180	—
15. Benzaldehyde	▲	>480	E	NR	—	—	NR	—	—	G	>360	E	NR	—	—	G	10	VG	G	25	F
16. Benzene, Benzol	▲	>480	E	P	—	—	NR	—	—	E	>360	E	NR	—	—	NR	—	—	NR	—	—
17. Benzotrichloride	—	—	—	E	>480	E	NR	—	—	—	—	—	—	—	—	NR	—	—	NR	—	—
18. Benzotrifluoride	—	—	—	E	170	G	F	—	—	E	—	—	G	<10	F	P	50	G	—	—	—
19. Bromine Water	—	—	—	E	>480	E	E	>480	E	—	—	—	—	—	—	—	—	—	—	—	—
20. 1-Bromopropane	▲	>480	E	■	23	F	■	<10	P	▲	>480	E	■	<10	F	■	<10	P	■	<10	P

Types of Gloves

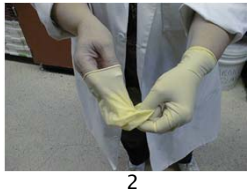
- Latex, natural rubber
- Polyethylene/Ethylene-vinyl Alcohol {"Silver Shield®"}
- Butyl Rubber
- Viton
- Nitrile (acrylonitrile-butadiene rubber)
- Neoprene
- Poly vinyl chloride (PVC)

Latex Allergies

- Symptoms may occur within minutes of exposure or may take several hours depending on the individual.
  - Skin Redness
  - Hives
  - Itching
  - Respiratory Symptoms
    - Runny Nose
    - Itchy Eyes
    - Scratchy Throat
    - Asthma

Proper Steps for Removing Gloves

1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3

4

5

6

Respiratory Protection

Respiratory Protection Program

- Written program
- Administered by Safety Office
- Medical clearance
  - Respiratory Protection Questionnai
  - No beards
- Fit testing
- Respirator selection
  - Air monitoring
- Training (annual refresher)

Hazards Requiring Body Protection

- *Hazardous chemicals.*
- Potentially infectious materials.
- Intense heat.
- Splashes of hot metals and hot liquids.

Body Protection for Emergency Response

Full suits:

- Class A
- Class B
- Class C
- Class D

Level A Protective Suits

Potential exposure to unknown:

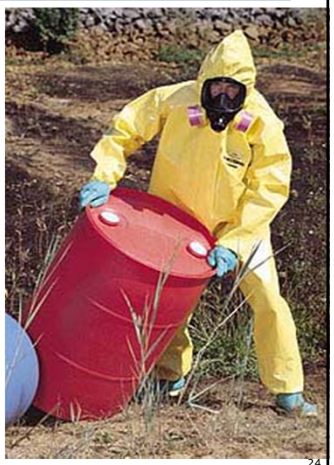
- Greatest level of skin, respiratory, and eye protection.
- Positive-pressure, full face-piece Self Contained Breathing Apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA.
- Totally encapsulated (air-tight) chemical and vapor protective suit.
- Inner and outer chemical-resistant gloves, and boots.

Level B Protective Suits

- Atmospheric vapors or gas levels not sufficient to warrant level A protection.
- Highest level of respiratory protection, with lesser level of skin protection.
  - Positive-pressure, full face-piece self contained breathing apparatus (SCBA) or positive pressure supplied air respirator with escape SCBA
  - Hooded chemical resistant clothing or coveralls (non-totally-encapsulating suit), inner and outer chemical-resistant gloves, and boots

Level C Protective Suits

- Concentration or contaminant known
- Full-face air purifying respirator permitted with a lesser skin protection_
- Inner and outer chemical-resistant gloves, hard hat, escape mask, disposable chemical-resistant outer boots
  - *Difference in Level C and level B is respiratory protection*



Level D Protective Suits

- Minimum protection.
- *No* respiratory or skin protection.
- Used only if no known or suspected airborne contaminants present.
- May include gloves, coveralls, safety glasses, face shield, and chemical-resistant, steel-toe boots or shoes.

Foot Protection

Should meet or exceed ANSI Standard.

Types:

- Impact, penetration, compression, steel toe, etc.
- Non-skid, with slip resistant soles.
- Chemical resistant (rubber, vinyl, plastic, with synthetic stitching to resist chemical penetration).
- Anti-static
- Temperature resistant (high or low extremes).
- Electrical protection (non-conducting).
- Water resistant
- Combination shoes

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.

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

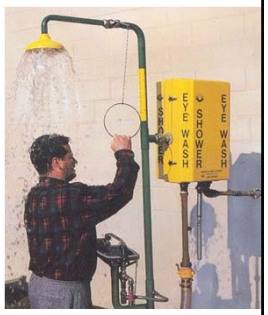
Safety Equipment

Eyewash and Showers

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

Eyewash and Showers

- Know their locations
  - Easily accessible locations
- Maintenance and testing program
  - Eyewash-Weekly
    - Portable: clean/refill (6 mo - 2 yrs)
  - Shower-Monthly
- Concerns:
  - Drainage
  - Freezing
  - contaminated water
  - Blankets/modesty curtains
  - Avoid or protect electrical outlets



Blocked Eyewash & Safety Shower

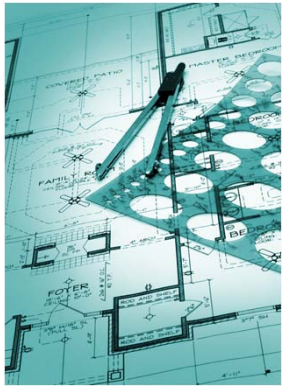
Dirty Eyewash Station

Any Questions?

Principles and Concepts of Laboratory/ Facility Design

Laboratory Design: Overview

- Lab Design Basics
- Chemical Containment
- Design Guidelines & Examples
- Renovations
- Security, Safety & Sustainability



Laboratory Design Basics: Goals

- Protection of:
  - All occupants,
    - users,
    - staff/workers,
    - visitors,
  - Community
  - Environment
  - Property

- Enable the Work
  - Efficiently and effectively
  - Safely
  - Interface with services
    - utilities
    - surrounding facilities and activities

- Secure the Facility
  - Control access
  - Control activities
  - Natural events (weather, etc)
  - Emergency response & systems
- **All of above, plus:**
  - **Keep in budget**
  - **Energy efficiency**
  - **Environmentally sustainable**
  - **Community friendly**
  - **Aesthetics**

Laboratory Design Basics: Stakeholders and Roles

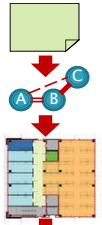
- **Stakeholders:**
  - Owner & Administrators
  - *Laboratory Users*
  - Building users
  - Environmental, health, and safety personnel
  - Facilities
  - Community
    - Surrounding businesses/neighbors
  - Architects
  - Engineers
  - Builders
- **Roles:**
  - Funding, management, ownership
  - *Expertise, needs, operations*
  - Building activities, needs
  - Safety expertise, regulation compliance
  - Standards & policy, maintenance
  - Inform and consent,
    - "good neighbors"
  - Project design/coordination
  - Utilities & systems design
  - Construction coordination

If possible, make *your self* a part of the laboratory design process

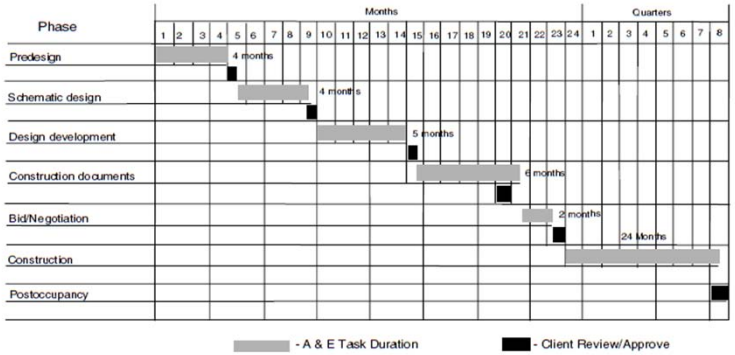
Laboratory Design Basics: Design Process

Design & building is an <u>iterative</u> process:

1. **Programming**
   - needs & requirements
2. **Schematic Design**
   - Basic relationships/layout
3. **Design Development**
   - Detailed coordination
4. **Final Design & Bidding**
   - Select Contractor for construction
5. **Construction**



Laboratory Design Basics: Design Process



Source: National Academies of Science; "Laboratory Design, Construction, and Renovation: Participants, Process, and Product ", 2000; http://www.nap.edu/catalog.php?record_id=9799

Getting involved *early* is best, but **GET INVOLVED**

Laboratory Design Basics: Considerations

- Location of buildings and rooms
- In Labs:
  - Type of work/research
  - Number of occupants and their technical qualifications
  - Time and duration of occupancy
  - Anticipated changes in work/research
  - Hazards
  - Waste
  - Space and storage requirements
  - Arrangement of equipment and benches
  - Traffic flow of people, equipment, and materials
- Emergencies
  - Fires
  - Spills/chemical exposure
  - Evacuation
- Systems and maintenance
  - Electrical
  - Plumbing
  - Heating, Ventilation, and Air Conditioning (HVAC)
- Security/access controls
- Environment
  - Energy efficiency
  - Pollution
- Laws and regulations
- More…

There are a large number of things to consider !!

- Iterative design process
- Many challenges

Laboratory Design Basics: Challenges

- Complicated Projects:
  - Costly
    - cabinetry
    - finishes
    - utilities
    - fixtures
    - equipment
  - Maintenance & life cycle
  - Changing needs
  - Scientific processes & equipment
  - Hazards
  - Communication & specialties
  - Personalities
  - Priorities/trade-offs

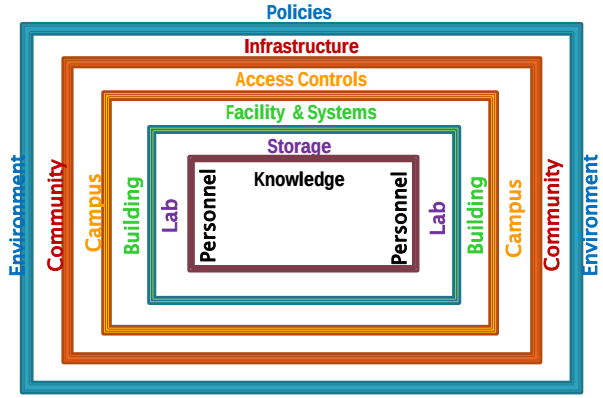
- There are a large number of things that can go wrong
- Important to not forget the *purpose* of good laboratory design

- Code Requirements Affect Lab Design:
  - Ventilation—to maintain comfort & health,
  - Fire protection— suppress fires, limit amounts of hazardous chemicals,
  - Emergency power—to maintain life-safety systems during electrical interruption,
  - Control of hazards—to reduce risk from releases of materials,
  - Building height—limits the height of lab buildings based on chemical use,
    - Design: Stack departments. Place labs using the most chemicals, at the lower floors (not at top, for easier vent hood & ductwork access).
    - Reason: Codes allow more chemicals on the first floor. Labs that need less chemicals can be at upper floors.
  - Seismic requirements—to reduce the damage & injury from earthquakes.

Laboratory Design: Chemical Containment

- Protection depends on…
  - Behavior/policies
  - Chemistry knowledge/operations
  - Containment & support systems
  - Construction quality
- Maximize containment:
  - Minimize safety and security risks
- Redundancy:
  - Key to optimal containment
  - Accidents typically a cascade of faults

Laboratory Design: Chemical Containment



- Maximize containment
- Redundancy is the key

Laboratory Design: Chemical Containment

- Spill protection & secondary containment:
  - Liquid-tight dikes,
  - Recessed noncombustible floors,
  - Containment so a leak from one container does not contact other containers,
  - Raised steel or fiberglass grating,
  - Removable grating and supports for clean up of any leaked material,
  - Separate secondary containment to prevent mixing of spilled/leaked materials.
- Store large volumes of chemical waste in buildings with few people
  - Access restricted to responsible personnel
  - Divide into chemically compatible groups
  - Provide safety equipment and alarms

Laboratory Design: Chemical Containment

- Secure Storage:
  - Surety agents
  - Precursors
  - High-hazard chemicals
  - Theft targets
- **Proper Storage:**
  - Flammable cabinets
  - Acid cabinets
  - Refrigeration
  - Segregation of chemicals
    - new stocks
    - waste chemicals

Design Guidelines: Site Issues

- **Primary Site Risks for chemical facilities involve:**
  - Security of access,
  - Transport of materials, and
  - Emergency response
- **Site Design Considerations:**
  - Risk characteristics of the surrounding area for adjacent targets, etc,
    - types of buildings and occupancies,
    - types of activities,
    - off-site land uses,
    - proximity to traffic centers,
    - traffic patterns/types,
    - topography & sight lines,
      - natural physical barriers (i.e. water features, dense vegetation, and rough terrain) can help provide access control
    - future plans/development
  - Building configuration,
  - Setback distances,
  - Access control,
  - Activity areas,
  - Utility placement,
  - Parking.

Design Guidelines: Security & Site Design

- Campus Security design:
  - Buildings/sites differ in the level of protection
  - For multiple buildings on a site, cluster or disperse buildings?
    - Recommended approach:
      - dispersed layout requires a more extensive security system,
      - cluster buildings with compatible functions & similar threat levels,
      - separate higher risk buildings from lower risk buildings,
      - separate higher risk buildings from more populated areas/buildings.
  - Enhance security with new landforms
    - water features, planting, and grading,
  - Alter wind patterns to affect distribution of hazardous releases using
    - slopes and valleys to channel wind flow,
    - vegetative windbreaks and buildings can affect air flow.

Design Guidelines: Security & Site Design

- Site Security Design Examples:
  - Drainage:
    - design to reduce drainage structures that may provide concealment,
    - consider use of dry wells into the ground,
    - pervious pavements and planted areas allow storm water back into the ground.
  - Access and circulation control:
    - locations and number of access points,
    - how many people/vehicles should they handle,
    - signage for visitors and emergency response,
    - circulation within the site and parking,
    - avoid long, straight vehicular approaches,
    - speed of vehicles in the site should be limited by the design of roads & barriers,
    - design loading docks so that vehicles will not be under a building,
    - separate loading docks from utility mains by at least 50' (15m).

Design Guidelines: Buildings

- Entrances and Exits
  - Safety: 2 or more exits from each room and building
  - Security: access control
- Emergency exit doors
  - Lack handles/locked on outside
  - Have "panic bar" on inside
  - Set off alarm when opened
- What about high rise buildings & basements?

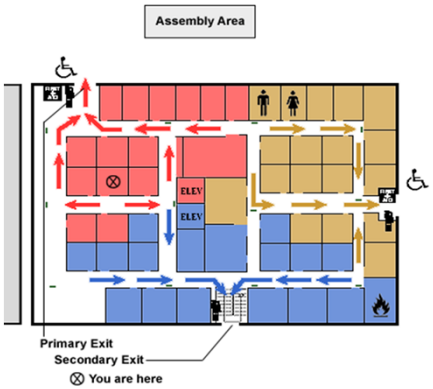
Design Guidelines: Buildings

- Separate stock rooms:
  - Teaching
    - High traffic
    - Only keep ~1 week supply of chemicals needed for student experiments
  - Research
    - Wide variety of chemicals and materials
    - Additional controls for regulated, attractive, or dual-use chemicals

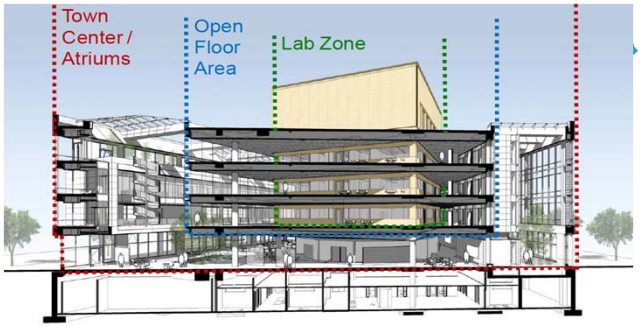
Graded application of controls

Design Guidelines: Buildings & Zoning

- Zones
  - Based on hazards, access and activities
  - Allows for graded application of controls
- Examples
  - Fire safety
  - Access control for security reasons
  - Separate atmospheres
  - Building floors



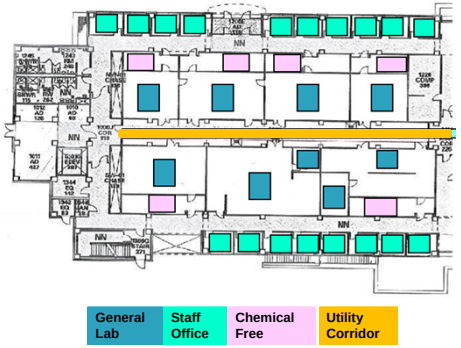
Design Guidelines: Buildings & Zoning



- Risk zones:
  - Safety
    - separation
    - egress
  - Security
    - access control,
    - standoff
  - Efficiency
    - utilities,
    - ventilation,
    - daylighting

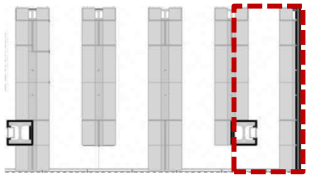
Design Guidelines: Buildings & Zoning

- Corridors
  - Separate movement of
    - general population
    - laboratory personnel
    - chemicals and laboratory materials
  - Internal utility corridor provides
    - access to utilities for maintenance
    - additional emergency exits



Design Guidelines: Lab Modules

- **The laboratory module is the key unit in any lab facility:**
- a good lab module will *coordinate all systems* to provide:
  - *Function*—you can use it now.
  - *Flexibility*—Research is changing all the time, and buildings must allow for it.
    - private companies physically change labs by ~25% each year.
    - academic labs change layouts for 5–10% of their labs annually.
  - *Expansion*—lab modules allow for simpler building expansions or contractions.



- A common laboratory module design:
  - width of ~10'-6" (3.2m),
    - based on casework and equipment of 2'-6" (0.76m) deep on each wall, a 5' (1.5m) aisle, and 6" (15cm) for a wall.
    - the 5' (1.5m) aisle is a minimum in US for the Americans with Disabilities Act (ADA).
  - length of 20–30' (6.1–9.1m),
    - based on the size necessary for the lab work, equipment, and cost of the structure.

Design Guidelines: Laboratories

- General considerations:
- 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)
- Construction materials should be appropriate for chemicals
  - Benchtops
  - Cabinets & shelving
  - Flooring
  - Avoid metal drainpipes
- Consider all hazards
  - Natural disasters
  - Accidents
  - Malicious

Equipment Tie-downs for Earthquake

Design Guidelines: Laboratories

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

Consider using both or having connected access

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Design Guidelines: Laboratories

- Teaching laboratories:
  - Open floor plan
  - Two safe exits minimum
  - Benches in "Islands"
  - Write-up areas often in the lab
  - Higher occupancy than research labs
  - Less instrumentation than research labs
  - Storage for student book bags and coats
  - Design for small teams to work, in addition to lectures
  - May have mobile casework that allows for different classes to be taught in the same space
  - Sound levels in labs must be low to allow normal conversations and collaboration
  - commonly taught only during the day, during the workweek.

- 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
- Prep rooms to set up supplies before classes may be located between labs

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

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Design Guidelines: Wet Labs

Wet Labs:

- Utility connections at each lab module
  - Utility connections can include electrical, vacuum, natural gas, oxygen, CO_2, and distilled water.
- Approximately one 6' (2m) fume hood for each lab module, with
  - direct 100% exhaust
  - vented chemical storage cabinets under the fume hood (acids, flammables)
- Constant conditions for equipment performance and accurate experimental results
- No return air from the laboratory to other spaces
- Supply air is less than the exhaust air, for a negative pressure in labs.

- Finishes:
  - Resilient surfaces are essential.
    - epoxy paint for lab walls (floors optional),
    - monolithic, seamless, chemical-resistant vinyl flooring with integral coved base.
- Safety:
  - All lab spaces should contain:
    - a hand-held chemical fire extinguisher
    - a fire alarm pull station by each egress point
    - an audible and visible alarm in each occupiable space
    - toxic gas monitors (when present) at lab modules and gas storage area
    - eyewash and deluge shower located at every 4 modules.

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Laboratory Renovation: New or Renovated Labs?

Decision is often based on:

- Construction cost
- Feasibility
  - Structural capacity,
  - Code changes,
  - Community impacts.
- Scope of renovation,
- Loss of use during renovation,
- Time and phasing of construction,
- Expected performance of a renovated versus a new lab facility,
- Flexibility to meet future needs
- Maintenance & energy costs
- Environmental considerations,
- Municipal review boards and historical-building commissions
  - Authority to deny permits for
    - historical reasons, and
    - Political reasons.

Source: Forrest et al.; "Application of Lean Tools for Improving Space Utilization for Existing R&D Laboratories ; Labs21 Conference, 2010.

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Laboratory Renovation: Costs !!!!

Building Type	$/Sq Ft	$/Sq M	Relative Cost*	New/Renovate Ratio
*Relative Cost from normalized cost of office buildings				
Classrooms	99.50	9.24	**0.65**	New/renovate
new	232.00	21.55	1.53	4.19
renovated	55.33	5.14	0.36	
Offices	152.00	14.12	**1.00**	New/renovate
new	192.67	17.90	1.27	**1.73**
renovated	111.33	10.34	0.73	
College Dry Labs	193.00	17.93	**1.27**	New/renovate
new	249.50	23.18	1.64	**2.12**
renovated	117.67	10.93	0.77	
Hospital/Clinic	251.60	23.37	**1.66**	New/renovate
new	281.50	26.15	1.85	2.13
renovated	132.00	12.26	0.87	
College Wet Labs	282.25	26.22	**1.86**	New/renovate
new	302.33	28.09	1.99	**1.36**
renovated	222.00	20.62	1.46	
Biotech Labs	414.00	38.46	**2.72**	
Research Labs	435.00	40.41	**2.86**	New/renovate
new	454.00	42.18	2.99	**1.14**
renovated	397.00	36.88	2.61	

- Must balance cost with future function when considering new versus remodeled laboratory space.

source: State of Virginia, "Virginia Building Construction Cost Database", 2012; http://dgs.virginia.gov/LinkClick.aspx?fileticket=rLfxqDCCZS8%3D&tabid=1209

Laboratory Renovation: Costs !!!!

Component pricing for small-scale Lab refurbishing

Item	Cost-installed (Location 1)	Cost installed (Location 2)
Install & reconnect existing fume hoods to existing ductwork	$6,000 each	$7,500 each
Purchase & install new 6-ft (2m) fume hoods and connect to existing ductwork	$13,200 each	$16,500 each
Replace Piping	$20-28.50/linear ft	$28-32/linear ft
Replace Piping to benches (4 services + outlets)	$32-42/linear ft	$38-45/linear ft
Install new 5-ft (1.7m) epoxy resin benchtops	$325-450/linear ft	$425-550/linear ft
New island bench	$800-900/linear ft	$900-1,100/linear ft
Install end sink	$3,000 each	$3,300 each
Install new fluorescent lighting fixtures	$375 each	$400 each
New mylar finished acoustical ceiling tile w/grid	$8/sq.ft.	$10/sq.ft.
New flooring (not counting removal), vinyl composite tile	$3.50/sq.ft.	$4/sq.ft.
New flooring (not counting removal), seamless vinyl/heat sealed	$10/sq.ft.	$12.50/sq.ft.
Run dedicated outlet from existing panel with new circuit breaker to outlet 50 ft (16m) away	$750 each	$900 each

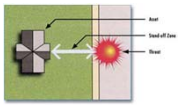
- For the same work, renovation costs more than original construction.
- Design time is to save costs and improve work.

Laboratory Renovation: Demolition Hazards

- 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

Image: Wikipedia; http://en.wikipedia.org/wiki/File:Sewer_pipe_Bremerhaven.jpg ; _

Security, Safety & Sustainability: Balancing SS&S

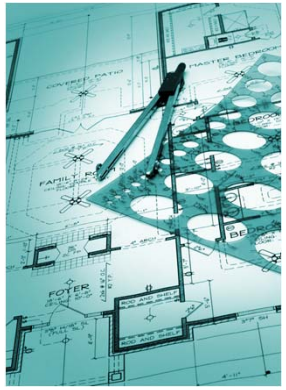


- SS&S conflicts:
  - Traffic control
    - stand-off to prevent attack
    - barriers versus emergency response
    - increase occupant exposure to weather
  - Building access
    - fewer exits for security
    - more exits for safety
  - Increased glazing
    - more daylighting
    - less blast resistance
  - Site selection trade-offs
    - urban saves open space
    - urban has more hazards, traffic/exposure, less visibility
    - urban heat-island effect
    - urban has available utilities
- SS&S compatibilities:
  - Compact, zoned building
    - efficient heating/cooling
    - simplified egress & access control
    - increase stand-off distance
  - Massive reinforced concrete wall
    - blast protection
    - passive solar energy storage
  - High-efficiency systems
    - reduce energy use
    - increased reliability (safer and more secure)
  - Erosion controls
    - stabilize building foundations, site features
    - trees shade sun and filter air
    - reduce flooding/weather impacts
  - Dry fire hydrants
    - reduce water demand
    - increased reliability (no power, non-potable water okay)
  - Computer energy management system
    - increased reliability (safer and more secure)
    - energy efficient controls
    - detection and monitoring
  - Renewable distributed energy
    - Backup energy on-site (energy security)
    - Reduced emissions

Laboratory Design: Conclusions

- ☑ Basics
- ☑ Chemical Containment
- ☑ Design Examples
- ☑ Renovation
- ☑ Security, Safety & Sustainability

Make yourself a part of the laboratory design process in order to support Chemical Safety and Security



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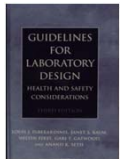


Chemical Waste Management & Disposal

Overview of Presentation

- Definitions of hazardous waste
- Why government regulation is necessary
- Key elements of chemical waste management
- Laboratory waste management
- Industrial waste management
- Disposal considerations
- References

Definition of Waste

- **Definition of Waste- Basel Convention 1992**

  "Substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law"

- **Definition of Hazardous Waste- EPA**

" Liquid, solid, contained gas, or sludge wastes that contain properties that are dangerous or potentially harmful to human health or the environment."

Characteristic – Ignitable–Corrosive–Reactive–Toxic

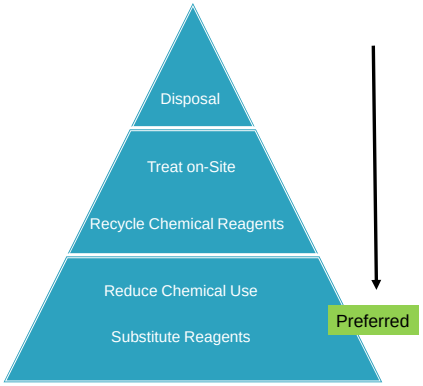
Listed – by industrial source

Why Government Intervention is Necessary

- Hazardous waste will be disposed of in the least expensive manner
- There is no profitable market for hazardous waste products
- Government regulations and fines provide an incentive for proper management
- Without regulation dumping will prevail

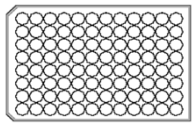
Chemical Waste Management

- Key Elements
  - Product substitution
  - Reduce use
  - Recycling
  - Treatment
  - Disposal
- *Chemical management is intrinsic to waste management*



Laboratory Chemical Waste: Substitution and Reduction

- Substitution
  - Replace a hazardous solvent with a non-hazardous one
- When purchasing automated equipment think of chemical waste
- Reduction
  - Procure and use less
  - Control "orphan" chemicals
  - Use microscale instrumentation



Industrial Chemical Waste Substitution and Reduction

- Substitute less hazardous raw materials for processes
- Improve process controls
  - –Separate waste streams
  - –Combine streams for waste neutralization (acid–base)
- Improve equipment design
- Perform regular preventive maintenance on process equipment
- Convert waste to energy when feasible

Laboratory Chemical Waste: Recycling

- Appropriate for laboratory or small facilities
- Create an active chemical exchange program
- Reuse by others in the university
- Beware of accepting unusable chemicals
- Exchange for credit with suppliers by agreement

Donated chemicals are not always "free"

Laboratory Chemical Waste: Recycling

May Recycle (examples)

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

Do NOT Recycle (examples)

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

Do NOT recycle if it presents a safety or security hazard

Laboratory Chemical Waste: Recycling

Laboratory Solvents

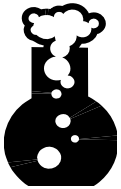
- May be distilled
- Keep solvents segregated prior to separation
- Avoid contamination due to careless handling
  - Requires good labeling
    - A small amount of the wrong chemical can ruin a desired separation
- Azeotropes may prevent separation
- Boiling points must be widely different

- Be aware of hazards
  - Do not evaporate or distill corrosive, radioactive, peroxides or peroxide formers
  - Beware of toxics and flammables
  - Use proper ventilation

Solvents that should not be recycled by distillation

Accidents have been reported for these distillations

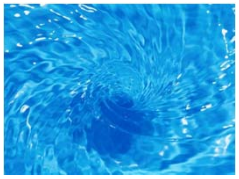
- Individual Substances
  - Di-isopropyl ether (isopropyl alcohol)
  - Nitromethane
  - Tetrahydrofuran
  - Vinylidene chloride (1,1 dichloroethylene)
- Mixtures
  - Chloroform + acetone
  - Any ether + any ketone
  - Isopropyl alcohol + any ketone
  - Any nitro compound + any amine



Laboratory Chemical Waste: Dilution

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



Laboratory Chemical Waste: Treatment References

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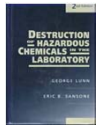
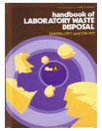




Industrial Hazardous Waste: Treatment Methods

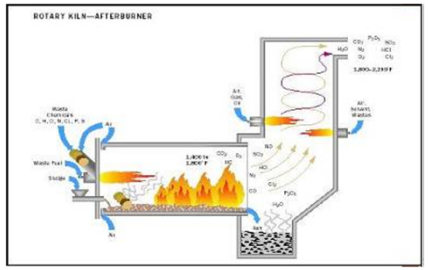
- Thermal desorption
- Pyrolysis gasification
- Combustion
  - -Incineration
    - -Industrial furnaces
    - -Cement kilns
- Molten glass solidification
- Plasma
- Stabilization
- Waste to Energy

Thermal Desorption: Advantages-Disadvantages

- Advantages
  - Low $$ compared to other thermal technologies
  - Low regulatory hurdles for permitting
  - Can be applied in the field
  - Allows for both destruction and recovery of organic contaminants
- Disadvantages
  - Material larger than 2 inches needs to be crushed or removed
  - Plastic soils tend to stick to equipment and agglomerate
  - Highly contaminated soils will require multiple cycles
  - Not amenable to semi-volatile or non-volatile, chlorinated hazardous constituents. (Example: PCBs, pesticides)
  - Fugitive emissions
    - Exposure risk to workers and environment

Incineration

- Incineration = "The controlled burning of waste"
- Requires 3 "T's":
  - Time: 2 seconds minimum
  - Temperatures: 1000°C-1200°C
  - Turbulence: Mixing during burn
- Rotary Kiln or Fixed Grate
- Secondary Combustion Chamber (afterburner)
- Rapid cooling of ash to prevent toxic air emissions (dioxins/furans)



Source :http://www.pollutionissues.com/

Incineration: Is not the same as Open Burning

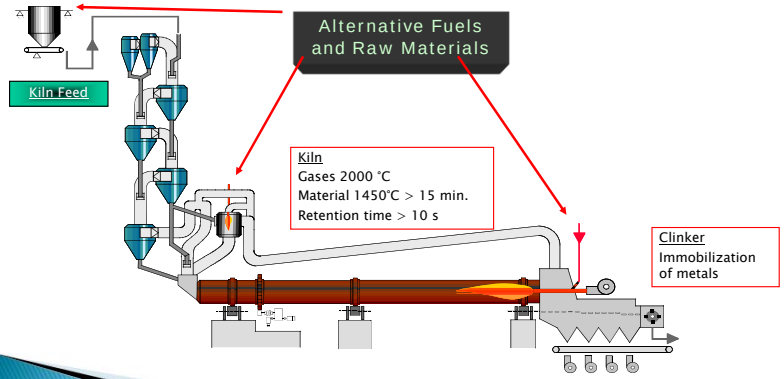
	Open Burn (µg/kg)	Municipal Waste Incinerator (µg/kg)
PCDDs	38	0.002
PCDFs	6	0.002
Chlorobenzenes	424150	1.2
PAHs	66035	17
VOCs	4277500	1.2

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

Incineration: Advantages-Disadvantages

- Advantages:
  - Can be applied to a wide variety of hazardous wastes
  - Provides destruction and volume reduction of the waste
- Disadvantages
  - Not amenable to waste containing high concentration of heavy metals (> 1%)
  - Waste feed mechanisms often complex
  - High capital cost due to extensive Air Pollution Control (APC) system and sophisticated controls required to meet emission standards
  - Ash must be treated for leachable metals prior to land disposal

Typical Dry Process Cement Kiln



Industrial Furnaces: Kilns, Furnaces, and Boilers

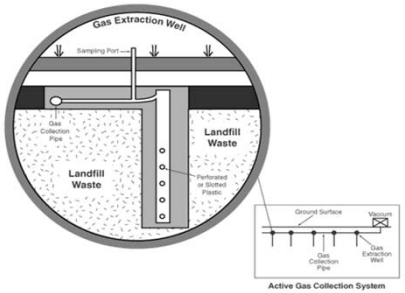
- Advantages:
  - Owners of industrial furnaces make profit from treating waste
  - Air pollution control equipment is already in place
  - Cement kilns have a sufficient residence time and temperature for treating hazardous chemical waste
- Disadvantages
  - Some industrial waste may not be allowed
  - The waste feed mechanisms are complex
  - The admixture rate may be too low
  - Using industrial furnaces for waste treatment may interrupt industrial processes

Stabilization Processes

- Stabilization techniques chemically treat hazardous waste by converting them into a less soluble, or less toxic form.
- Principally used for metal-bearing wastes
- Stabilization has a limited applicability to organic wastes
- Advantage
  - Low cost, simple technology, suitable for many types of hazardous waste
- Disadvantages
  - Increases waste volume

Waste Disposal Methods

- Landfills
- Surface impoundment
- Waste pile
- Land treatment unit
- Injection well
- Salt dome formation
- Salt bed formation
- Underground mine
- Underground cave

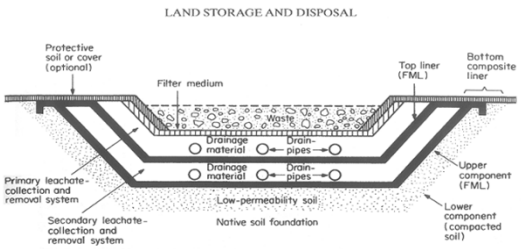


http://www.epa.gov/lmop/basic-info/lfg.html#01

Waste Disposal: Landfills

- Design
- Must have liners compatible with waste
  - Clay, or
  - Flexible membrane
- Leachate
  - Primary and secondary collection systems
  - Removal system
  - Leak detection system
- Surface water collection
- Gas collection and removal
- Are capped and monitored

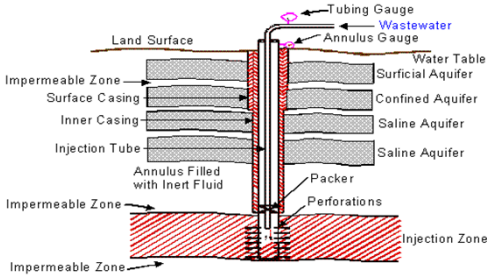
Example: Landfill Liner System



http://www.epa.gov/wastes/hazard/tsd/td/disposal.htm

Groundwater and leachate monitoring are essential

Disposal: Deep Well Injection



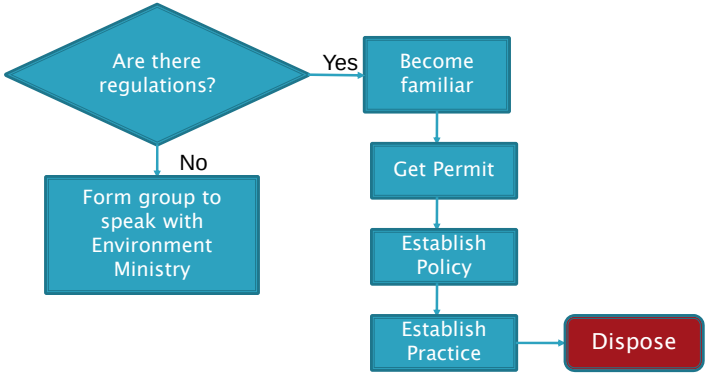
- *550 Class I wells in the United States*
- 43% of all hazardous waste in United States !!!

http://www.epa.gov/safewater/uic/index.html

Waste Disposal: Selection of Contractor

- Consider:
  - Disposal service licensed or compliant with your country's regulations
  - Employees are trained in handling and emergency response
  - Packaging requirements
    - Lab packs
  - How will waste be transported?
  - Where and how will waste be disposed?
  - Chain of custody
  - Always maintain records

Waste Disposal Flow Chart



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  - http://www.epa.gov/epawaste/partnerships/sc3/index.htm
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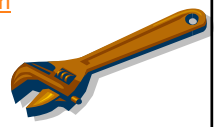
  - http://www.iswa.org/



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  - http://dels.nas.edu/Report/Prudent-Practices-Laboratory-Handling/12654

US Environmental Protection Agency Resources

Summary of Discussion

- Gave definition of hazardous waste
- Provided reason for government regulation
- Discussed methods for reducing, treating, and disposing of laboratory waste
- Discussed methods for reducing, treating, and disposing of industrial waste
- Discussed the merits of using waste to energy technology Provided examples of hazardous waste methodologies

On-site Recycling and Waste Treatment

Waste Management: Recycling

Recycling by redistribution

Recycling of metals

- Gold-mercury-lead- silver

Recycling of solvents

- Clean for reuse-rotovap
- Distill for purity

Recycling of oil

Recycling of E-waste

Chemical recycling

Reuse by others in the organization or community

An active chemical exchange program
Beware of accepting unusable chemicals

Reuse in experiments in the laboratory

Exchange for credit with suppliers by agreement

What should <u>not</u> be recycled

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

What should be recycled or redistributed?

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

Chemical Recycling –Precious Metal

For reuse in lab or for exchange

- Requires chemical knowledge for lab reuse
- Recover from solution – evaporate then
  - Ignite (Au, Pd, Pt)
  - Reduce with $NaBH_4$ for metal powder or by electroless plating (Pt, Au, Pd, Ag, Rh).
  - Electroplate
  - Metal recovery Ion exchange–then ash

Source : Handbook of Laboratory Waste Disposal, Pitt &Pitt, John Wiley, 1986

Chemical Recycling – Silver

Recovery from chemical oxygen demand (COD) test

- Acidification and ppt as AgCl

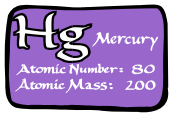
Recovery from photographic fixing solution

- Precipitate as sulfide
- Precipitate with TMT (trimercapto-s-triazine)
- Electrolysis (terminal and in-line)
- Metal replacement (iron containing cartridges)
- Ion exchange

Many companies will buy the recovered silver

Chemical Recycling – Mercury

- Mercury can be recovered for subsequent lab use or for recycle by vendor
- Remove particulates and moisture by allowing slow drip through a hole in a conical filter paper
- Never distill Hg on-site



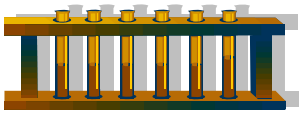
Solvents can be recovered by distillation

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

Solvent recycling – general guidance

Solvent recycling requires care and organization

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



Solvent recycling – general guidance

Solvent recycling requires care and organization

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

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

Solvent recycling – low efficiency

Rotovap can be used to pretreat

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

Solvents that should not be recycled by distillation

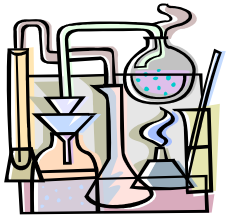
Accidents have been reported for these distillations

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

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

Practical examples of recycling

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



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

Chemical Spill Response and Cleanup

Size of spill determines response

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Emergency Notification and Response

- The notification and emergency response procedure for accidents and incidents should be written and understood by everyone.
- A rapid and effective response helps insure injured persons receive rapid and correct medical attention and/or that incidents are quickly contained and controlled, and that effects and damage to people, facilities, the environment and the community are minimized.

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Potentially Hazardous Chemical Spill Cleanup Procedure

- Attend to injured/contaminated or exposed individuals.
- Remove persons from the exposure without endangering yourself
- Alert persons in the immediate area to evacuate.
- Consider people with disabilities
- If spill is flammable, turn off heat and ignition sources (if possible)
- Call Emergency Phone Number to report incident
- Post area—**Danger, Keep Out! Hazardous Chemical Spill**
- Close doors to affected area
- Locate MSDS
- Assist Specialized Safety Cleanup personnel if you are knowledgeable about the spill.

Only trained personnel should do cleanup!

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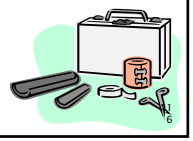
Chemical Laboratory First Aid

- First aid kits for minor injuries should be centrally located and available in or nearby each laboratory.
- Use for minor accidents/incidents.
- Determine if medical attention is necessary.
- Immediately notify proper authorities, if necessary or in doubt.
- Determine if chemical exposure occurred.
- If necessary, take immediate preventative action to make lab safe, e.g., shut down reactions, electricity, etc.



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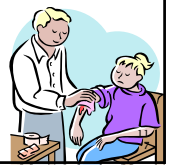
Chemical Laboratory First Aid

Wounds:

- If bleeding is profuse, apply steady, direct pressure over the wound using a sterile dressing, if possible, or clean cloth.
- Keep the wound as clean as possible.
- Remove or cut away any clothing covering the wound.
- Flush with water to wash out loose dirt and debris.
- Do NOT try to remove foreign matter embedded in the wound
- If there is an impaled object, Do NOT try to remove it. Efforts to do so may cause severe bleeding and further damage.
- Control bleeding by direct pressure, but do not apply pressure on the impaled object itself or on immediately adjacent tissues.
- Stabilize the impaled object with a bulky dressing.



Chemical Laboratory First Aid

Thermal Burns:

- Immerse burned area in cold water or apply cold compresses for 30 minutes
- Do NOT attempt to rupture blisters on the burn

Chemical Laboratory First Aid

- Chemical Burns:
  - Speed is essential.
  - Consult chemical labels & MSDS for special instructions.
  - Flush burn area immediately with water for 15 minutes.
  - Taking care not to spread the chemical, remove any clothing,especially shoes and socks, that may be contaminated.
  - Do NOT use salves, ointments, cream, sprays, or any other covering except for chemical-specific remedies such as for HF or phenol.
  - Do NOT attempt to rupture blisters over the burn.
- If chemicals splashed into the eyes:
  - Flush the affected area with water for a minimum of 15 minutes.
  - Remove contact lenses, if present, as rapidly as possible, since they prevent water from reaching the cornea.
  - Eyelids may have to be forced open so eyes can be totally flushed.
  - If large particles are in the eye, an eye wash should not be used.
  - Do NOT use salves, ointments, cream, sprays, or any other covering except for chemical-specific remedies such as for HF or phenol.

Spill Cleanup Preparation

- Emergency Equipment
  - Internal communication/alarm system
    - Telephones (Label all phones with emergency numbers)
    - Alarm pull boxes
  - External communication/alarm system
  - Fire extinguishers
  - Emergency eyewash and showers
  - Spill stations

Spill Cleanup Preparation

- Knowledge Needed
  - Location of emergency electrical circuit breakers, shutoff valves, switches, disconnects for building, area, laboratory, room, equipment
  - Response procedures for personal injuries/ exposures and emergencies
  - Emergency evacuation routes (posted)

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Spill Cleanup Preparation

- Maintain Current Safety Data Sheets

  Attention to:
  - Chemical hazards
  - First aid information
  - Spill response
  - Firefighting information
  - Engineering controls
  - Stability and reactivity
  - Proper storage
  - Disposal considerations

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Spill Cleanup Preparation

- Maintain complete Spill Kits
  - Absorbent material
    - Absorbent pillows or powders
    - Activated carbon for organic solvents
  - Neutralizing agents
    - Acid Neutralizers –e.g., sodium bicarbonate ($NaHCO_3$) powder
    - Base Neutralizers–e.g., citric acid powder
    - Solvent Spills–activated carbon
  - Personal Protective Equipment (PPE)
    - 2 pairs of chemical splash proof goggles
    - Several pair of disposable gloves
    - Disposable, charcoal (volatile, aerosol) respirators
    - Disposable aprons or jump suits
    - Disposable shoe covers (for floor spills)

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Spill Cleanup Preparation

- Additional cleanup equipment:
  - Plastic pail/bucket(s) with lids (large enough to contain spill and cleanup material)
  - Plastic dust pan
  - Broom or brush
  - Plastic bags
  - Sealing tape
  - pH paper
  - Sign(s):
    - Danger Chemical Spill
    - Keep Out

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Spill Cleanup Preparation Risk Assessment

(Anticipation)

- What is the worst thing that could happen if a chemical was dropped/spilled, etc.?
  - inconvenience
  - skin burns
  - fire
  - explosion
  - chemical exposure (fatality; injury, permanent, temporary)
- Know the worst case scenario for a spill
- How you would respond to a spill, emergency situation?
- What are the appropriate clean-up and decontamination procedures?

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Spill Cleanup Preparation Risk Assessment

Estimating Potential Hazards (Evaluation)

- What are the chemical, physical and toxicological properties of the chemicals you are using?
- What is the amount of chemical?
- What are your knowledge and skills?
- What are possible locations/conditions of a spill, accident?
- Ask for assistance if you are unsure

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Spill Cleanup Preparation Risk Assessment

Chemical Toxicity (Evaluation)

- Route of exposure
- Acute toxins
- Acids and corrosives
- Lachrymators, irritants and allergens
- Carcinogens, repro-toxins, etc.
- Biohazardous, radioactive material

Chemical Flammability (Evaluation)

- Hazardous locations
- Ignition sources
- Presence of other flammables
- Store excess flammables in flammable storage cabinets
  - Use external flammable storage rooms for large quantities.

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Spill Cleanup Prevention (Control)

- Eliminate clutter
- Purchase only amount of chemical required
- Understand work practices and procedures
- Use unbreakable secondary containers
- Store chemicals properly
- Dispose of waste and excess chemicals properly and timely

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Cleanup Responsibilities

- Laboratory Staff:
  - Ensuring timely spill reporting and cleaned up
  - Cleaning up nuisance spills in their area, even if someone else spills them (janitors, service people)
  - Knowing the properties of what they work with
  - Taking reasonable steps to prevent spills
- Specially trained Safety Cleanup Team:
  - Assist researchers not comfortable cleaning up spills (including nuisance spills)
  - Clean-up serious/major spills

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Nuisance Chemical Spill

- **Spills of < 4L of known hazard, that you are comfortable cleaning up**
  - Assess the hazard
  - Alert people in immediate area
  - Post area
  - Wear appropriate PPE
  - Confine spill
  - Absorb excess, surround area with absorbent material
  - Avoid breathing aerosols
  - Use forceps, etc., to pickup broken glassware, etc.
  - Work from outer edge toward center to cleanup
  - Do not dry sweep
  - Clean spill area with soap & water, specific solvent or neutralizing material (if known)
  - Collect contaminated absorbent, gloves, residues in plastic bag(s)
  - Label, with chemical name if possible, and dispose of waste properly

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

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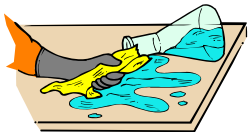
Potentially Hazardous Spills



- Spills of > 4L or
- Smaller spills of:
  - Low LD_{50} (high acute toxicity)
  - Carcinogens, repro-toxins, etc.
  - Flammable liquids or metals
  - Chemicals of unknown toxicity or hazards

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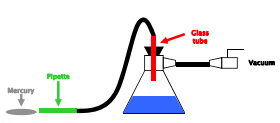
Mercury Spill Cleanup

- Cover spill from perimeter toward the center.
- Remove debris:
  - Dispose of as hazardous waste and cleanup material (gloves, towels, etc).
  - All waste should be placed in labeled, sealed, leak-proof, containers.
  - Never dispose of mercury waste in sewer system.
- Special vacuum cleaners designed to pick up mercury safely are available for cleanup.
- NEVER sweep up spill or use a regular vacuum.



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Acknowledgement

Mercury Spill Cleanup,
University of Wisconsin Safety Office
http://www.uwm.edu/Dept/EHSRM/LAB/labHg.html

Chemical Spill Response Record Keeping

- Maintain accurate records of accidents/incidents response
  - All involved personnel
  - Exposure measurements
  - Medical examination, consultations
  - Medical tests
  - Medical follow-ups
- Records should be confidential and protected from unauthorized disclosure
- Records should be shared with victim
- Records should be examined for patterns.

Emergency/Security Planning Management

Overview of Presentation

- *Emergency* Defined
- Types of Emergencies
- Emergency Management
  - Emergency Planning
  - Incident Command System
  - Emergency Response

Emergency Defined

"An unforeseen combination of circumstances or the resulting state that calls for immediate action"

"An urgent need for assistance or relief"

"May occur without advance warning"

Merriam Webster definition Photo Credit: http://www.fema.gov/

Emergencies

- Hazardous materials releases
  - Accidental
  - Intentional
- Fires
- Explosions
- Medical

- Natural Occurrences
  - Earthquakes, typhoons, fires, floods, etc.
- Other incidents
  - Bomb threat
  - Terrorism

Emergency Management

- Planning
  - A continuous process
  - Purpose:
    - Avoid the emergency
    - Reduce the impact
- Response/Mitigation
  - Requires highly-trained personn
- Recovery/Stabilization
  - Community or government support

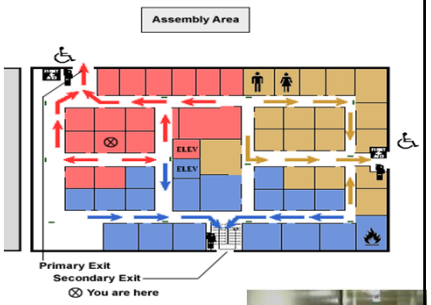
Emergency Planning

General Plant Emergency Plan

- Involve engineering, safety, & security
- Distribute to and train all employees
- Include in the plan:
  - Roles and responsibilities
  - Procedures for reporting emergencies
  - Emergency phone numbers
  - Procedures for specific emergencies
  - Maps
    - Evacuation routes
    - Assembly areas

Emergency Planning

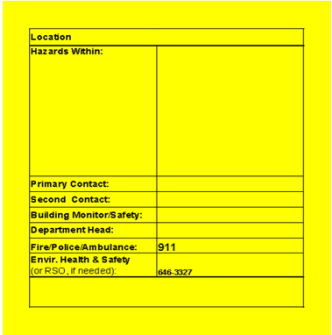
- Have an evacuation map for all buildings and areas and POST IT
- Continuous and unobstructed path from any point within a workplace
- Consists of three parts:
  - Exit access
  - Exit
  - Exit discharge
- Exit routes must be permanent
  - Unobstructed
- Well marked



Emergency Planning

Post each area with:

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



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

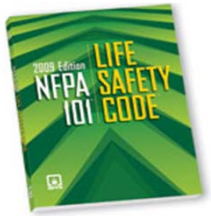
Plant Emergency Response Procedures

- Evacuate or shelter in place?
- Respond?
- Who will respond?
  - On-site HAZMAT team?
    - Require training
  - Community fire department?
    - Establish memorandum of understanding
- Medical support
  - In-house?
  - When to call for outside assistance
- Emergency shutdown procedures
- Decontamination procedure

Emergency Planning

General Fire Protection

- Identify your fire and life safety codes
- Inventory your flammable materials
  - Quantity
  - Location
- Secure appropriate flammable liquid storage
- Identify & control ignition sources
- Housekeeping
  - Control combustible materials



Emergency Planning

Post exit signs
Keep exits unlocked or equipped with panic bars.

Emergency Planning

Detection & Mitigation Equipment

Alarms, smoke & heat detectors, sprinklers, emergency lighting and fire extinguishers need to be properly located, maintained, and serviced regularly.

Emergency Planning

Response Equipment

- Initial hazard assessment
- Place in accessible locations
  - Fire extinguishers
  - Spill control kits
  - PPE
  - Respirators
  - DECON showers
- Schedule routine maintenance and inspection of all response equipment

Emergency Planning

American Industrial Hygiene Association Emergency Response Planning Guidelines

- *ERPG-1*

  The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.
- *ERPG-2*

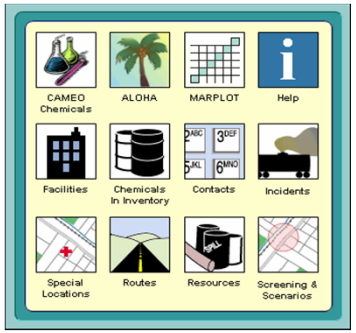
  The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- *ERPG-3*

  The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Emergency Planning

Software Applications

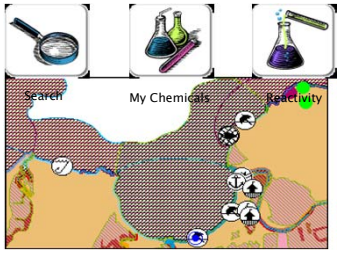
- Assist first responders with accessible and accurate response information
  - Interactive *Cameo* software modules
  - *Cameo Data Management*
    - Location of chemicals
    - Chemical quantities
    - Storage conditions



http://www.epa.gov/emergencies/content/cameo/request.htm

Emergency Planning

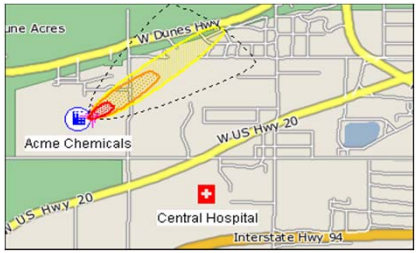
- Cameo Chemicals
  - Supplies information on the substance released and safe response actions
  - Outputs *chemical response datasheets*
  - http://cameochemicals.noaa.gov
- Mapping applications
  - *MARPLOT*
  - Can overlay a contaminated area over a map
  - Displays threat zones



http://www.epa.gov/emergencies/content/cameo/request.htm

Emergency Planning

- Atmospheric dispersion models
- *Aloha* software
- Estimates threat zones associated with chemical releases, including toxic gas clouds, fires, and explosions



http://www.epa.gov/emergencies/content/cameo/request.htm

Emergency Planning

Aloha Software:

- Example of Inputs
  - Enter date, time, location
  - Choose a chemical (Aloha library)
  - Enter atmospheric information
  - Choose a source:
    - direct, puddle, pipeline, or tank
  - Enter source information
    - Release amount, chemical fire
  - Specify the Levels of Concern (LOCs)
  - Choose the type of hazard
    - Toxic vapor cloud or a vapor cloud explosion

Emergency Planning

Unity of Effort:

- Success in managing an emergency depends on clear roles and responsibilities and a clear chain of command.
- Use of an Incident Command System (ICS) allows coordination among different jurisdictions and functional responsibilities to interact effectively on the scene.

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Emergency Planning

Incident Command System:

- Developed to resolve:
  - Ineffective communication
  - Lack of common command structure
  - Lack of accountability
  - Inability to coordinate resources
- Based on basic business management
  - Plan
  - Direct
  - Organize
  - Communicate
  - Delegate
  - Evaluate

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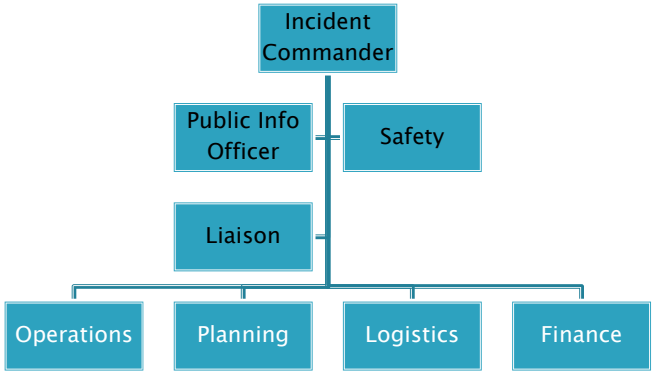
Incident Management System



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Emergency Response

SAND No. 2011-0722C
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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Sandia National Laboratories

Response to Hazardous Materials Incidents

What makes hazardous materials incidents so dangerous?

- Material characteristics may be unknown
- Chemical, physical hazards, biological (?) hazards
  - Toxic
  - Corrosive
  - Flammable
  - Reactive

- Conditions may be confusing
- Limited time to respond to the incident

Who Will Respond?

- Employees?
- Local police and fire department?
- Local ambulance, hospital?
- Military?
- Local HAZMAT team?
- Plant HAZMAT team?

OR, ALL OF THE ABOVE

Emergency Response Decision Making

DECIDE Process

- Detect hazmat presence
- Estimate likely harm
  - Material properties
  - Containment
  - Weather
  - Modeling data
- Decide on objectives
- Identify action options
- Do best option
- Evaluate progress

Benner, L. (1978) DECIDE for Hazardous Materials Emergencies, Presented Papers.

Emergency Response Decision Making

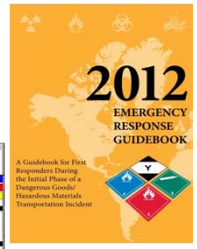
Detect Hazardous Material Presence

- Worker reports incident/spill/injury
- Odors, smoke, flames, reactions
- Response team detection
  - Instrumentation must be calibrated!
  - Direct reading instruments
    - LEL, oxygen monitors
    - Photoionization detectors
    - Gas detectors-methane, NH_3, CO, Cl_2, H_2S
  - Personal sampling and analysis

Industrial Scientific. http://www.indsci.com/products/#multi
RAE Instruments. http://www.raesystems.com/products
Sensidyne Air pumps. http://www.sensidyne.com

Emergency Response
Estimate Likely Harm

- Determine material properties
  - Safety data sheets
  - Emergency Response Guidebook
  - ERPGs
- Access site conditions
  - Size of spill / release
  - Weather
  - Models
    - Cameo software



Emergency Response
Estimate Likely Harm

Evaluate chemical(s) released:

- By quantity
  - Greater than 500 grams ? (40 CFR 302 & 355)
- Toxicity
  - $LC_{50} \leq$ 200 ppm or 20mg/liter
- Dispensability
  - Boiling point $\leq$ 100º C, $\leq$ 10 microns particle size
- Flammability/Reactivity
  - Flashpoint < 60º C
- Dispersion Modeling
  - Example: AIHA ERPG 1 at 30 meters

(ERPG-1: 2 ppm; ERPG-2: 50 ppm; ERPG-3: 170 ppm)

Emergency Response
Decide on Objectives

Priorities

1. Persons
   - Responders
   - Workers
   - Community
2. Property
   - At the site
   - Protecting community
3. Environment
   - Air, ground and surface water, soil, wildlife

Emergency Response

Initiate the Incident Command System:

- Incident Commander
  - Establishes the strategy and tactics
  - Has ultimate responsibility for incident outcome
  - The position is established for every incident
  - May establish a command post
- Command Staff positions
  - Safety officer
  - Liaison officer
  - Information officer

Emergency Response Identify Action Options

Large Catastrophic Incidents

- Perform a risk analysis of response options
  - Risk analysis should be a continuous process during an event
- Response options are dependent on plant capabilities and approach
  - Mode of response–defensive or offensive?
  - Training levels of responders (HAZMAT trained?)
  - Technical resources
  - External support available?
    - Local fire department or HAZMAT
    - Military

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Identify Action Options Offensive Options Large Event

- Written Standard Operating Procedures
  - For each hazardous material or process on-site
- Select action from alternative strategies
- Select PPE/equipment for responders
  - http://osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9767
  - Ensure compatibility of PPE with hazards
- Safe approach is to select the highest PPE level
- Then, reduce the level when sufficient information on the hazard

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Identify Action Options Laboratory Incidents

- Perform an emergency response risk assessment
  - Identify potential hazards associated with laboratory tasks
  - Identify equipment and personal protective equipment required in the event of an incident
  - Document response and evacuation procedures (SOPs)
  - Train laboratory personnel to procedures
  - Report incidents and revise procedures as needed

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Fires

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

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Home Fires

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

[redacted]

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

Industrial Fires

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

Key Elements of Fire Safety

Get occupants out

Minimize property loss and interruption

Fire Containment/Suppression

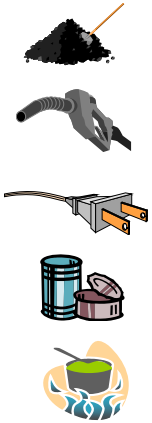
Common Myths

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

Classification of Fires

With recommended extinguisher distances

- **A** Ordinary combustibles – cloth, paper, wood, coal — ~23 m
  - Extinguish by cooling or smothering
- **B** Flammable/combustible liquids, gases, greases and oils – gasoline, diesel fuel — ~15 m
  - CO_2 or dry powder: monoammonium phosphate
- **C** Energized Electrical equipment cables, motors — nearby
  - Extinguishing agent must *not* be conductive
  - CO_2 or dry powder
- **D** Combustible metals – sodium, magnesium, titanium — ~23 m
  - Extinguishing agents must absorb heat and not react with the metal
  - special dry powder, sand
- **K** Restaurant grease fires associated with cooking — nearby
  - Special liquid chemicals



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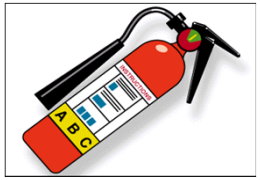
Fire Extinguishers

Dry Chemical



Water

Placed within ~15–25 m

Annual & Monthly inspections

CO_2

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Responding To A Fire

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Employee Training

- Few employees know how to *effectively* use extinguishers!
- Need for training:
  - Initial training
  - Annual refresher

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Using a Fire Extinguisher

P Pull
A Aim
S Squeeze
S Sweep

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

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Electrical Fires

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

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WHAT TO DO IF SOMEONE CATCHES ON FIRE

If *you* should catch on fire:

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

This smothers the flames, possibly saving your life.

Remember *STOP, DROP and ROLL*

If a *co-worker* catches on fire:

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

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WHEN NOT TO FIGHT A FIRE

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

DON'T FIGHT THE FIRE YOURSELF

CALL FOR HELP

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Proper storage of Flammables is an important part of Fire Safety

Limit quantities stored

Safety cans

Secondary Containment

Flammable storage cabinets, rooms or buildings

Fire Prevention Inspections

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

Violations

Violations

6-Way Multi-plug

Multi-plug

Any Questions?

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Chemical Safety and Security Plan

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Sandia National Laboratories

First step: Collect information

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

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Assessment Questionnaire

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

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Assessment Questionnaire, cont'd.

- List individuals (managers, PIs, professionals, technicians) with Safety & Security responsibilities; 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 (SOPs)

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

Standard Operating Procedures (SOPs), cont'd.

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

Standard Operating Procedures (SOPs)

Consider written SOPs on:

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

Plan and SOPs Revision Guidelines

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

Lab Assessment, Part 5

Lab Assessment Exercise, Part 5

- Preparation for Group Presentations