Chemical Management and Risk Reduction

International Symposium on Chemistry for Life
Tlemcen, Algeria
13 March 2013

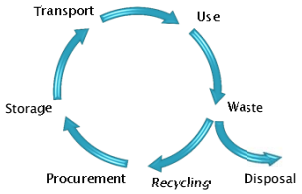
Workshop Overview:

- Chemical Management
  - Key Principles
  - Procurement
  - Inventory Management
  - Storage
  - Transport
  - Use of Chemicals
    - Activity: Standard Operating Procedures (SOPs)
  - Waste Management
    - Activity: Hazardous Waste Tags and Labeling
- CSS Risk Assessment
  - Risk Basics
    - Activity: Risk Perception
  - Chemical Risk Assessment
    - Activity: Chemical Safety Risk Assessment
- Summary, Conclusions, and Evaluations

Chemical Management

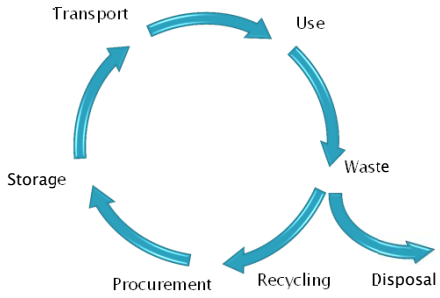
Overview: Chemical Management

- Key Principles
- Procurement
- Inventory Management
- Storage
- Transport
- Use of Chemicals
- Waste Management
- Summary and Conclusions



Key Principles: Chemical Life Cycle

- Control and accountability of chemicals at all times, from procurement to disposal as waste



Key Principles: Chemical Life Cycle

- Orphan Chemical
  - Does not have an owner
    - Person accountable
  - Does not have an apparent use or purpose
    - Surplus
  - Sometimes not labeled or identified
    - Unknown chemical

- **Cradle to Grave management of chemicals**
  - **Prevent chemicals from becoming orphans**
  - **Improve safety**
  - **Improve security**

Key Principles: Advance Planning

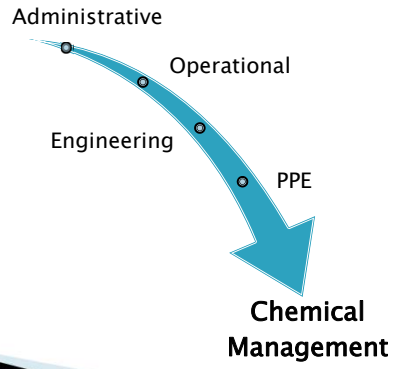
- When is the best time to figure out how to dispose of waste?

- Example, synthesis
  - What are the reaction products and byproducts?
    - How will they be handled?
    - How will they be stored?
    - How will they be labeled and accounted for?
    - How will they be disposed of?

Key Principles: Benefits of Chemical Management Best Practices

- Reduces Costs
- Saves Time
- Improves Research and Teaching
- Environment and Community Friendly
- Safety and Security

Key Principles: Components of Chemical Management



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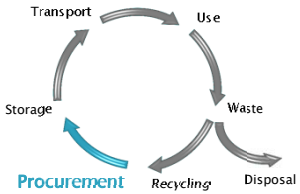
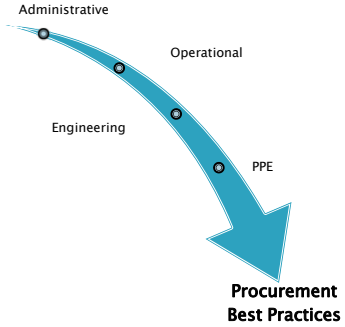


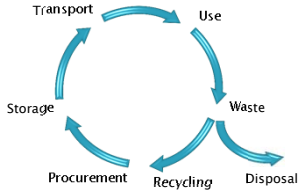
Procurement

- Planning
- Substitution
- Source reduction
- Surplus sharing
- Ordering Chemicals
- Receiving Chemicals



Procurement: Planning

- Think "Cradle to Grave" before purchasing or accepting chemicals
  - What chemicals are needed?
  - How much is needed?
  - How/where will they be stored?
  - How will they be handled/used?
  - How will disposal take place?



"Extra" chemicals are not usually a good idea

Donated chemicals are not always "free"

Procurement: Surplus Sharing

- How it works
  - Extra chemicals in good condition are posted to a list
  - Procurement requests go first to the surplus list
  - If in stock, requester gets option of taking surplus chemicals for free
- Barriers to surplus sharing
  - Requires coordination with centralized procurement
  - Chemical collecting, hoarding
  - Requires training
- Benefits
  - Reduces cost, waste, and hazards

Procurement: Ordering Chemicals

Things to Consider

- Costs
  - Purchase
  - Handling
    - Human
    - Monetary
  - Storage
  - Disposal
- Know your suppliers
  - Chemical shelf-life
    - Assay expiration, impurities
    - Hazardous decomposition
      - Peroxide-forming chemicals
  - Legitimate/licensed source

Ordering Procedure

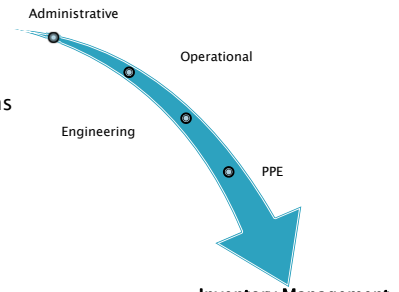
- Centralized system
  - Ensure proper planning
  - Tracking and accountability
    - Chemicals are going to people who are trusted, trained, and with a legitimate need

Procurement: Receiving Chemicals

- Receive deliveries of chemicals in a properly prepared area
  - Trained personnel
  - Storage requirements
  - Broken containers, spills
  - Inventory and tracking

Inventory Management

- "Living" database of chemicals
  - Updated with procurement, transport, use, and disposal
- Requires training and maintenance with inspections
- Control access to database
- Ensure control and accountability
  - Designated owner
  - No orphan chemicals
- May be required for regulatory compliance



Inventory Management: Database

- Name
  - IUPAC, common, trade
- CAS number
- Formula
- Ingredient
- Location
  - Facility, building, room, cabinet, shelf
- Owner
  - Organization
  - Individual
- Requester
- Purchaser
- Barcode
- Supplier or producer
- Physical state
- Hazards
  - Compatibility/storage info
  - COC flag
  - Biosafety/biosecurity level
- Safety Data Sheet (SDS)
- Certificate of analysis
- Quantity
- Date purchased or received
- Expiration date
- Status (open or not)
- Use and transfer history

It is possible to keep track of a lot of useful information with a computer/web-based chemical inventory management system

Inventory Management: Access Control

- Different levels of access to inventory system and database
  - Students
  - Faculty, staff researchers
  - Department heads, system administrators
  - Chemical safety and security officers, centralized procurement
- Outsider Threat
  - **Restrict access to information about COC locations and physical security**

- Insider threat
  - Personnel management
  - Procurement
  - **Inventory management**
    - **Chemical Owner**
    - **Physical Inspection**

Inventory Management: Physical Inspection and Reporting

- Assures accuracy of inventory database
- Provides visual assessment of chemical condition
- Should be done once or twice a year
  - More often for COCs
- Inventory reports may be required by law or by institution policy
  - Based on location
  - Quantities of chemicals purchased or used
  - Price
  - Expiration
  - Transport
  - COCs
- Use of a computer/web-based system makes reporting easier

Inventory Management: Conclusions

- What are the main challenges to effective chemical inventory management?
- Benefits of a Chemical Inventory Management System
  - Save time
  - Save money
  - Improve research
  - Improve safety
  - Improve security
  - Regulatory compliance
  - Earn recognition
- Published articles about chemical inventory management[1]
  - Ateneo de Manila University
  - Stanford University
  - Temple University
  - Los Alamos National Laboratory

[1] These and other articles are in *Journal of Chemical Health and Safety* http://www.journals.elsevier.com/journal-of-chemical-health-and-safety/

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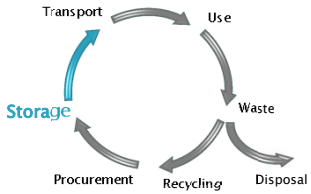
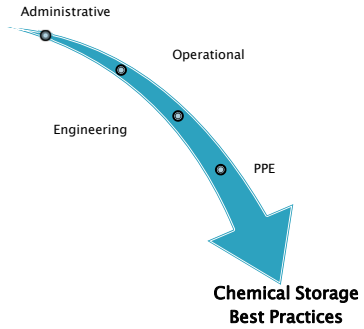


Storage

- General Guidelines
- Reactive Chemicals
- Labels
- Compressed Gas Cylinders
- Refrigeration
- Examples
- Access Control
- Activity: Chemical Storage



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Storage: General Guidelines

- Separate incompatible chemicals
- Separate flammables and explosives from ignition sources
  - Flammable storage cabinets
- Large containers on bottom shelves
- All containers properly labeled and closed

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Storage: General Guidelines

- Wipe-off outside of container before returning to storage area
- Secure COCs
- Use secondary containment
  - Label with compatibility group
- Fasten storage shelves to wall or floor
- Shelves should have a lip and/or rod

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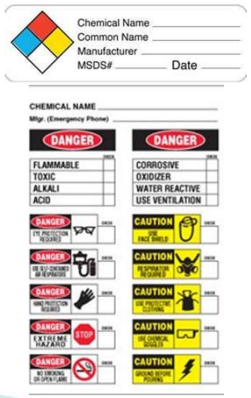
Storage: General Guidelines

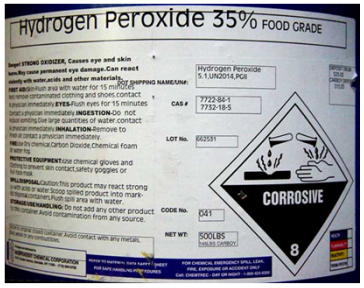
- **Do Not Store Chemicals**
  - On top of cabinets
  - On the floor
  - In hoods
  - Where there are wide variations in temperature, humidity or sunlight
  - In hallways
  - With food

Storage: Reactive Chemicals

- Water reactive, pyrophoric, oxidizers
- Peroxide-forming
  - Ethers, butadiene, others
  - Store in tightly closed original container
  - Avoid exposure to light, air, heat
  - Crystals or discoloration? Do not move or open container
  - Test for peroxides before using
    - Especially if distilling/concentrating
  - Know when to dispose
    - Mark when opened
    - Dispose even if unused

Storage: Labels





Storage: Compressed Gas Cylinders

- Keep cylinders outside and pipe into lab
- Store cylinders in lab
- Secure (chain/clamp)
- Screw down cylinder caps
- Store in well-ventilated area
- Separate and label empty cylinders
- Separate incompatible gases
- Transport safely

Storage: Refrigeration

- Types
  - Ordinary, household refrigerator/freezers
    - NOT safe for flammables
  - Flammables-safe refrigerator/freezer
    - May contain flammables, but are NOT safe to be in areas with flammable vapors
  - Explosion-proof storage
- Proper refrigerator/freezer labeling
- Precautions
  - Stable power
  - Not all refrigerants are completely safe
    - Toxicity, flammability, and physical hazards
- Do not store peroxide formers in a refrigerator
- Defrost occasionally to prevent chemicals from becoming trapped in the ice formations

Storage: Access Control

- Access limitations depend on the material or information
  - More control of access if COCs are present
- Lock areas, rooms, cabinets
  - Control of keys
- Label areas "Authorized Personnel Only"
  - Means of identifying authorized personnel
- Authorized personnel
  - Trusted, background check
  - Trained
  - Legitimate need
- Chemical management
  - Inventory control and accountability

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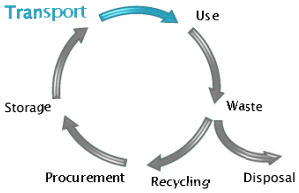
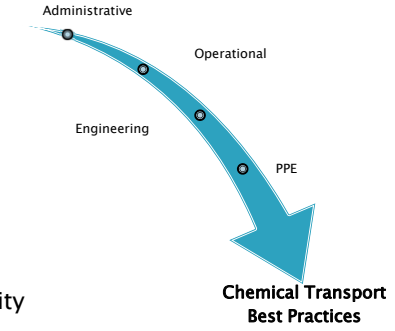


Transport

- Hazardous Shipments
- Modes of Transport
- Regulations
- Packaging
- Labels
- Documentation
- Emergencies and Security



Transportation: Hazardous Shipments

- Laboratory samples
- Equipment
- Domestic shipments
- International shipments
- Quantity of material

Take what, where, and how much into account when making hazardous shipments

Transportation: Modes of Transport

- Air
- Waterway
- Rail
- Road
  - Vehicle
  - Cart or bicycle
- Hand carry
- Transport vehicle may carry both people and your shipment

Take mode of transport into account when making hazardous shipments

Transportation: Regulations

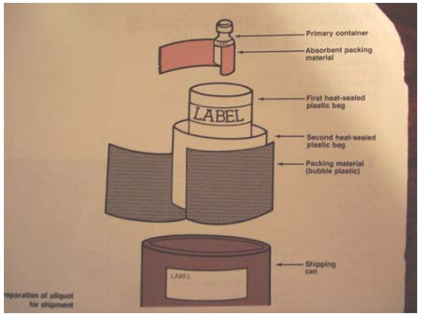
- Thousands of regulated hazardous materials
- Differences in regulations by country
- Penalties can be severe
  - Willfully violation of US hazardous material transportation regulations
    - Fines up to $250,000
    - Prison for up to 5 years
    - Both fine and prison
- International regulations
  - UN Model Regulations
  - International Maritime Dangerous Goods (IMDG) Code
  - International Air Transport Association (IATA)
- Special requirements, restrictions, or limitations
- Training requirements, certifications

Take regulations into account when making hazardous shipments

Title 18 U.S.C.
HMR; 49 CFR Parts 171-180

Transportation: Packaging

- Container within a container
- Specific requirements depend on material and other factors



Transportation: Labels

- Identify material
  - Proper, full chemical name
  - ID codes (e.g., UN number)
  - Quantities, concentrations, number of containers
- Hazard class according to regulations
  - Transport symbols
- Emergency information
- Contact names and phone numbers
- Languages

Transportation: Emergencies and Security

- Emergency contacts
  - Regulation requirements
    - local, national, international
- Public relations
  - Designate spokesperson beforehand
  - Be responsive to public concerns
- Higher risk shipments require higher security
  - Special regulations

Photos: TSA User's Guide on Security Seals for Domestic Cargo

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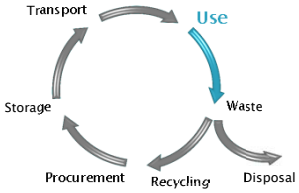
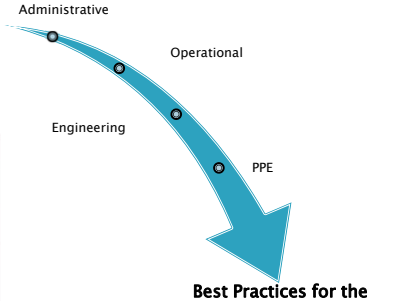


Use of Chemicals

- Standard Operating Procedures (SOPs)



Best Practices for the Laboratory Use of Chemicals

- Spills

http://0.tqn.com/d/chemistry/1/7/Q/q/testtubespill.jpg

Standard Operating Procedures (SOPs)

- Describes how your lab will carry out a certain procedure
- A lab may have SOPs for
  - Security clearance and visitor access
  - Employee training
  - Respiratory protection and equipment fitting
  - Eye protection
  - Housekeeping
  - Ventilation system maintenance
  - Storage, receipt, and transport of hazardous materials
  - Accident and emergency response including natural disasters
  - Hazardous material handling or special equipment operation
    - Toxic chemicals, radiation, lasers, infectious agents, flammable chemicals
  - Spill cleanup
  - Waste management
- No specific format exists for SOPs

Standard Operating Procedures (SOPs)

- SOPs for work with hazardous chemicals can be written into a set of steps for an experiment or procedure
- Should include
  - Date
    - Issued
    - Reviewed
    - Revised
  - Subject, title and identification code
  - Amounts and/or concentrations used
  - Special handling procedures, engineering controls, and personal protective equipment
  - Official review by management, signed
  - Review by all responsible parties, signed
- Should be written in a consistent and official format
  - Example SOP templates
    http://www.safety.duke.edu/OHS/chemsopsTemplates.htm

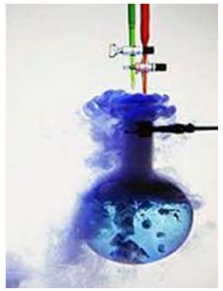
Activity: Standard Operating Procedures (SOPs)

- Scenario: You are a chemist in a Quality Control (QC) lab
- Goal: Develop an SOP for preparing a standard acid solution for titration
- Get in groups of 3-5 people per group

Burette photograph courtesy of Indigo® Instruments

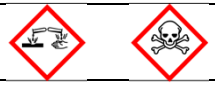
Activity: Standard Operating Procedures (SOPs)

- Refer to the SDS for H_2SO_4, and the partially completed SOP
- In your groups, discuss
  - Hazards
    - Chemicals, reactions, and products
    - Equipment
    - Storage
    - Disposal
    - Security
  - Controls
    - Operational
    - Engineering
    - PPE
- Fill in the blanks to complete the SOP
  - Be prepared to discuss with the whole group



Take about 20 minutes to do this

Activity: Standard Operating Procedures (SOPs)

Hazards in this SOP	
Preparation of solutions	
Equipment	
Waste/disposal	
Security	

Activity: Standard Operating Procedures (SOPs)

Controls

- Operational
  - Substitution
  - Scale down
  - SOP
- Engineering
- PPE
  - Quantity dependent

Activity: Standard Operating Procedures (SOPs)

Conclusions

- SOP can be a set of steps for carrying out a laboratory task safely and securely
- Should be part of a formal training procedure
  - Update regularly
- Protects students/workers, faculty, administrators, chemicals/info

http://www.lab-initio.com/index.html

Spills: Hazard Assessment

- Plan ahead – know the worst case scenario for a spill
  - Hazards of the spilled material
    - Toxic, flammable, etc.
  - Size of spill
    - Smaller or greater than 4 L
  - Location of spill
    - Ventilation
- Know if spill is an emergency situation or not
  - Emergency
    - Isolate
    - Communicate
    - Evacuate
  - Not an emergency
    - Know the appropriate cleanup and decontamination procedures
    - Have the necessary equipment

Spills: Preparation

- Spill Kits
  - Absorbent material
  - Neutralizing agents
    - $NaHCO_3$, citric acid powder, activated carbon (for organic solvents)
  - Plastic bucket with lid
  - Plastic dust pan
  - Broom or brush
  - Plastic bags
  - Tape
  - pH paper
  - Signs: Keep Out, Danger Chemical Spill
  - PPE for at least 2 people
    - Goggles
    - Gloves
    - Disposable aprons or jump suits
    - Disposable shoe covers
    - Respirators

- Emergency Equipment
  - Phones with emergency numbers
  - Alarms
  - Fire extinguishers
  - Emergency eyewash and showers
  - First Aid
  - Safety Data Sheets

Spills: Prevention

- Have only the amount of chemical required
- Understand work practices and procedures
  - SOP
- Eliminate clutter
- Use secondary containers
  - Storage
  - Transport
  - Work
- Dispose of waste and excess chemicals properly and timely

Spills: Reporting

- Maintain accurate records of near misses, incidents, and response
  - All involved personnel
  - Exposure measurements
  - Medical treatment
- Examine records for patterns
  - Use to improve safety and security program
- Encourage reporting and discourage hiding of incidents
  - Maintain confidentiality

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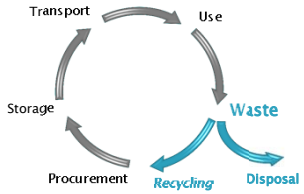
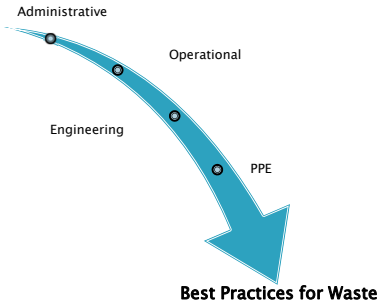


Waste

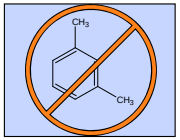
- Prevention
- Categories
- Treatment
- Collection
- Activity: Waste Container Label
- Storage
- Recycling
- Disposal
- Orphans and Unknowns



Best Practices for Waste Recycling and Disposal

Waste: Prevention

- Substitution
  - Replace a hazardous chemical with a less hazardous one



- Source Reduction
  - Scale down
  - Procure and use less

6th International Symposium on Microscale Chemistry, Kuwait, 2011
http://www.6ismc2011.com/images/welcome_img.jpg

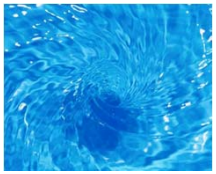
Waste: Categories

- Nonhazardous Waste (if uncontaminated)
  - Used oil
  - PPE
  - Some salts, sugars, amino acids
  - Some resins, gels, sand, etc.
- Hazardous Waste
  - Toxic, flammable, etc.
- Hazardous Mixed Waste
  - Chemical
  - Biological
  - Radiological

Waste: Treatment

For Disposal – Not legal everywhere

- If legal, deactivate/neutralize and dispose of some wastes in the lab yourself
  - Example: Acids and Bases
    - Do not damage drain pipes
    - Dilute with lots of water while pouring down the drain
    - Be sure not to form more hazardous substances
    - Check references, scientific literature



Waste: Treatment

If legal, consider treating waste to reduce the volume

- Evaporation
  - Only if can be done safely
    - Not with corrosive, radioactive, peroxides or peroxide-formers
- Adsorption
  - Activated carbon
  - Activated alumina
  - Ion exchange
- Precipitation – Extraction

Minimization of the volume of waste is best accomplished when?

http://www.sartorius.com/typo3temp/pics/LT_Vivapure-_0430_RGB_ca7cec6815.jpg

Waste: Treatment

If legal, consider treating waste to reduce the hazards

- Requires chemical expertise
  - Ability and legality may be specific to each chemical
- Dilution
  - H_2O_2, $HClO_4$, HNO_3
    - Never add water to a concentrated acid
- Hydrolysis
  - Halogen compounds with NaOH
  - Carboxamides with HCl
- Oxidation – Reduction

Waste: Treatment

References

- "Procedures for the Laboratory-Scale Treatment of Surplus and Waste Chemicals, Section 8.D in Prudent Practices in the Laboratory: Handling and Disposal of Chemicals," National Academy Press, 2011, available online: http://dels.nas.edu/Report/Prudent-Practices-Laboratory-Handling/12654
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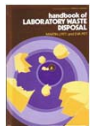
- "Hazardous Laboratory Chemicals Disposal Guide, Third Edition", Margaret-Ann Armour, CRC Press, 2003, ISBN 978-1566705677
- "Handbook of Laboratory Waste Disposal", Martin Pitt and Eva Pitt, 1986, ISBN 0-85312-634-8



Waste: Collection Containers

- Avoid creating mixed waste during collection
- Use separate containers for incompatible wastes (e.g., organic solvents and oxidizers)
- Container must be compatible with waste (e.g., no hydrofluoric acid in glass)
- Label containers
- Keep containers closed
- Use secondary containment
- Avoid using containers that will easily break

Waste: Storage

- Use the same safety and security precautions for waste storage area that are used in the laboratory
  - Access control
  - Warning signs
  - Storage considerations
  - Ventilation
  - Emergency equipment
  - Spill kits
  - PPE

- Facility should be designed and prepared for spills/chemical releases on a larger scale
  - Leak collection, containment, cleanup

Waste: 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
- Build recycling into curriculum
  - Using waste to test an analytical method
  - Waste remediation research

Donated chemicals are not always "free"

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
- Solvent 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

Waste: Recycling

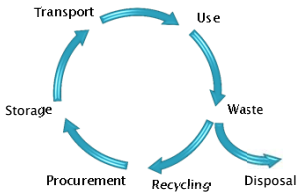
Solvents

- Distillation or Evaporation
- 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 toxics and flammables
  - Use proper ventilation

Waste: Disposal

- If using a disposal service:
  - Are there regulations?
  - Permits/licensing requirements?
  - How will waste be packaged?
  - How will waste be transported?
  - Where and how will waste be disposed?
  - Where does your liability end?
    - Incineration vs. landfill
    - Maintain records
- **When is the best time to figure out how to dispose of waste?**



Waste: Disposal

- 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

Waste: Orphans and Unknowns

Preventing Orphan Chemicals and Waste

- Have a checkout procedure for those leaving the laboratory
- For chemicals and samples being kept
  - Label all carefully
  - Document in lab notebook and elsewhere
- Dispose of all unneeded or excess chemicals
  - Put into chemical exchange program
  - Dispose of as hazardous waste

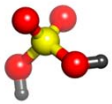
Everything left behind has a new owner

Waste: Orphans and Unknowns

Dealing with Unknown Chemicals and Waste, "Legacy" Waste

- Avoid creating
- Not necessary to know exact identity
  - Need hazard information for disposal
- Consider more serious hazards first
  - Radioactive, explosive, bio-waste
- Look for hints from container, physical characteristics, location found, talk to other people
- Before handling, prepare for the worst
- Test
  - pH
  - Reactivity
    - Air, water, flammability, redox
  - Solubility
  - Qualitative analysis for presence of heavy metals, cyanide, etc.

Activity: Hazardous Waste Tags and Labeling



Activity: Hazardous Waste label

- **Scenario:** You have completed an experiment and need to dispose of the excess chemicals. You have 2 bottles to choose from but BOTH need waste labels
- **In your Group:** Read you Group Scenario
  - Identify and classify all chemicals in your scenario
- **Individually:** Fill out Both Hazardous Waste Label Tags, and include your waste into ONE of the bottles
- Discuss your considerations and differences with your group

Activity: Solutions

- Group 1:
  - Your Waste: 5mL concentrated sulfuric acid
  - Waste Bottles:
    - 4L bottle contains 500mL of acetonitrile, 500mL ethanol and 200 mL acetone
    - 1L bottle that contains 800mL water and 5mL acetic acid
- Group 2:
  - Your Waste: 1g NaCN
  - Waste Bottles:
    - 1L bottle that contains 500mL of 5M NaOH and 1mL HCl
    - 1kg plastic container of 10g of MgOH, 5g of KCl2, and 10g of NaOH
- Group 3:
  - Your Waste: 10mL diethyl ether
  - Waste Bottles:
    - 4L bottle contains 500mL ethanol and 200 mL acetone
    - 1L bottle contains 500mL water and 10mL acetic acid
- Group 4:
  - Your Waste: 100mL hexane
  - Waste Bottles:
    - 1L bottle that contains 500mL of 5M NaOH and 1mL HCl
    - 4L bottle contains 500mL ethanol and 200 mL acetone
- Group 5:
  - Your Waste: 10ml concentrated nitric acid
  - Waste Bottles:
    - 4L bottle contains 500mL ethanol and 200 mL acetone
    - 1L bottle that contains 800mL water and 5mL HCl

- Group 1
  - Hint – dilute acid
  - 5mL concentrated sulfuric acid → 1L bottle that contains 800mL water and 5mL acetic acid
  - Check "ready for disposal"
- Group 2
  - Hint – "like goes with like"
  - 1g NaCN → solid waste container
- Group 3
  - Hint – organic solvents
  - 10mL diethyl ether → 4L bottle of ethanol and acetone
- Group 4
  - Hint – organic solvents
  - 100mL hexane → 4L bottle of ethanol and acetone
- Group 5
  - Hint – dilute acid
  - 10ml concentrated nitric acid → 1L bottle of 800 mL water and 5 mL HCl
  - Check "ready for disposal"

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Activity: Conclusion

- Discussion
  - Was there any difficulty in this activity?
  - Was the activity useful for you?
  - What is something new your learned?
  - Would this activity be useful in your teaching?

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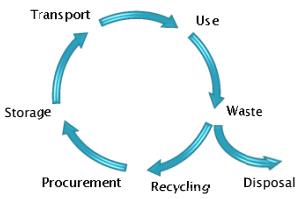
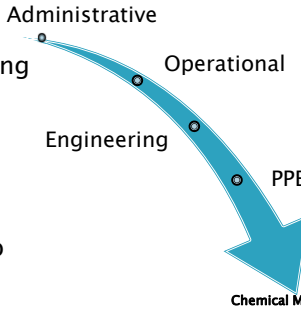
Summary: Chemical Management

- ☑Key Principles
- ☑Procurement
- ☑Inventory Management
- ☑Storage
- ☑Transport
- ☑Use of Chemicals
- ☑Waste Recycling and Disposal
- ☑Activity: Hazardous Waste Tag and Labeling
- Summary and Conclusions



Chemical Management: Conclusions

- Key to chemical safety and security
- Involves all CSS controls
- Many issues addressed by planning ahead
- Best practices in chemical management and high quality research are positively correlated
- Opportunities for those willing to pioneer improvements



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Chemical Safety and Security Risk Assessment

SAND No. 2012-7128P

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

Overview: Chemical Safety and Security Risk Assessment

- Risk Basics
- Chemical Risk Assessment
- Summary and Conclusions

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Risk Basics Overview

- Hazard vs. Risk
- Definition of Risk
- Activity: Risk Perception
- Safety and Security
- Risk Characterization
- Risk Reduction

Risk Basics: Hazard vs. Risk

- There is a difference between ***hazard*** and ***risk***
  - Hazard
    - Something that has the potential to do harm
- Is there a hazard in this picture? If so, what type?
- Is it a risk? If so, how much of a risk?
  - Depends on the situation

Risk Basics: Hazard vs. Risk

- What is wrong?
  - Overloaded circuit

Hazard

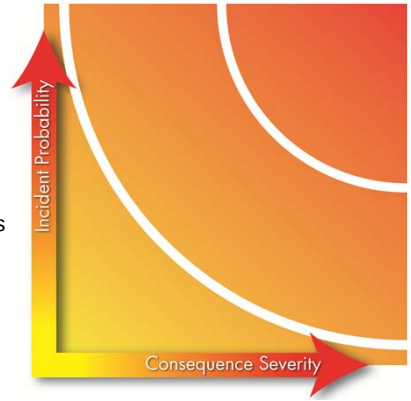
- What are the possible scenarios?
  - Blown fuse
  - Worker injury
  - Fire
- What is the likelihood?
  - Factors that lead to an event
    - Work habits, no electrical training
- What are the consequences?
  - Other factors and things that follow an event
    - Electrocution, fire, loss of experiment/process

Risk

Risk Basics: Definition

Risk is a function of

- Probability that an incident will occur (**likelihood**)
- Severity if the event occurs (**consequence**)



Risk = *f* (Likelihood, Consequence)

Activity: Risk Perception

- On the next page--
- Rank each action or technology according to your perception of its RISK
  - A rank of 1 means riskiest
  - A rank of 15 means least risky

Take about 10 minutes to do this

* Adapted from Slovic et al. "Facts and Fears: Understanding Perceived Risk." In R. C. Schwing and W. A. Albbers, Jr. (eds.) Societal Risk Assessment: How Safe is Safe Enough? New York: Plenum, 1980, 181–216.

Rank these Activities (#1 – #15) by Risk Level

Police work
Commercial Air
X-rays
Mountain climbing
Prescription antibiotics
Alcoholic beverages
Nonnuclear electric power
Railroads
Smoking
Pesticides
Motor vehicles
Spray cans
Bicycles
Swimming
Nuclear power

Activity: Risk Perception

College Students[1]

1. Nuclear power
2. Smoking
3. Pesticides
4. Motor vehicles
5. Alcoholic beverages
6. Police work
7. Spray cans
8. Traveling by commercial flight
9. X-rays
10. Nonnuclear electric power
11. Prescription antibiotics
12. Mountain climbing
13. Railroads
14. Bicycles
15. Swimming

Experts[2]

1. Motor vehicles
2. Smoking
3. Alcoholic beverages
4. X-rays
5. Pesticides
6. Nonnuclear electric power
7. Swimming
8. Bicycles
9. Travelling by commercial flight
10. Police work
11. Railroads
12. Nuclear power
13. Prescription antibiotics
14. Spray cans
15. Mountain climbing

1 Thirty US college students participated in this study
2 A group of fifteen risk assessment professionals in the US

Risk Basics: Definition

College Students

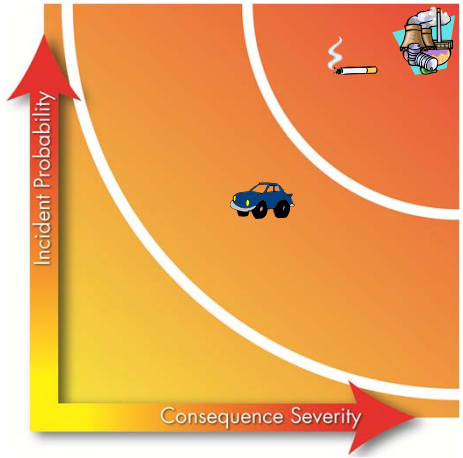
1. Nuclear Power
2. Smoking

4. Motor Vehicles

Experts

1. Motor Vehicles
2. Smoking

12. Nuclear Power



Activity: Risk Perception

- What do you think may have influenced your risk assessment besides your best guesses regarding ***likelihood*** and ***consequence***?
- Emotional Risk Perception Factors (examples)
  - Involuntary vs. Voluntary
  - Immoral vs. Moral
  - Unfamiliar vs. Familiar

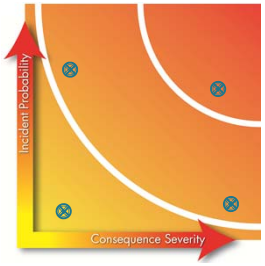
What ***should*** be the basis for your professional Risk Assessment of Chemical Safety and Security?

Risk Basics: Safety and Security

- Risk concept
  - Applies to both Chemical ***Safety*** and Chemical ***Security***
- Safety Incident
  - Spill
  - Accidental exposure
  - Uncontrolled reaction
- Security Incident
  - Theft or diversion of dual-use chemicals
  - Intentional release
  - Sabotage

Chemical Safety Risk Characterization

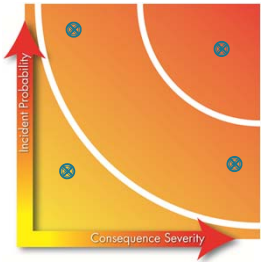
1. **Low**
   - Procedures are routine; staff is trained and experienced; materials used are mostly benign and/or present in microscale amounts only
   - An incident would not likely be an emergency
2. **Moderate**
   - Procedures are not routine; staff may be partially trained or have limited experience; materials are reactive, flammable, toxic, and/or present in moderate quantity
   - An incident could constitute or develop into an emergency



3. **High**
   - Procedures are novel or extremely delicate; staff may be untrained or inexperienced; materials are highly reactive, toxic, explosive and/or present in large quantities
   - Process is under high temperature and/or pressure
   - An incident would be a life and facility-threatening emergency

Security Risk Characterization

1. **Low**
   - Assets are possibly targets for theft or diversion
   - Consequences of loss or release are minimal
2. **Moderate**
   - Assets are attractive for theft or diversion due to monetary value or dual-use
   - Consequences could threaten the public; misuse could be harmful or even lethal to a small number of people, and would certainly damage the institution, its programs, and reputation
3. **High**
   - Assets are very valuable or hard to acquire dual-use materials
   - Consequences of misuse could result in harm or death to many people



Safety and Security Risk Characterization

- What are the benefits of characterizing risks?
- Can risks ever be reduced to zero?
- What does it take to reduce CSS risk?
  - Are resources for risk reduction limitless?

Characterizing CSS risks is a necessary step toward responsible and effective allocation of finite resources to reduce risk to acceptable levels

Risk reduction measures should always be applied in a graded manner

Large effort made to reduce high risks

Smaller effort made to reduce low risks

Risk Basics: Reduction

- Types of CSS Controls
  - Administrative
  - Operational
  - Engineering
  - PPE
- Decrease likelihood
- Decrease consequence

Risk = *f*(Likelihood, Consequence)

Overview: Chemical Safety and Security Risk Assessment

☑Module Learning Objectives

☑Risk Basics

- **Chemical Risk Assessment**
- Summary and Conclusions

Chemical Safety Risk Assessment: Overview of the Process

Chemical Safety Risk Assessment

1. Examine jobs and processes

- Analyze for each step in the process
  - Who, what, where, when, and how?
    - Could exposure occur?
    - Could an accident occur?

Chemical Safety Risk Assessment

2. Identify hazards

- On the basis of materials and equipment present

Example: 100 mL of a 0.10 M sodium cyanide solution

- Acute toxin
  - Harmful exposure can occur through ingestion, absorption through broken skin, or inhalation upon conversion to HCN gas by reaction with an acid

Chemical Safety Risk Assessment

3. Characterize safety risks

Example: regular work with sodium cyanide solutions

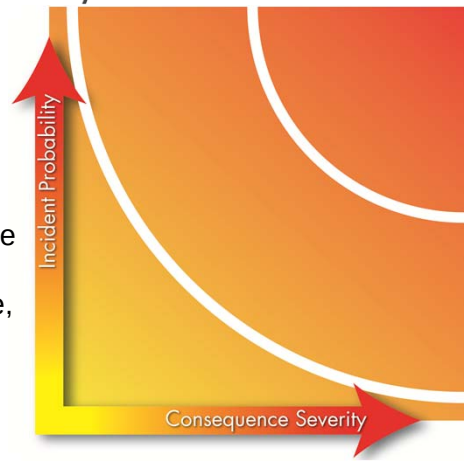
- What are the factors affecting the likelihood of exposure?
  - Do you think the likelihood of exposure is low, moderate, or high?
- What are the factors affecting the consequences of exposure?
  - Do you think the consequences of exposure are low, moderate, or high?

Chemical Safety Risk Assessment

3. Characterize safety risks

On the basis of *likelihood* and *consequence*, are the risks of exposure to NaCN low, moderate, or high?

Why?



Chemical Safety Risk Assessment

4. Are risks acceptable?

- Would you feel safe if you were doing this work?
  - Why/why not?
- Are current controls and practices reducing risk of exposure to acceptable levels?
  - Why or why not?
- Are there national standards for occupational exposure to cyanide?
- Are there other limits imposed by the institution?
  - If you don't know, how can you find out?
  - What do you do if there are not established limits?

Chemical Safety Risk Assessment

5. Implement additional control measures where needed to reduce safety risks to acceptable levels

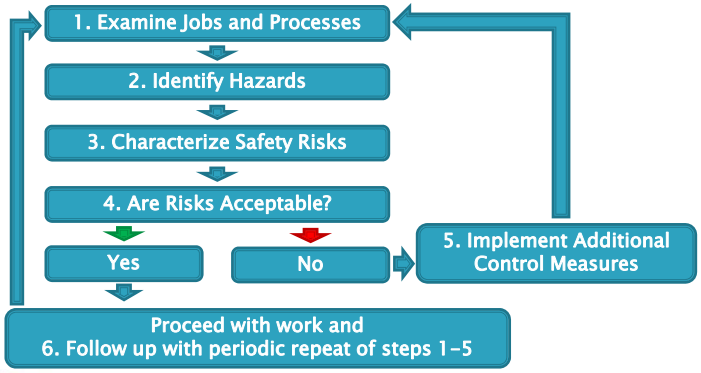
- What controls are needed to reduce the risk of exposure?
  - Substitution
  - Engineering
  - Administrative
  - PPE

Chemical Safety Risk Assessment

6. Follow up with periodic repeat of steps 1-5

- Have practices or people changed?
- Could further improvements be made?
- How often should follow-up assessments be performed?

Chemical Safety Risk Assessment: Overview of the Process



Chemical Security Risk Assessment

- Main points
  - Likelihood of a security threat scenario may be higher than you think
    - Out of chemical, biological, nuclear, and radiological materials, ***chemicals*** are used maliciously ***the most often***
  - Consequences can range from low to high

Summary: Chemical Safety and Security Risk Assessment

- ☑Module Learning Objectives
- ☑Risk Basics
- ☑Chemical Risk Assessment
- **Summary and Conclusions**

Conclusions

- Risk is a function of Likelihood and Consequence
  - Applies to both safety and security
- Chemical labs and plants need to be ***safe***, ***secure***, and ***productive***
  - Assessing and characterizing CSS risks allows controls to be applied in a graded manner
    - Larger efforts toward reducing high risks
    - Smaller efforts toward reducing low risks

Thank You!!

Drs. Joe, and Christine

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