Chemical

SAFETY AND SECURITY TRAINING

Chemical Safety and Security Training

Balitvet – Indonesian Institute for Veterinary Science

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

Sandia National Laboratories

The Chemical Security Engagement Program (CSP)

Sponsored by:

US. Department of State

Washington, DC 20520

What is CSP?
Program Goals

The Chemical Security Engagement Program (CSP) seeks to improve global chemical security and safety by raising awareness and improving security and safety best practices.

Program Goals:

- Raise awareness about chemical threats and dual-use nature of chemicals.
- Provide technical assistance to improve chemical security and safety best practices.
- Foster national and regional dialogue focused on improving chemical security and safety.
- Promote and strengthen international scientific cooperation among chemical professionals.
- Establish cadres of safety and security officers.

What do we do?
CSP Strategy

- Work with host countries to assess priorities and gaps in chemical security and safety
- Bring together experts to identify chemical security assistance needs
- Partner with :
  - National chemical organizations (HKI, IKM, etc.)
  - Regional chemical organizations (FACS, FASC, etc.)
  - International chemical organizations (OPCW, IUPAC, UNFAO, etc)
  - Chemical Industry (ACC)
- Engage countries with:
  - Growing chemistry capabilities and industry
  - Regional security concerns
  - Active producers/exporters of industrial chemicals

Initial Workshops Identified Risks and Gaps

In Industry:

- Theft of unsecured chemicals
- Improper chemical management
- Improper disposal of chemicals
- Lack of enforcement of safety rules/laws

At Universities:

- Lack of safe practices
- Presence of dual-use of chemicals
- Improper chemical management
- Improper storage of chemicals
- Lack of enforcement of safety rules/laws

Involving Academia and Industry

- To address chemical threat, both sectors must be involved.
  - Academia/laboratories have a large variety of chemicals in small amounts
  - Industry has a smaller variety of chemicals but in large amounts
  - Quite different in needs, outlook, security issues

Chemical Safety and Security Training

Course Goals:

- Increase awareness of the importance of chemical safety and security
- Increase awareness of methods for improving chemical safety and security
- Determine needs for future training/actions

Safety vs. Security:

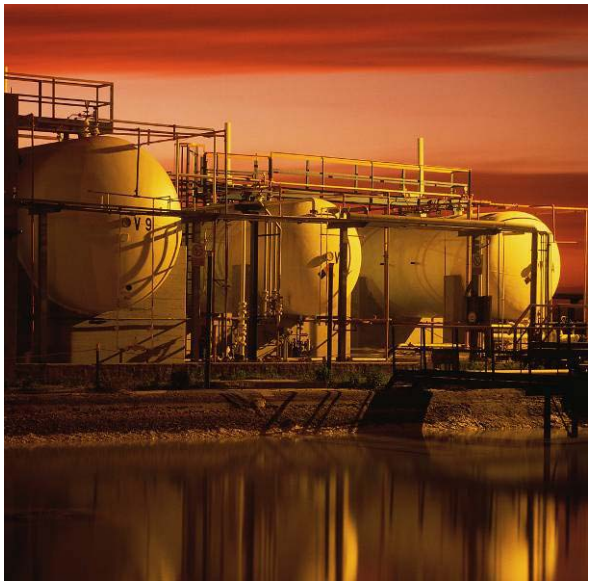
- Chemical Safety: Protecting people from chemicals
- Chemical Security: Protecting chemicals from people (i.e., terrorists or thieves)

•Half-day seminars
•1.5-2 day workshops
•5 day trainings

Chemical Safety and Security Overview

Why worry about chemical safety?

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



Studies indicate lab chemists *may* have:

- **Shorter life spans, more disease**

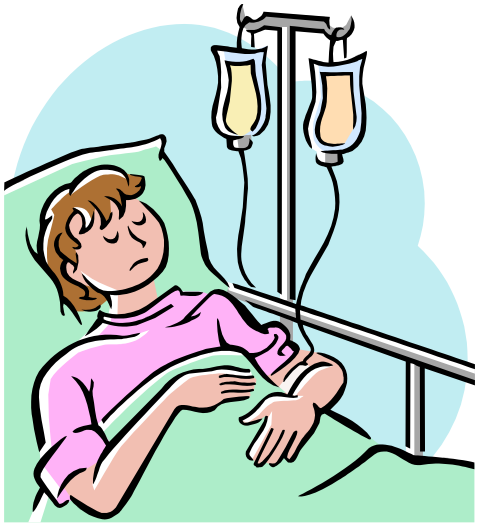
  Hoar, S. K. et al, *J. Occup. Med,.* 23, **485 (1981)**

- **Higher cancer incidence**

  Dement J.M. & Cromer J.R., *Appl. Ocup. Environ. Hyg*., 7,**120 (1992)**

- **Higher suicide rate (females)**

  Walrath J. et al, *Amer. J. Pub. Health*, 35, **883 (1985)**



Possible chemical health problems

Chemicals

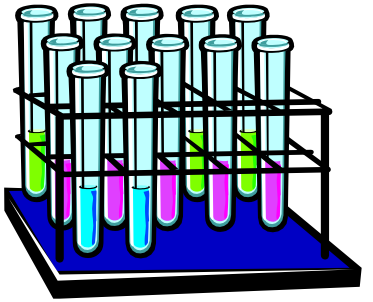
- Vinyl chloride
- Asbestos
- Carbon tetrachloride
- Mercury
- Lead
- Thalidomide
- Methanol
- CO, CS_2

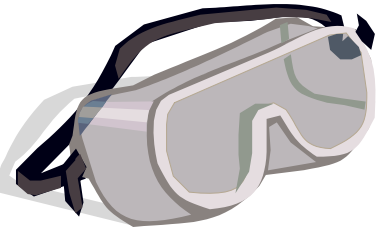
Diseases

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

But disease depends on many factors…

- Genetics
- Specific chemical
- Protection controls used
- Dose
- Concentration
- Duration
- Life style
- Environment





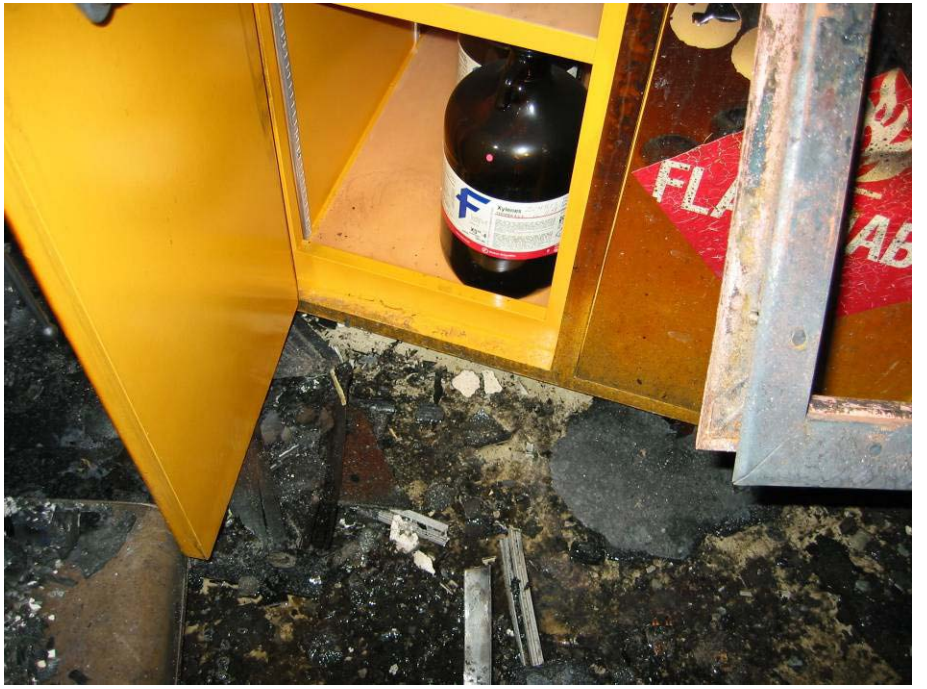
University of California Santa Cruz: Fire

- **January 11, 2002: about 5:30 am, 4th floor of Sinsheimer Lab building, Dept. of Molecular, Cell and Developmental Biology.**
  - Firefighters responded to alert from heat-detection system in building.
  - Controlled by noon.
  - Up-to-date inventory of hazardous materials allowed firefighters to enter building and contain fire.
  - Building did not have automatic sprinkler system.

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

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

- **Professors and students lost equipment, notes, materials, samples.**
- **Other labs in building closed for weeks to months.**
  - Water and smoke damage
- **Burned labs took 2 years to reopen.**
- **Cause never determined.**



Environmental hazards
California State Univ. Northridge: Earthquake

- Magnitude 6.7
- January 17, 1994 – 4:31 am
- 57 deaths, 11000 injuries

- Epicenter a few km from California State University Northridge campus

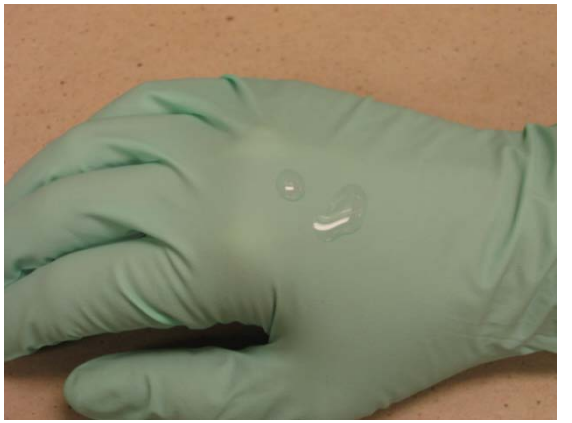
- Several fires in science buildings allowed to burn because firemen worried about chemical hazards

- Professors and students lost equipment, notes, materials, samples

Images courtesy: P.W. Weigand, California State University Northridge Geology Department, Image source: Earth Science World Image Bank http://www.earthscienceworld.org/images

Dartmouth College: Dimethylmercury poisoning

- Karen Wetterhahn, professor and founding director of Dartmouth's Toxic Metals Research Program
  - expert in the mechanisms of metal toxicity
- In 1996, spilled a few drops of dimethylmercury on her gloved hand
  - Cleaned up spill immediately
  - Latex glove believed protective
- Six months later, became ill and died of acute mercury poisoning at age 48



Bhopal: Pesticide plant chemical release

- **One of the greatest chemical disasters in history, December 1984**
- **Union Carbide plant making Sevin released ~40 tonnes of methyl isocyanate in the middle of the night**
- **Low local demand for pesticides meant the plant was only partially running**
- **Some hardware was broken or turned off, including safety equipment**
  - Safety measures and equipment far below US standards
- **Plant in heavily populated area**

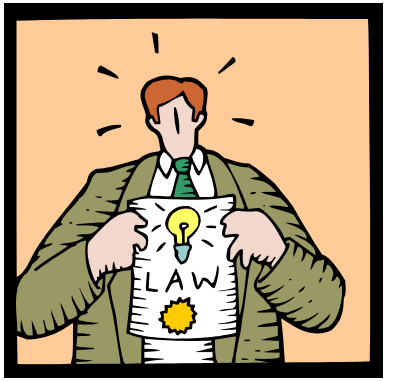
* "The Bhopal disaster and its aftermath: a review", Edward Broughton, *Environmental Health: A Global Access Science Source* 2005, **4**:6, http://www.ehjournal.net/content/4/1/6, accessed 12/07

Safety Video: Reactive Hazards

Taiwan: Silane fire

- Motech Industries solar cell plant in Tainan Industrial Park
  - 1 death
  - US $1.3 million damage
  - Silane / air explosion
    - Operator responded to gas-cabinet alarm
    - Explosion occurred when he opened gas-cabinet
    - Fire burned for 1 hour before being controlled
      - Caused other SiH_4 and NH_3 cylinders to empty
  - November 2005

Chemical accidents are now under stricter control and scrutiny



- **Better individual country regulations**
- **Better international regulations**
  - IATA
  - GHS
  - REACH
- **Environmental problems after natural disasters**
  - Earthquakes, cyclones, hurricanes, floods
- **Increased public awareness**
- **Increased media coverage**
- **Less public tolerance**

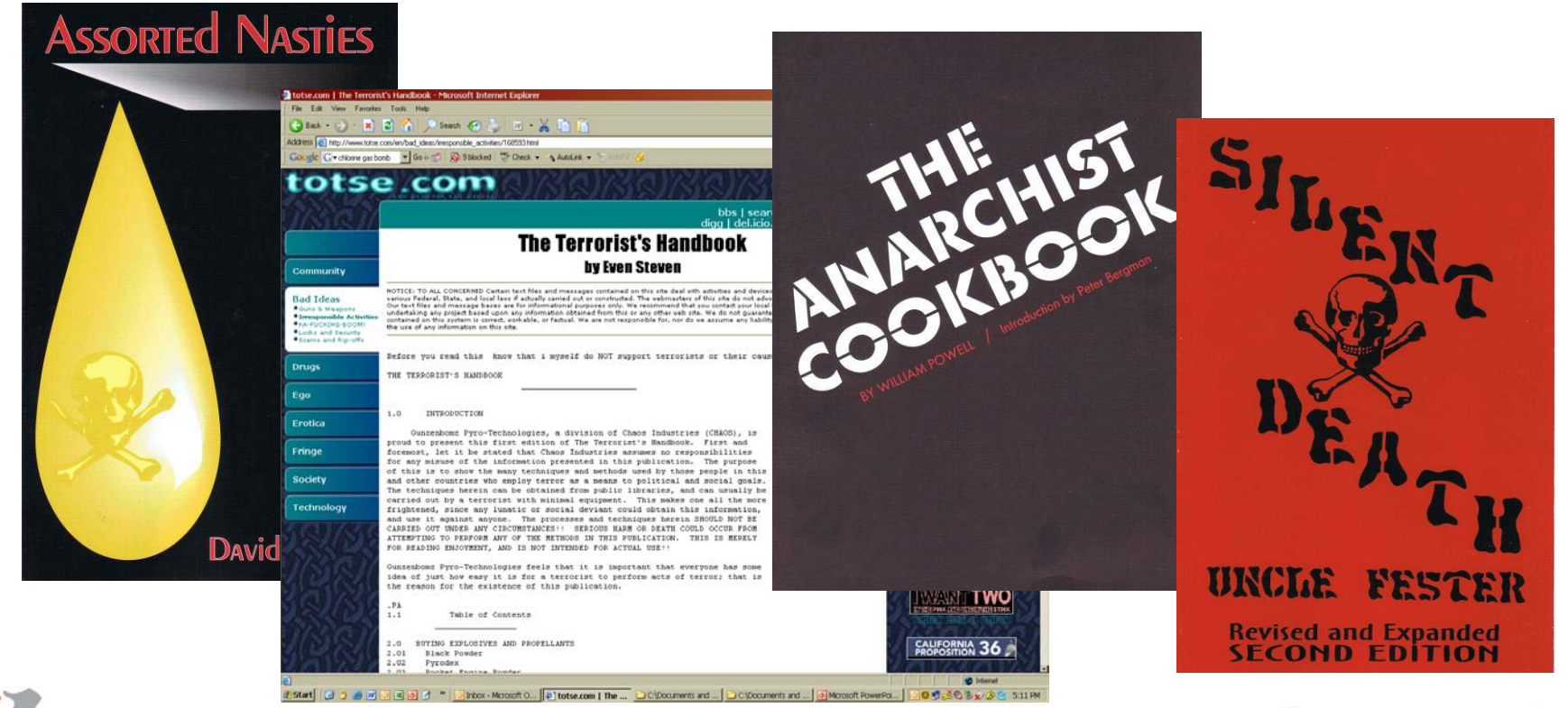
Why worry about chemical safety?

- **Health of the workers**
- **Safety of the workers**
- **Safety of the community**
- **Safety of the environment**

…It's the right thing to do!

Why worry about chemical security?

- Long history of people deliberately using chemicals to harm others.
- Information on how to acquire and deliver them is easy to get:



Aum Shinrikyo: Matsumoto and Tokyo, Japan

- **Sarin attack on Judges in Matsumoto, June 1994**
  - Sarin sprayed from truck at night
  - 7 deaths, 144 injuries

- **Sarin attack on Tokyo subway, March 1995**
  - 11 bags with 600 g each on 3 main subway lines
  - 12 deaths, 3938 injuries

- **Hydrogen cyanide attacks on Tokyo subway, May 1995**
  - Bags of NaCN and sulfuric acid
  - No deaths, 4 injuries

Photo of wanted poster from Wikipedia commons

Aum Shinrikyo: Tokyo, Japan

Aum Shinrikyo: Matsumoto and Tokyo, Japan, cont'd.

- Recruited young scientists from top Japanese universities.
- Produced sarin, tabun, soman, VX.
- Purchased tons of chemicals through cult-owned companies.
- Motives: proof of religious prophecy, kill opponents, interfere with legal proceedings and police investigations.

Chicago, Illinois, USA

- March 2002, an anarchist (called himself "Dr. Chaos") was found at 2 am in a Univ. Illinois, Chicago, building carrying sodium cyanide
- Had chemicals in a storage room at the Chicago subway
  - included containers marked mercuric sulfate, sodium cyanide, potassium cyanide, and potassium chlorate
  - 0.25 pound of potassium cyanide and 0.9 pound of sodium cyanide
  - stolen from an abandoned warehouse, owned by a Chicago-based chemical company
    - 15 drums and 300 jars of various other laboratory chemicals were discovered there

- Sentenced to prison for "possessing a chemical weapon", as well as other charges (Interfering with power, air-traffic control systems, computer systems, broadcast systems and setting fires).

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

Iraq

- **Many incidents in which chlorine gas cylinders are blown up with explosives**
  - Chlorine probably stolen/diverted from water purification plants or oil industry
  - Many civilians and non-combatants injured
- **Chlorine first used in WWI as a chemical weapon**

On March 23, 2007, police in Ramadi's Jazeera district seized a truck filled with "five 1000-gallon barrels filled with chlorine and more than two tons of explosives"

From http://www.longwarjournal.org/archives/2007/03/al_qaedas_chlorine_w.php downloaded Jan 2008.

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

2.1 ACQUIRING CHEMICALS

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

9.0 CHECKLIST FOR RAIDS ON LABS

http://www.totse.com/en/bad_ideas/irresponsible_activities/168593.html, downloaded Nov. 2007

Why worry about chemical security?

- **Health and safety of people and environment**
- **Community relationships**
- **Reduce chance of accidental chemical release**
- **Avoid loss and damage to labs and equipment**
- **Prevent criminals and terrorists from getting dangerous chemicals**
  - Wide variety of chemicals have been used
  - Wide variety of motivations for actions
- **A deliberate attack on a chemical facility could release a large amount of hazardous chemicals**
  - Injure or kill people in nearby areas
  - Eliminate jobs and economic assets

Safety and Security Issues are similar

Variables

- **Many different chemicals with:**
  - different properties
  - different hazard
  - different applications
- **Many different ways to misuse chemicals**
  - chemical weapons
  - poisons

Protect

- **Workers**
- **Facility**
- **Community**
- **Environment**

Government regulations: Chemical security

- **Differ from country to country**

- **Legislation needed to fulfill requirements under the Chemical Weapons Convention**
  - Each country passes appropriate laws
  - Each country must declare and track certain chemicals

- **UN Resolution 1540**

- **Other export control legislation**

Important Questions:

How does your country regulate and control chemical safety and security?

…Is it effective?

…Could it be improved?

…How?

Fundamentals of

Chemical Laboratory Safety

References

"Safety in Academic Laboratories, Vol.1 & 2," American Chemical Society, Washington DC, 2003, also available online:

http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=2230&use_sec=false&sec_url_var=region1&__uuid=ef91c89e-8b83-43e6-bcd0-ff5b9ca0ca33

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

Definitions

Chemical Laboratory Safety

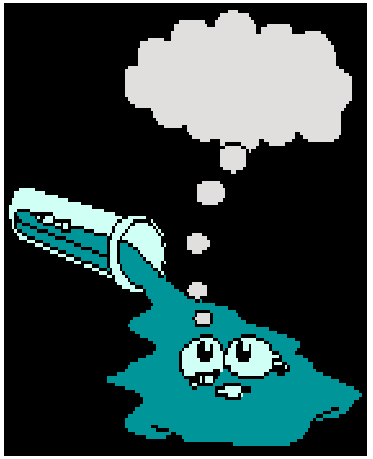
– ***The control of exposure to potentially hazardous substances to attain an acceptably low risk of exposure***

Chemical Laboratory Safety

Hazard – *the potential to harm*

Risk – *the probability that harm will result*

Chemical Laboratory Hazards



- **Chemical hazards**
  - dusts, fumes, mists, vapors, gases
- **Physical hazards**
  - fire, electrical, radiation, pressure vibration, temperatures, noise
- **Ergonomic hazards**
  - repetitive motion (pipetting), lifting, work areas (computers, instruments)
- **Biological hazards**
  - pathogens, blood or body fluids

Chemical Laboratory Safety

based on the principle of

Industrial Hygiene

– *The **anticipation, recognition, evaluation** and **control** of health hazards in the work environment to protect workers health and well-being and to safeguard the community and the environment*

Chemical Laboratory Safety

Industrial Hygiene Principles

Anticipation

Recognition

Evaluation

Control

Chemical hazards

Physical hazards

Ergonomic hazards

Biological hazards

Anticipation

Safety First !

To consider safety in the beginning is:

Easier,

Cheaper,

Safer,

… and it saves you time !

Anticipation

Advance Experiment Planning:

Outline proposed experiment

Acquire safety information (M)SDS, REACH

Consult with CSSO?

Anticipation

Risk Analysis

- Which chemicals?
- How much?
- Special equipment needed?
- Who does the work?
- Staff properly trained?
- Can the experiment go wrong?
- Do you have an emergency plan?

Recognition

Types of lab hazards:

chemical toxicity

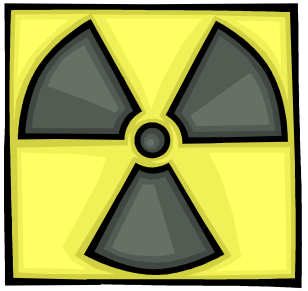
fire / explosion

physical hazards

biohazards

radiation

special substances



Recognition & Evaluation

What are the anticipated risks?

- Are the equipment & facilities adequate?
- Are staff properly and sufficiently trained?
- Risks if experiment goes wrong?
- Is there a plan for this?

Control

How are the risks controlled?

- **Engineering controls:**
  - enclosure / isolation
  - ventilation / hoods

- **Emergency Plan**

- **Personal Protective Equipment (PPE)**

Recognition of Chemistry Laboratory Hazards

Chemical Toxicity

Acute (short term, poisons, asthmagens)

cyanide

strychnine

Chronic (long term, carcinogens, reproductive)

vinyl chloride (liver cancer)

asbestos (mesothelioma, lung cancer)

thalidomide (developmental birth defects)

Routes of Exposure

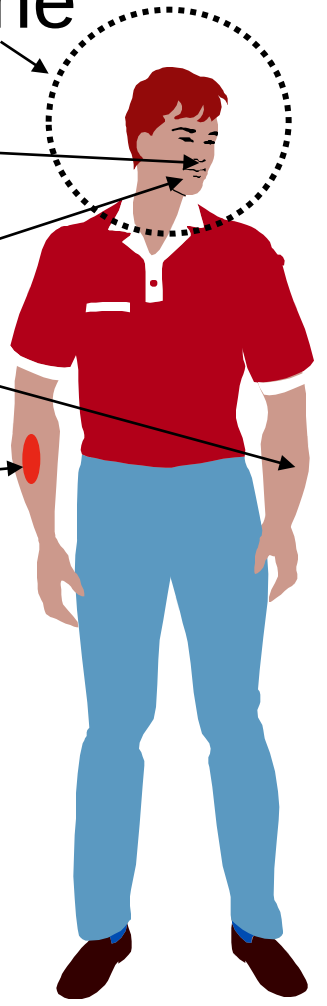
Breathing Zone

Inhalation*

Absorption

Ingestion

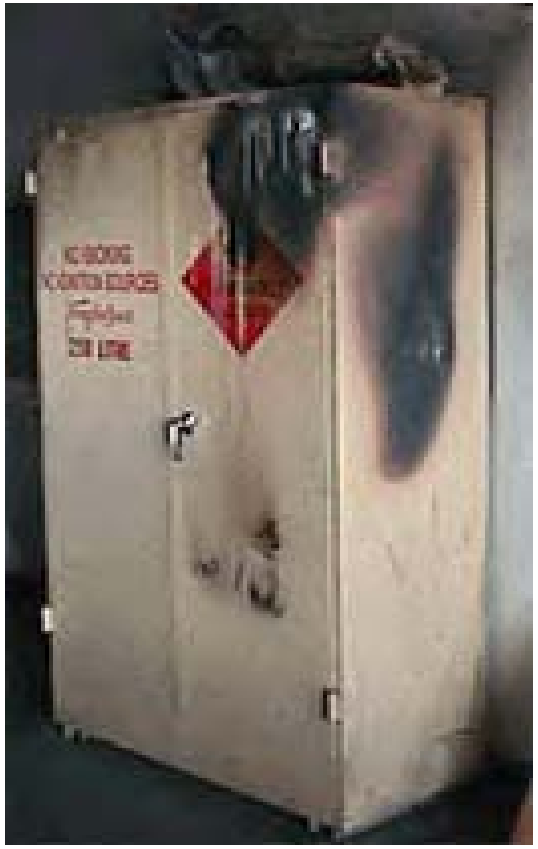
Injection

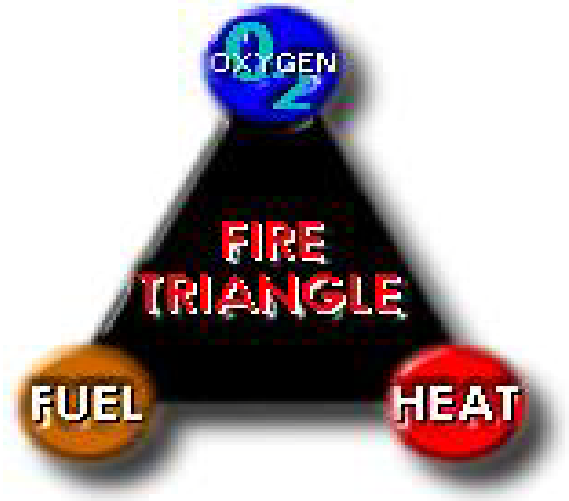


Eyes

*Most important route of entry

Fire and Explosion Hazards





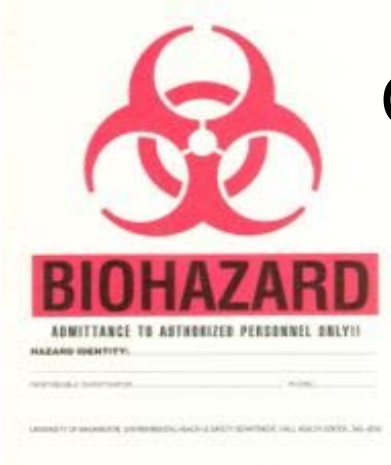
Physical and Ergonomic Hazards

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

Biohazards

- **Blood borne pathogens**

  AIDS, HIV, hepatitis, clinical chemistry labs



- **Recombinant DNA**

  Genetic engineering, cloning

- **Work with animals**

  Zoonoses,

  diseases from animals

Radiation Hazards

Ionizing Radiation:

alpha α, beta β, gamma γ,

X-rays, neutrons

Radioactive isotopes:

tritium, H-3, carbon, C-14, sulfur, S-35,phosphorus, P-32/33, iodine, I-135

Radiation Hazards

Non-Ionizing Radiation:

Ultraviolet (UV spectrometers)

Magnetic (NMR, MRI)

Microwave

(Heart pacemaker hazard)

Lasers

(eye protection required)

Special Chemical Substances

Controlled Substances:

regulated drugs, psychotropic (hallucinogenic) substances, heroin

Highly Toxic Chemicals:

nerve gas, phosgene, riot control agents, chemical warfare agents

Evaluation & Control

– **Administrative practices**

organizational policies

– **Operational practices**

work practices

– **Engineering controls**

ventilation, barriers

Break

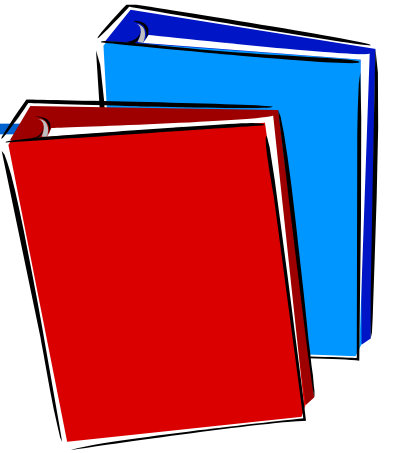
REHAT

Administrative Practices

organizational *safety policies*

that apply to everyone

Lab Safety Policies



❖ Have a Safety Manual

- Never work alone, especially after hours.
- Specify when eye protection & PPE is required.
- Specify operations that require hood use.
- Specify required training.
- No mouth pipetting.
- No long hair or dangling attire.

Lab Safety Policies

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

Operational Practices

Safe Laboratory Procedures:

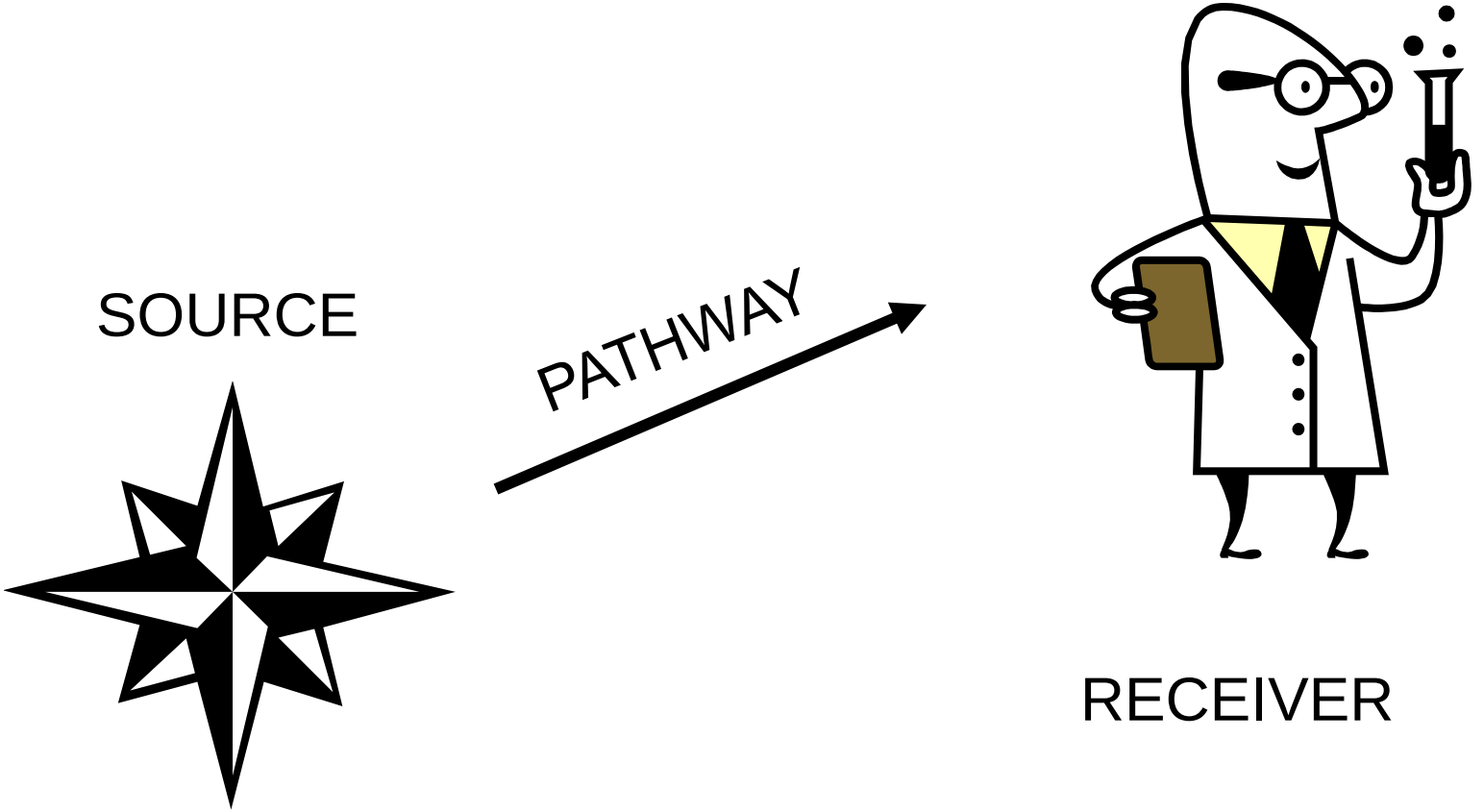
- Packages opened only in labs, not receiving
- Receiving staff trained to look for signs of breakage and/or leaking shipments
- Receiving area has spill kits
- Mailroom/receiving alert for suspicious shipments

Safe Laboratory Procedures

Use hoods properly:

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

Engineering Controls



Engineering Controls

1. Change the process

eliminate the hazard

2. Substitution

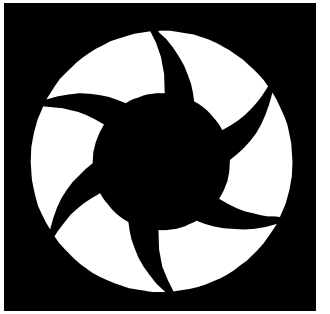
non-hazardous substance for hazardous

(e.g. - toluene for benzene)

Engineering Controls

3. Isolate or enclose the process or worker

Use a barrier



4. Ventilation

Dilution (general ventilation) - Not good

Local exhaust ventilation (LEV) - Preferred

Engineering Controls

Properly functioning & used correctly!

Laboratory hoods and ventilation are the basis of engineering controls.

Laboratory Hoods

Must be used and maintained properly.

Engineering Controls

Local exhaust ventilation includes:

snorkels

Engineering Controls

Local exhaust ventilation includes: *vented enclosures*

Engineering Controls

Local exhaust includes:

special containment devices

(e.g. - glove boxes)

Engineering Controls

Local exhaust includes:

special containment devices

(e.g. - isolation chambers)

Engineering Controls

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

Personal Protective Equipment

PPE includes:

eye protection,

gloves,

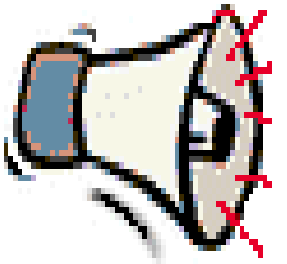
laboratory coats. etc.,

respirators,

appropriate foot protection

Emergency Planning & Response

- Have routine, unannounced evacuation drills.
- Designate a person for each area to ensure that inner rooms are evacuated.
- Locate outside staging areas at sufficient distance from the building.
- Test and maintain alarms.
- Post a person to meet/direct emergency vehicles.



Emergency Planning & Response

Post each room with:

Emergency phone numbers

After hour phone numbers

Person(s) to be contacted

Alternate person(s)

Unique procedures to be followed

Any Questions?

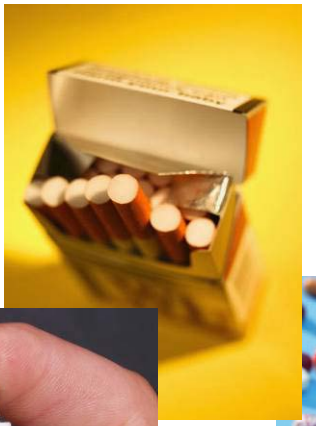
Aspects of

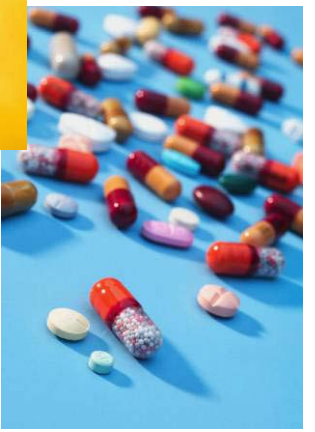
Chemical Security

77

Chemical dual-use awareness

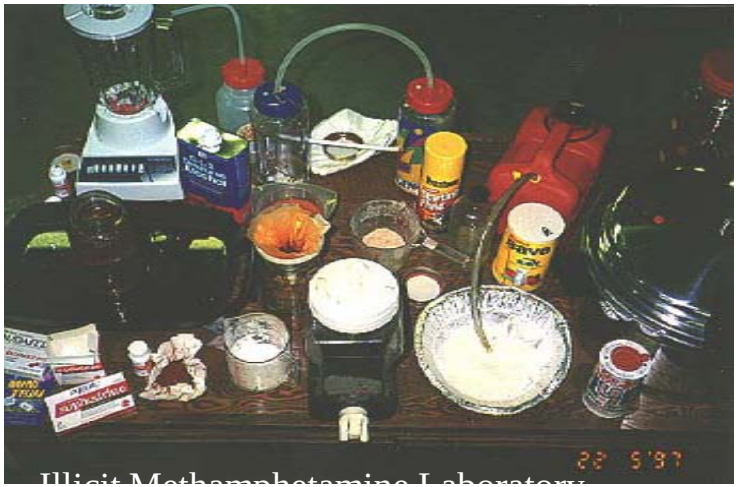
Dual use chemicals: **Chemicals used in industry or everyday life that can also be used in bad ways.**





Dual-use chemical example: Pseudoephedrine

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



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

US DEA, http://www.deadiversion.usdoj.gov/pubs/brochures/pseudo/pseudo_trifold.htm, viewed Dec 2007

Dual-use chemical example: Cyanide

Therence Koh/AFP/Getty Images

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

* "Tylenol Crisis of 1982." *Wikipedia, The Free Encyclopedia*. 22 Nov 2007, 06:04 UTC. Wikimedia Foundation, Inc. 28 Nov 2007 <http://en.wikipedia.org/w/index.php?title=Tylenol_Crisis_of_1982&oldid=173056508>.

Dual-use chemical example: Pesticides

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

FIGURE. Package of Chinese rodenticide implicated in the poisoning of a female infant aged 15 months — New York City, 2002

Photo/New York City Poison Control Center

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

Ann. Emerg. Med., Vol. 45, pg. 609, June 2005

Chemical Security Questions

- Is your facility secure?
- How easy would it be for someone to steal chemicals?
- Are the chemistry workrooms, stockrooms, classrooms and labs always locked and secure?
- Is someone always there when these rooms are open?
- Do you check your orders when chemicals arrive to be sure some chemicals are not missing?

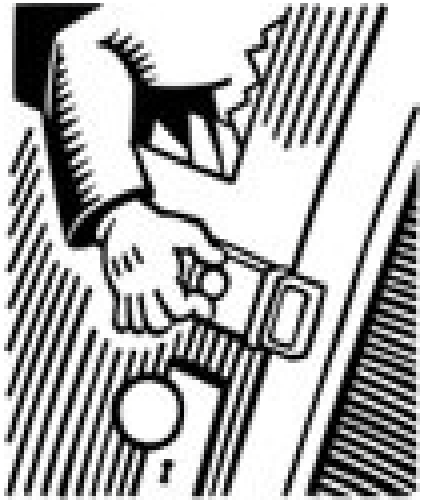
Components of Chemical Security

- Physical security of site
- Personnel management
- Information security
- Management of chemical security activities
- Allocation of chemical security responsibilities
- Development of emergency plans
- Chemical security training

Goal: Ensure that you don't accidently help a criminal or a terrorist get dangerous chemicals

Chemical Security: Physical Site

LOCK UP!!

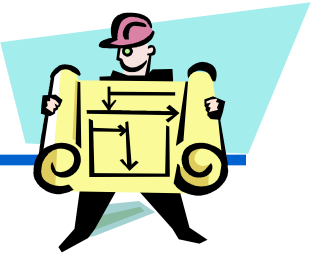


Controlled drugs

Chemical Surety Agents

Highly toxic chemicals

Facility Characterization



Characterize the facility in terms of:

- Site boundary
- Buildings (construction and HVAC systems)
- Room locations
- Access points
- Processes within the facility
- Existing Protection Systems
- Operating conditions (working hours, off-hours, potential emergencies)
- Safety considerations
- Types and numbers of employees
- Legal and regulatory issues

Facility Characterization

Facility characterization provides important data that:

- **Identifies locations and assets to be protected**
- **Establish what existing Protection System components are already present at the facility**
- **Documents facility layout for use in analysis**

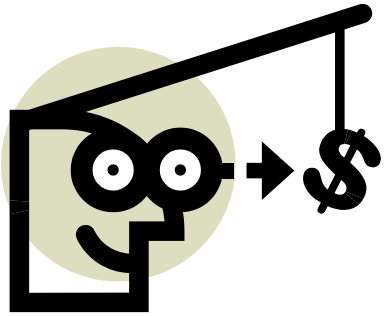
Threat Definition

Threat classes:

- Outsiders—no authorized access
- Insiders—authorized access
- Collusion—between Outsiders and Insiders

What Might Motivate Adversaries?

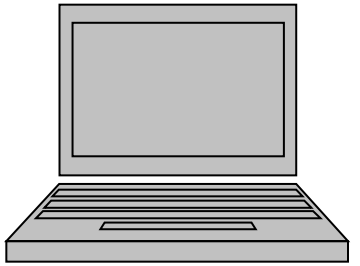
- **Terrorists**
  - Ideology
- **Criminals**
  - Financial
- **Activists**
  - Ideology
- **Insiders**
  - Ego
  - Ideology
  - Revenge
  - Financial
  - Coercion



Target Identification

- **Determine the possible targets for the following actions:**
  - **Sabotage**
    - **Identify vital areas to protect**
  - **Theft of chemicals**

  - **Theft of information**
    - **Identify location of materials to protect**



Chemical Security:
Personnel Management

- **Guard against both *Insider and Outsider* threat**
- **Who checks people entering the building?**
- **Who has keys? How do they get authorized?**
  - Building
  - Stockroom
  - Individual Labs

- **When someone leaves, do you make sure they turn in keys?**
  - Don’t want people making duplicate keys

Chemical Security: Information Security

- How do you track chemical inventory?
  - Is the information secured so unauthorized people can't read it or alter it?

- Would you know if:
  - some toxic chemicals disappeared overnight?
  - some toxic chemicals didn't arrive?
  - someone was ordered chemicals in the name of your institution but diverted them?

Chemical Security: Assign Responsibilities

- **Identify people responsible for various chemical security activities:**
  - Physical security, building modifications
  - Chemical tracking and reporting
  - Personnel and access management
  - Information management
  - Emergency planning

- **Ensure they have the time and resources to do the job.**
- **Integrate with chemical safety responsibilities.**

Chemical Security:
Professional Behavior

- **Chemical professionals use their scientific knowledge in a responsible manner.**

- **Chemical Educators need to train their students to use their scientific knowledge in a responsible manner.**

Relationships between

Chemical Security

and

Chemical Safety

94

Relationships Between Chemical Safety and Security

- **Chemical safety:** Protect against accidents
- **Chemical security:** Protect against deliberate harm

Many practices are the same for chemical safety and security, but there are a few areas of conflict.

Good Practices for Both Chemical Safety and Security

- **Minimize use of hazardous chemicals.**
  - Replace with less-hazardous chemicals, if possible.
  - Reduce scale of experiments.

- **Minimize supply of hazardous chemicals.**

- **Restrict access to hazardous chemicals.**
  - Know what you have.
  - Know how to store, handle and dispose of what you have.
  - Know who has access to materials, knowledge and expertise.

- **Plan what to do in an emergency.**

Conflicts Between Chemical Safety and Security: Information Sharing

Science generally means sharing information widely, but this may not always be advisable.

- **Safety**
  - **Label everything so people can recognize hazardous chemicals.**
  - **Let community and especially emergency responders know what chemical dangers are there.**
  - **Share knowledge about chemical hazards so people know to be alert.**
- **Security**
  - **Labels help identify targets for theft or attack.**
  - **Sharing locations of chemicals can publicize targets for theft or attack.**
  - **Sharing knowledge of chemical hazards could inspire harmful behavior (copy-cat criminals).**

Conflicts Between Chemical Safety and Security: Facility Exits

Locking exit doors is secure, but not safe.

- **For safety, people need to be able to leave the facility quickly and by many routes.**
- **For security, you want to control exits as well as entrances so chemicals (or equipment) are not taken.**

Setting Priorities

- **Labs need to be safe, secure and productive.**
  - Policies and practices need to be flexible enough to allow for the uncertainties of research.
  - Policies and practices need to align with local laws, regulations, practices and culture. Can't just copy from somewhere else.

- **Use risk-based security and safety measures.**
  - Can't afford to defend against every imaginable hazard.
  - Identify threats, characterize facilities, identify alternatives, analyze costs vs. performance.

- **Be alert for suspicious activities or inquiries.**

All Chemical Facilities Need to be Secured

- **Small-scale research laboratories**
  - **Many different chemicals used in small amounts.**
- **Large-scale manufacturing plants**
  - **Limited types of chemicals used in large amounts.**
- **Security measures need to match facility and threat**
  - **Can’t afford to defend against all imaginable threat.**

Lunch

MAKAN SIANG

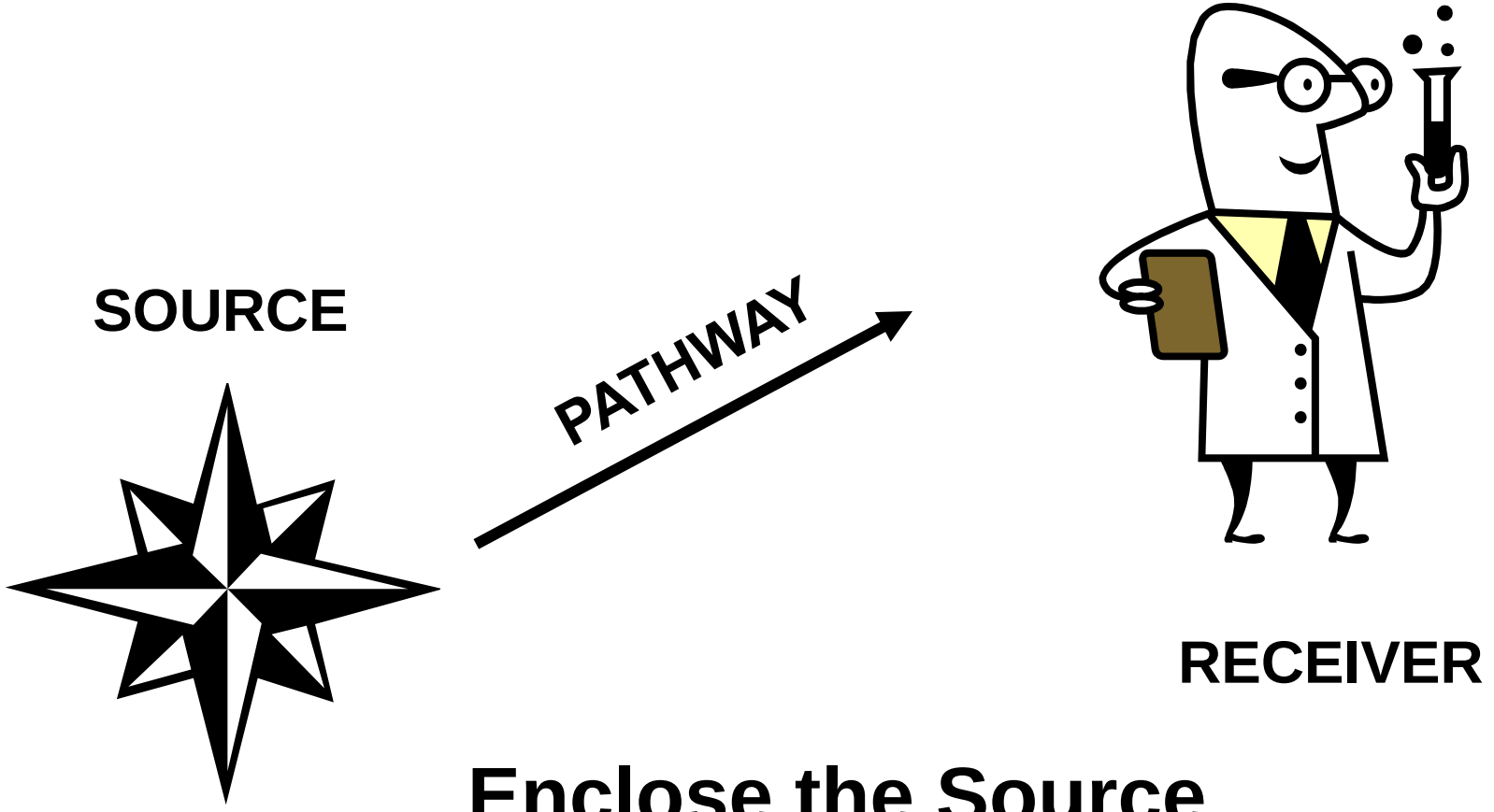
Chemical Safety & Security

Laboratory Ventilation: BSCs and Chemical Hoods

CSP
CHEMICAL SECURITY ENGAGEMENT PROGRAM

Chemical
SAFETY AND SECURITY TRAINING

Hazardous Exposure



Enclose the Source

Hazardous Exposure

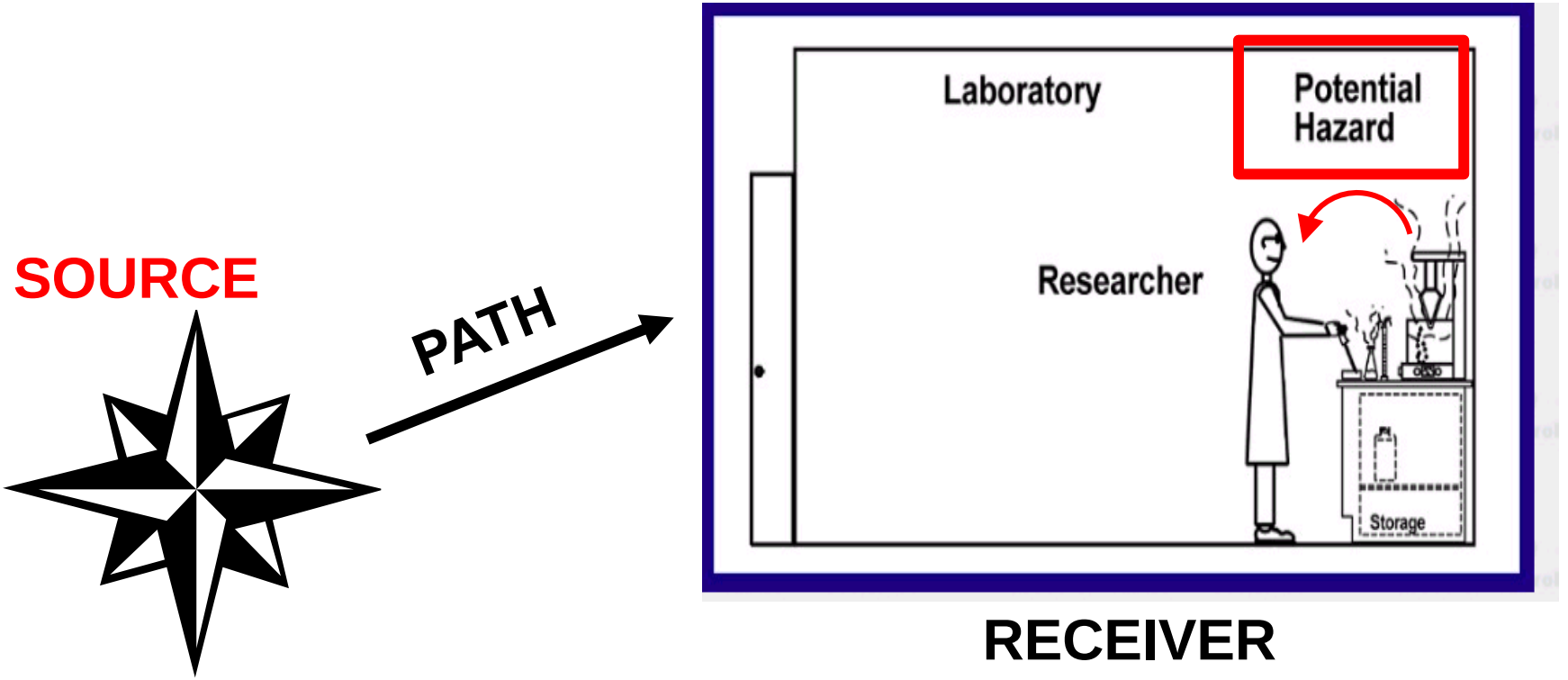
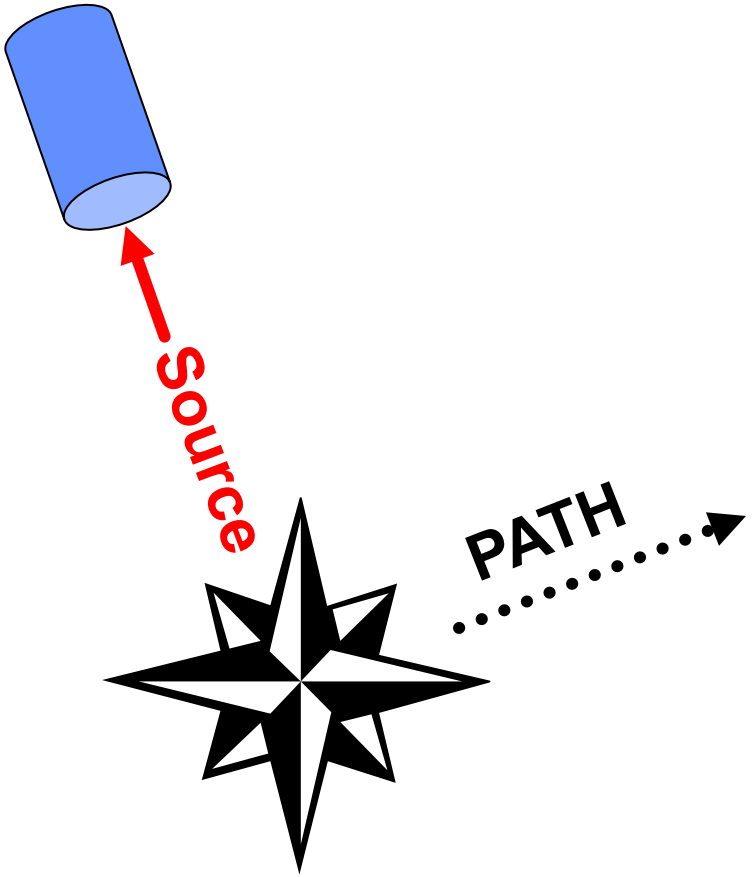
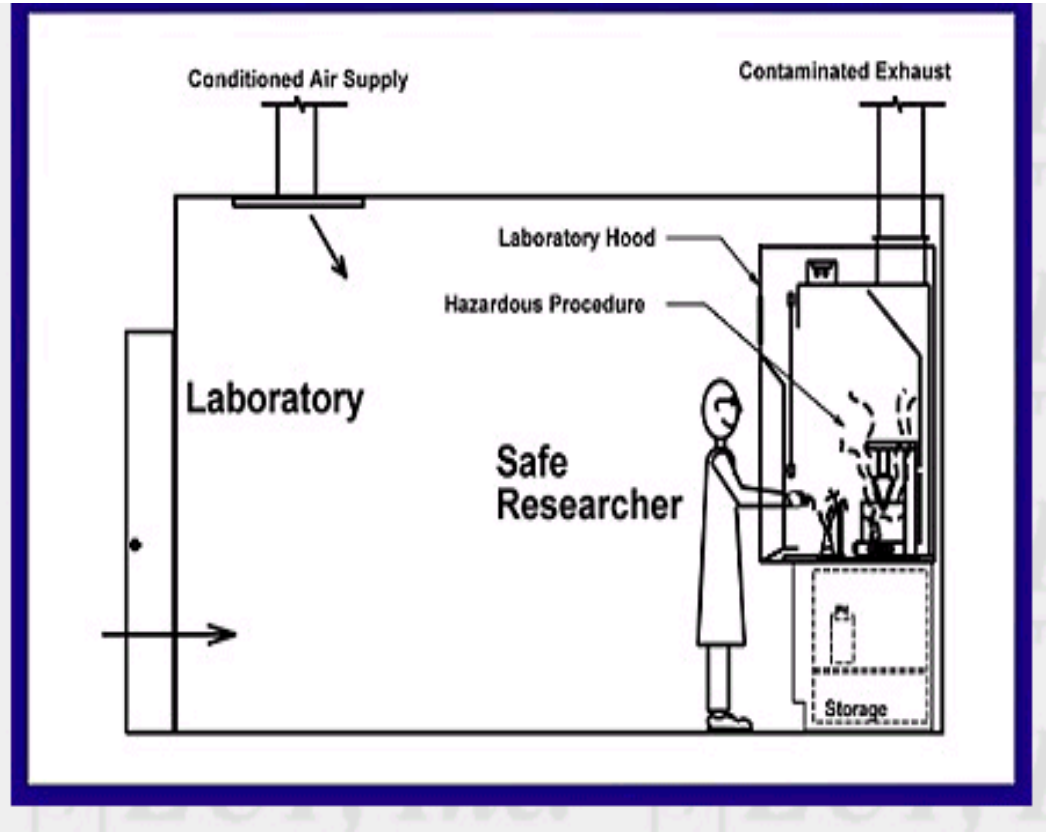


Illustration courtesy, Tom Smith, ECT Technologies, Cary NC USA

Ventilation





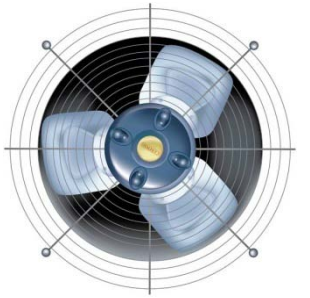
Safe Worker

Illustration courtesy, Tom Smith, ECT Technologies, Cary NC USA

Reminder: Prioritization of Controls

most preferred

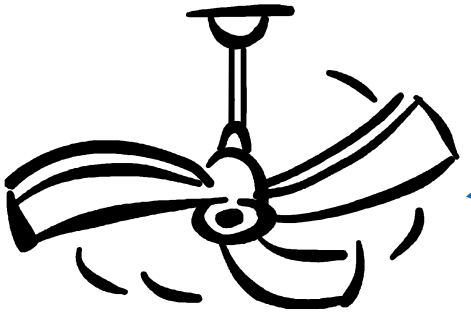
1. **Change the process**
   eliminate the hazard
2. **Substitution**
   use less-hazardous substances/methods
3. **Isolate or enclose the process or worker**
   use a barrier
4. **Ventilation**
   dilution (general ventilation) - not good
   local exhaust ventilation (LEV) – preferred



5. **Operational controls**
   policies & practices
6. **Personal Protective Equipment (PPE)**
   proper use related to hazard

least preferred

Engineering Controls: Ventilation



General dilution ventilation

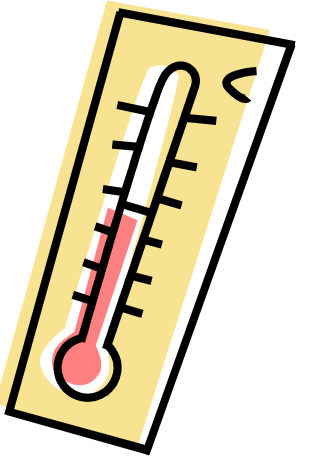
NOT good

Local exhaust ventilation (LEV)

MUCH Preferred

General Dilution Ventilation

- Use for control of:
  - temperature
  - harmless substances
  - nuisances
  - odors

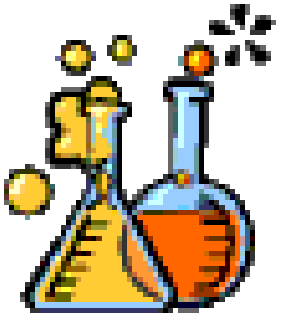


Local Exhaust Ventilation (LEV)

- **When to require this:**
  - **to enclose and contain contaminant**
  - **when contaminant is toxic/hazardous**
  - **when an employee works near the contamination**
  - **when complete containment/enclosure of a contaminant is not feasible**

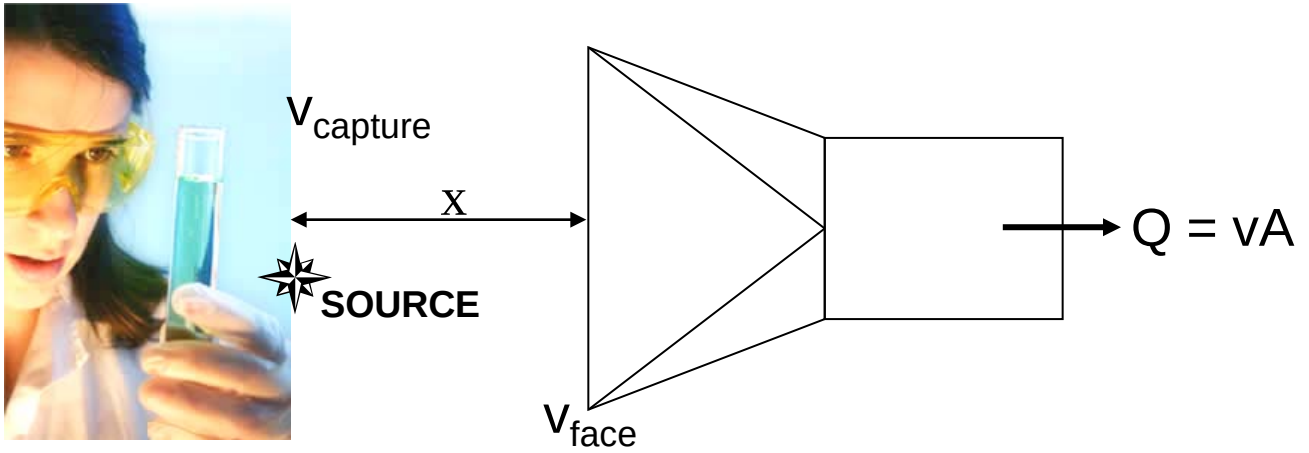
LEV Principles

- Enclose source
- Capture contaminant near source
- Keep contaminant out of breathing zone
- Provide adequate make-up air
- Discharge away from air intake

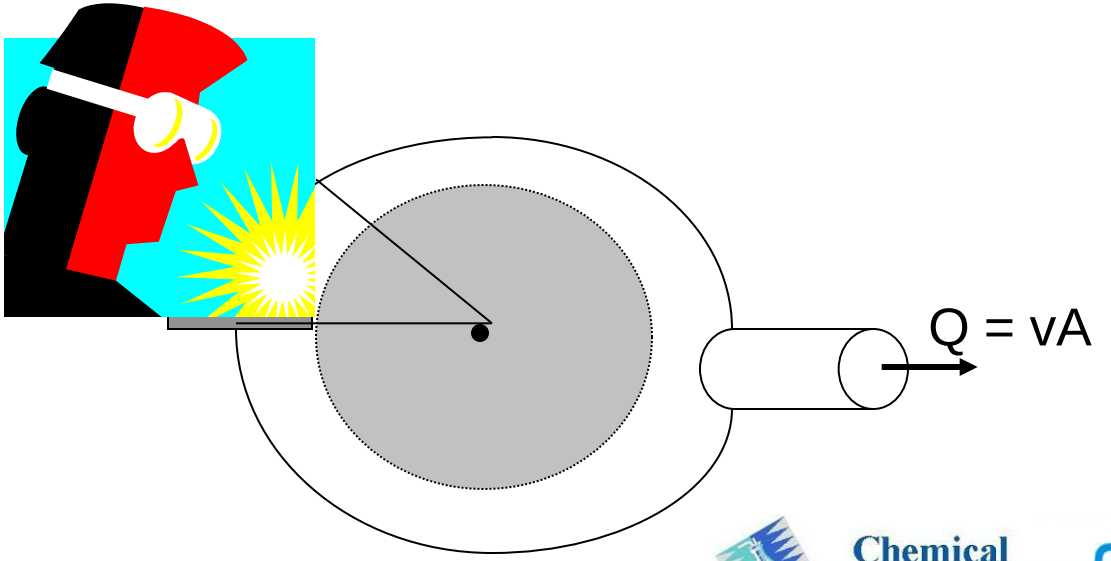


LEV: Source Control

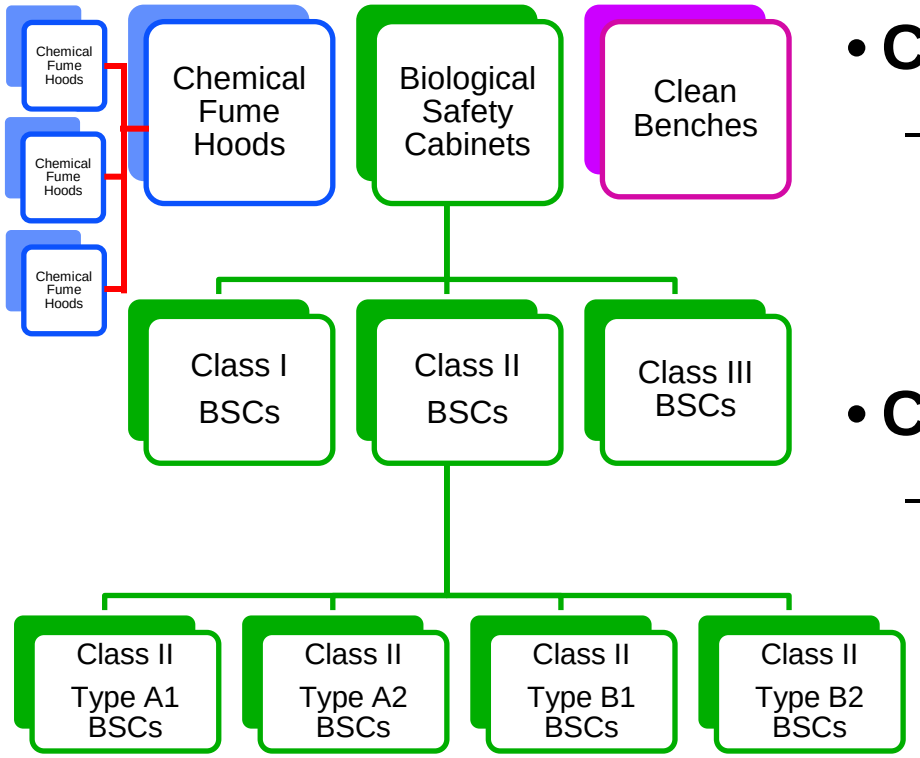
CAPTURE



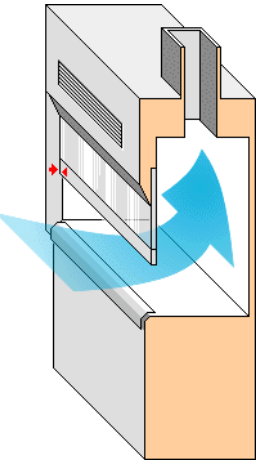
ENCLOSURE



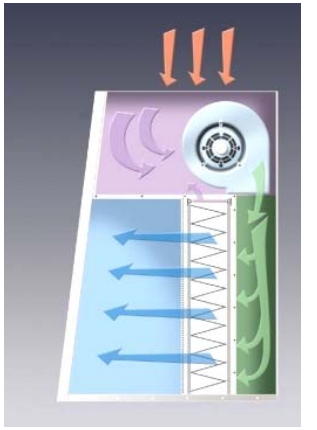
Types of Ventilated Cabinets



- **Chemical Fume Hoods**
  - **air is drawn in from the front and expelled or filtered & re-circulated**



- **Clean Benches**
  - **air is HEPA filtered and directed horizontally**



- **Biological Safety Cabinets (BSCs)**

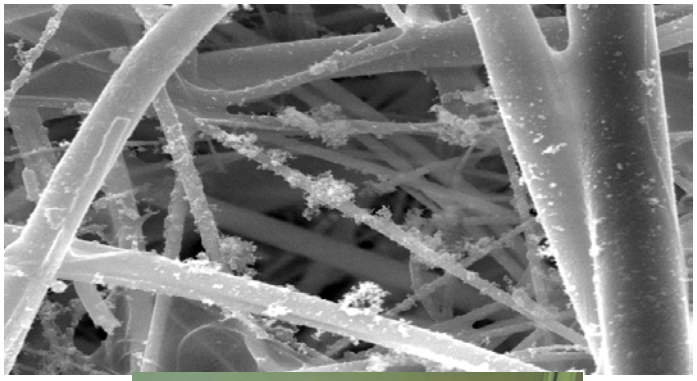
Pictures: http://www.ehs.ufl.edu/Lab/fumehood.htm
http://www.labconco.com

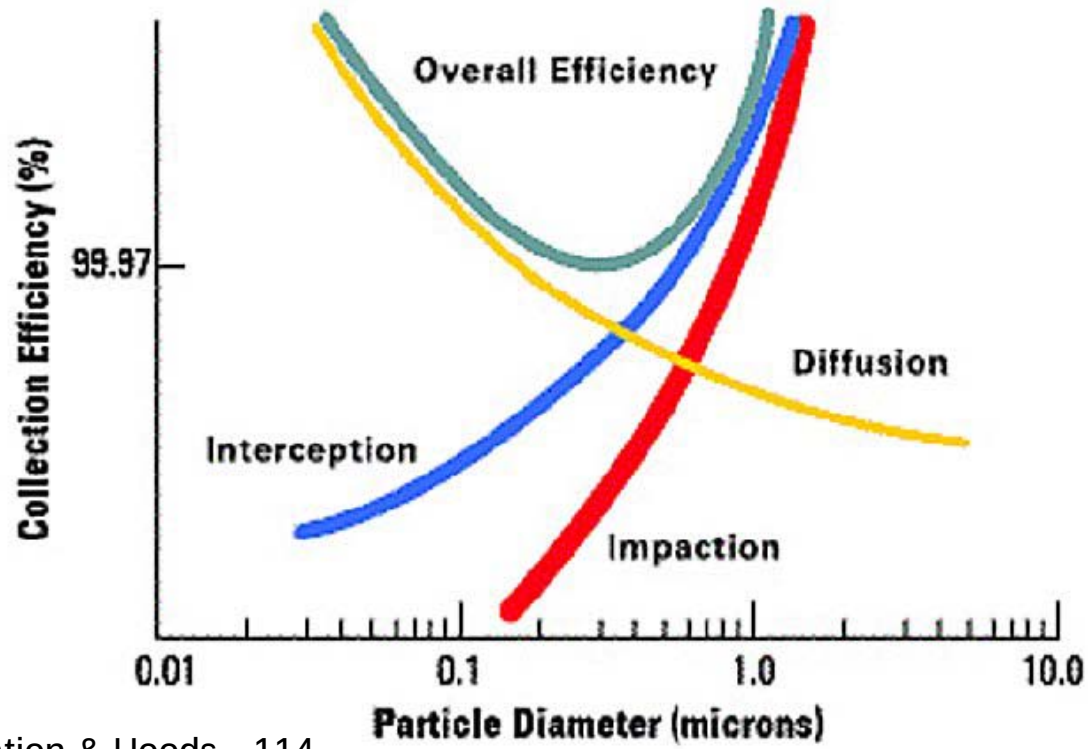
Biological Safety Cabinets (BSCs)

- Primary means of containment
  - for particulates/biologicals
- Three design types
  - Class I, Class II, and Class III
- Designed to provide protection for
  - personnel
    - directional flow of air into cabinet
  - environment
    - HEPA filtered exhaust
  - product (*except* Class I)
    - laminar flow of <u>HEPA filtered air</u>
  - but, how?
- Type of BSC used should be based on a risk assessment
- ***<u>If</u>*** a BSC is used should be based on a risk assessment

Chemicals vs Particles: How do HEPA Filters Work?

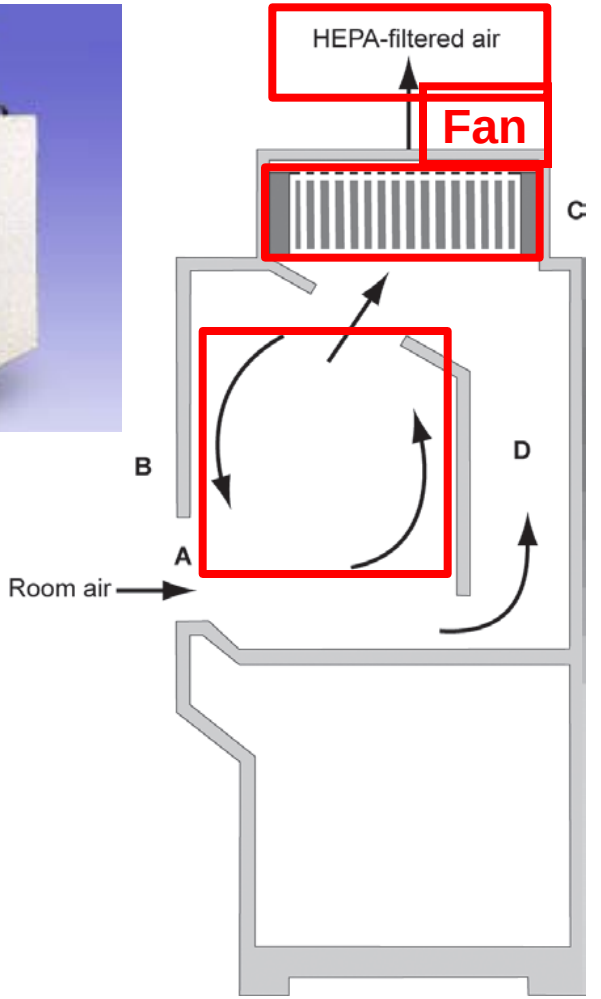
- HEPA filter = High Efficiency Particulate Air filter
- Minimum efficiency of 99.97% removal of 0.3 micron particles
- HEPA filters **do not filter out gases, vapors or volatile chemicals**, they only filter out particulates (bacteria and viruses)





Class I
Biological Safety Cabinet

- Provides personnel and environmental protection
  - from particulates
- Does <u>not</u> provide product protection
- Uses an exhaust blower to pull air through (negative P)
- HEPA filtered exhaust
- Chemical issues?

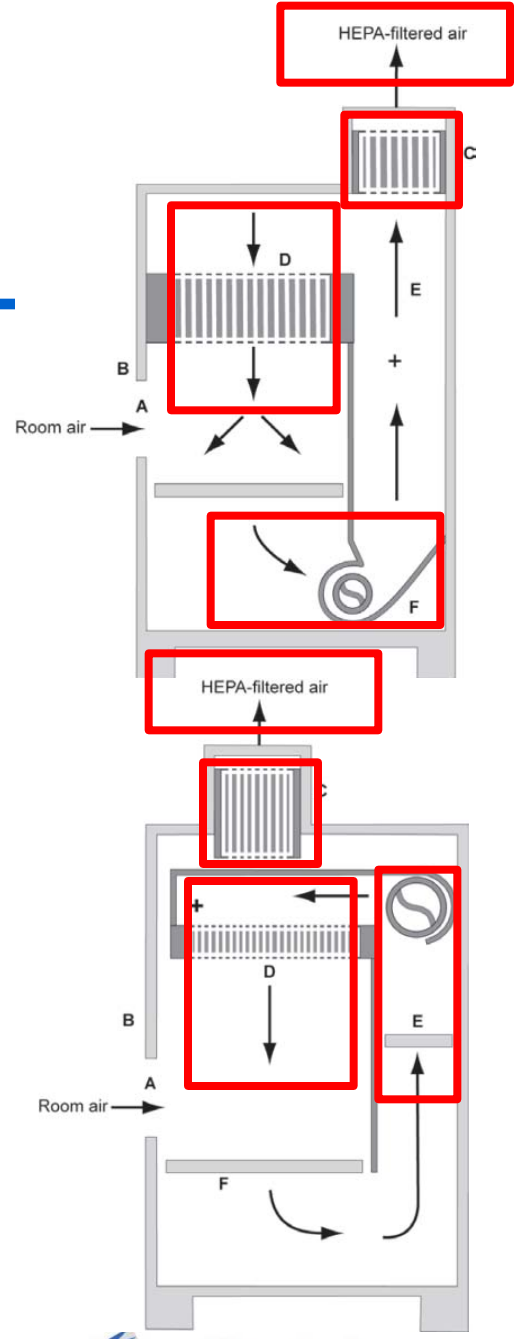


Class II Biological Safety Cabinet

- Provides personnel, product, and environment protection
  - from particulates, *some minute* chemicals
  - inward air flow
  - downward HEPA filtered laminar airflow
  - HEPA filtered exhaust
- Four types of Class II BSCs
  - cabinet type based on risk assessment
  - different vapor handling capabilities

Class II: A1 and A2 BSCs

- **Class II A1**
  - **minimum airflow velocity 75ft (24m)/min**
  - **30% exhausted, 70% re-circulated**
  - **downward HEPA filtered laminar airflow**
  - **HEPA filtered exhaust**
  - **not safe for work with *minute* quantities of hazardous chemicals unless ducted through properly functioning canopies**
- **Class II A2 (same as A1 except):**
  - **negative air pressure plenum surrounds all contaminated plenums under positive pressure**
  - **minimum airflow velocity of 100ft (33m)/min**
  - **not safe for work with *minute* quantities of hazardous chemicals unless ducted through properly functioning canopies**
- **Chemical issues?**



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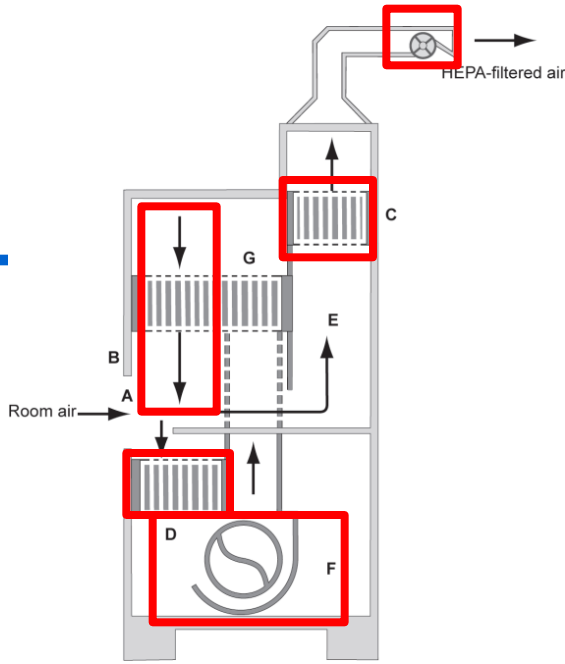
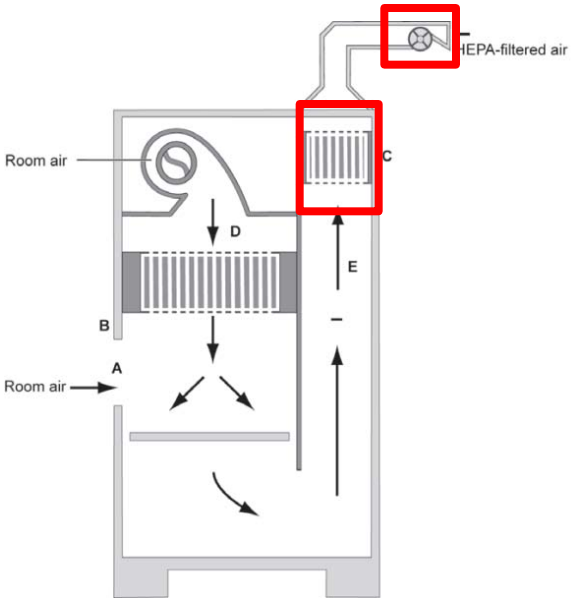
Class II: B1 and B2 BSCs

- **Class II B1:**
  - **70% exhausted, 30% re-circulated**
  - **downward HEPA filtered laminar airflow**
  - **HEPA filtered exhaust**
    - must be hard-ducted
    - directly from rear of work surface
  - **safe for work with *minute* quantities of hazardous chemicals when work is done in the back of the cabinet**
- **Class II B2:**
  - **100% exhaust cabinet**
  - **may be used with volatile toxic chemicals and radionuclides←flammables, corrosives?**
- **Chemical issues?**





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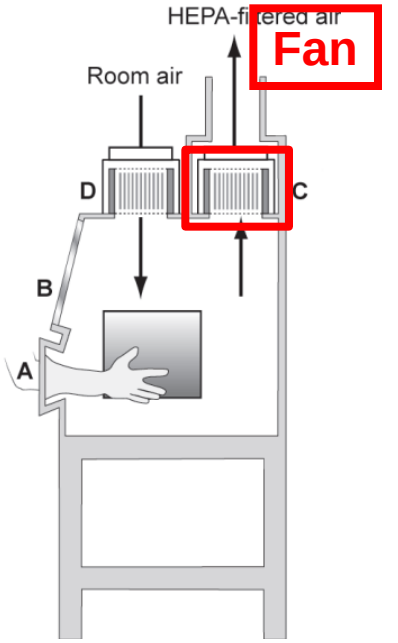
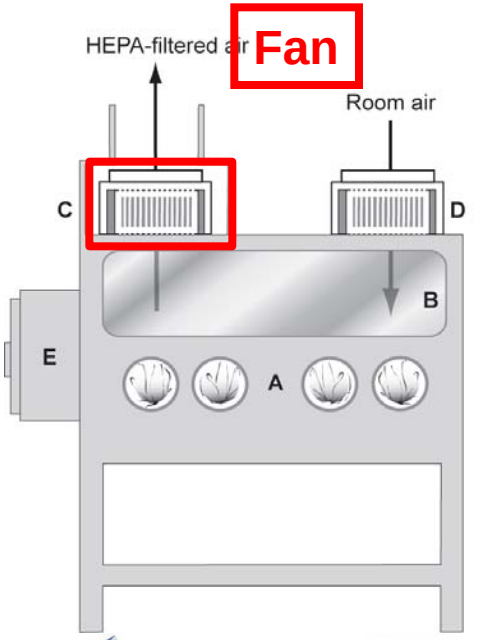
Class III BSCs

- Maximum protection
  - gas tight enclosure
  - ducting under negative pressure
- Protects product, personnel and environment
  - from particulates
- Supply and exhaust HEPA filtered
  - exhaust double HEPA filtration or HEPA filtration and air incinerator
- Heavy duty rubber gloves
  - restriction of movement
- Interchange box
- Chemical issues?





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BSC Class	Face Velocity	Airflow Pattern	Applications: Nonvolatile Toxic Chemicals and Radionuclides	Applications: Volatile Toxic Chemicals and Radionuclides
I	75	In at front through HEPA to the outside or into the room through HEPA (Figure 2)	Yes	When exhausted outdoors[1,2]
II, A1	75	70% recirculated to the cabinet work area through HEPA; 30% balance can be exhausted through HEPA back into the room or to outside through a canopy unit (Figure 3)	Yes (minute amounts)	No
II, B1	100	30% recirculated, 70% exhausted. Exhaust cabinet air must pass through a dedicated duct to the outside through a HEPA filter (Figures 5A, 5B)	Yes	Yes (minute amounts)[1,2]
I, B2	100	No recirculation; total exhaust to the outside through a HEPA filter (Figure 6)	Yes	Yes (small amounts)[1,2]
II, A2	100	Similar to II, A1, but has 100 lfm intake air velocity and plenums are under negative pressure to room; exhaust air can be ducted to the outside through a canopy unit (Figure 7)	Yes	When exhausted outdoors (FORMALLY "B3") (minute amounts)[1,2]
III	N/A	Supply air is HELP filtered. Exhaust air passes through two HEPA filters in series and is exhausted to the outside via a hard connection (Figure 8)	Yes	Yes (small amounts)[1,2]

1 Installation requires a special duct to the outside, an in-line charcoal filter, and a spark proof (explosion proof) motor and other electrical components in the cabinet.

2 Discharge of a Class I or Class II, Type A2 cabinet into a room should not occur if volatile chemicals are used. In no instance should the chemical concentration approach the lower explosion limits of the compounds.

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Biosafety Cabinets vs Chemical Hoods

- **Do not use BSCs in place of chemical hoods**
  - **exception is a Class II–B2 BSC, considering that:**
    - **only *small* amounts of toxic or volatile chemicals allowed**
    - **vent air is 100% exhausted**
    - **more expensive to install & maintain**

Type B2 Cabinet

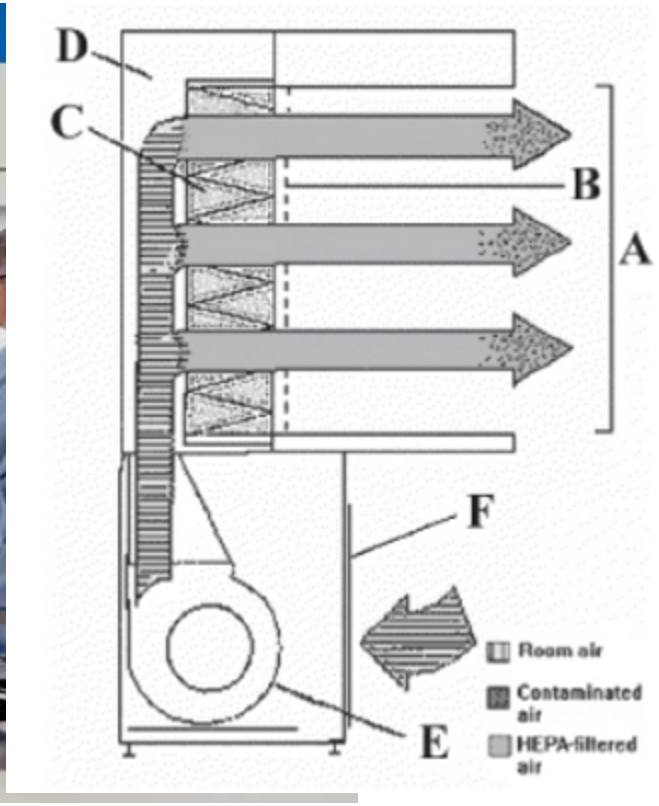
Biosafety Cabinets vs Chemical Hoods

- **Do *not* use BSCs in place of chemical hoods**
  - **chemicals may damage HEPA filters**
    - **solvents, acids**
  - **volatile or toxic chemicals should *not* be used in unducted Class II – Type A BSCs**
    - **increases vapor concentration ← exposure/fire hazard**
    - **volatiles not retained by HEPA filters, recirculate to lab, ← worker & work exposure**
    - **aerosolization of toxic chemicals ← exposure**
    - **fans not spark-proof ← explosion/fire hazard**
      - **for a typical 4-foot BSC, 10ml 70% isopropyl or ethyl alcohol is not likely to be a fire/explosion/exposure risk**
  - **manipulate biotoxins in a *chemical* hood**
    - **reduce exposure to lyophylized materials**

Biosafety Cabinets vs Chemical Hoods

- **No open flames in BSCs, but okay in a chemical hood**
  - **flames create turbulence in BSC airflow, compromising protection of workers and work**
  - **flames are a potential fire or explosion hazard**
  - **flames cause excessive heat build-up, and may damage HEPA filters**
  - **increased hazard from common use of ethanol and other flammable solvents**
  - **may inactivate the manufacturers warranty**

Group Exercise:
What type of Cabinet is this?



Clean Bench

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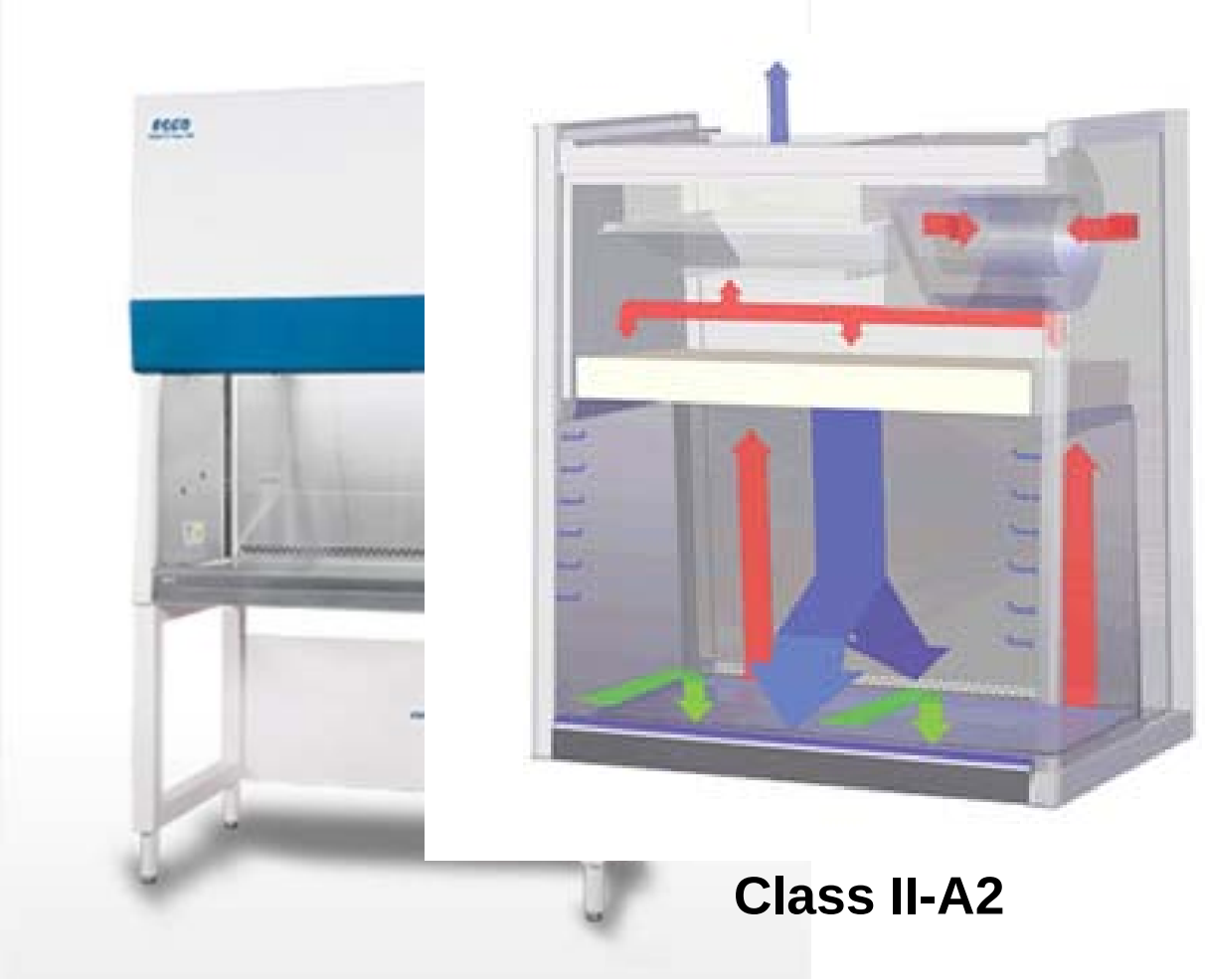
Group Exercise:
What type of Cabinet is this?

Class II-B2

http://www.labconco.com

Group Exercise:
What type of Cabinet is this?



Class II-A2

Group Exercise:
What type of Cabinet is this?

Traditional Laboratory Chemical Hood

Laboratory Chemical Hood

- **Also called a fume hood or fume cupboard**
  - **designed to limit exposure to hazardous and unpleasant aerosols**
  - **first used by alchemists 500 years ago**

LEV System Types

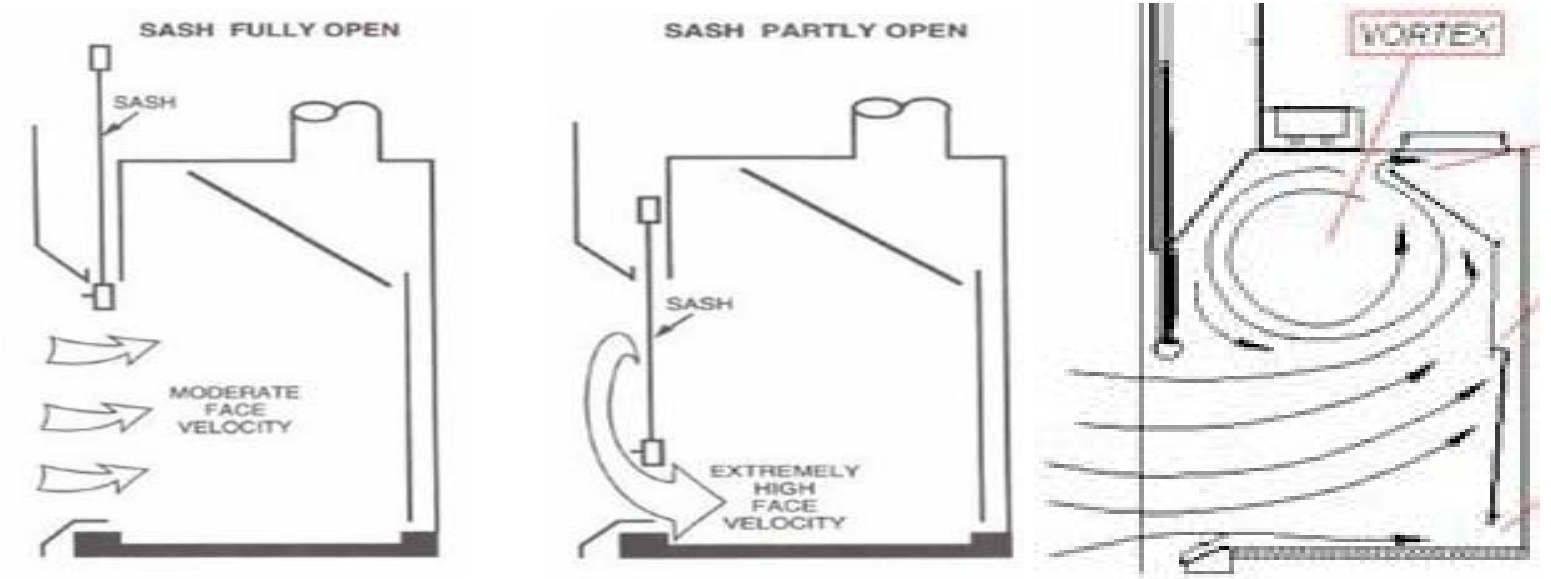
- **Local exhaust ventilation also includes:**
  - **snorkels**
  - **vented enclosures**
  - **glove boxes**
  - **isolation chambers**

Laboratory Hood Types

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

- **Variable Air Volume (VAV)**

Traditional Constant Volume Hood

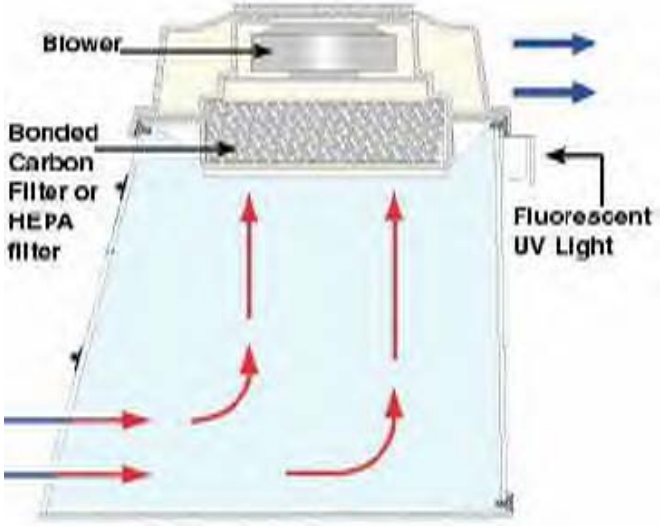


- **Standard type chemical hood:**
  - **constant air volume**
  - **used for general protection**
  - **face velocity is inversely proportional to sash height**
    - **the lower the sash, the higher the velocity**

Specialized Hoods

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

Ductless Hoods



Should only be used in laboratories with:

- Small quantities of *known* non-volatile substances.
- Only with HEPA filters
- *Never* with volatile substances
- Carbon filters:
  - are unreliable unless breakthrough time for the specific chemical being used is known.

Specialized Hoods

ADA Hood

Glove Box

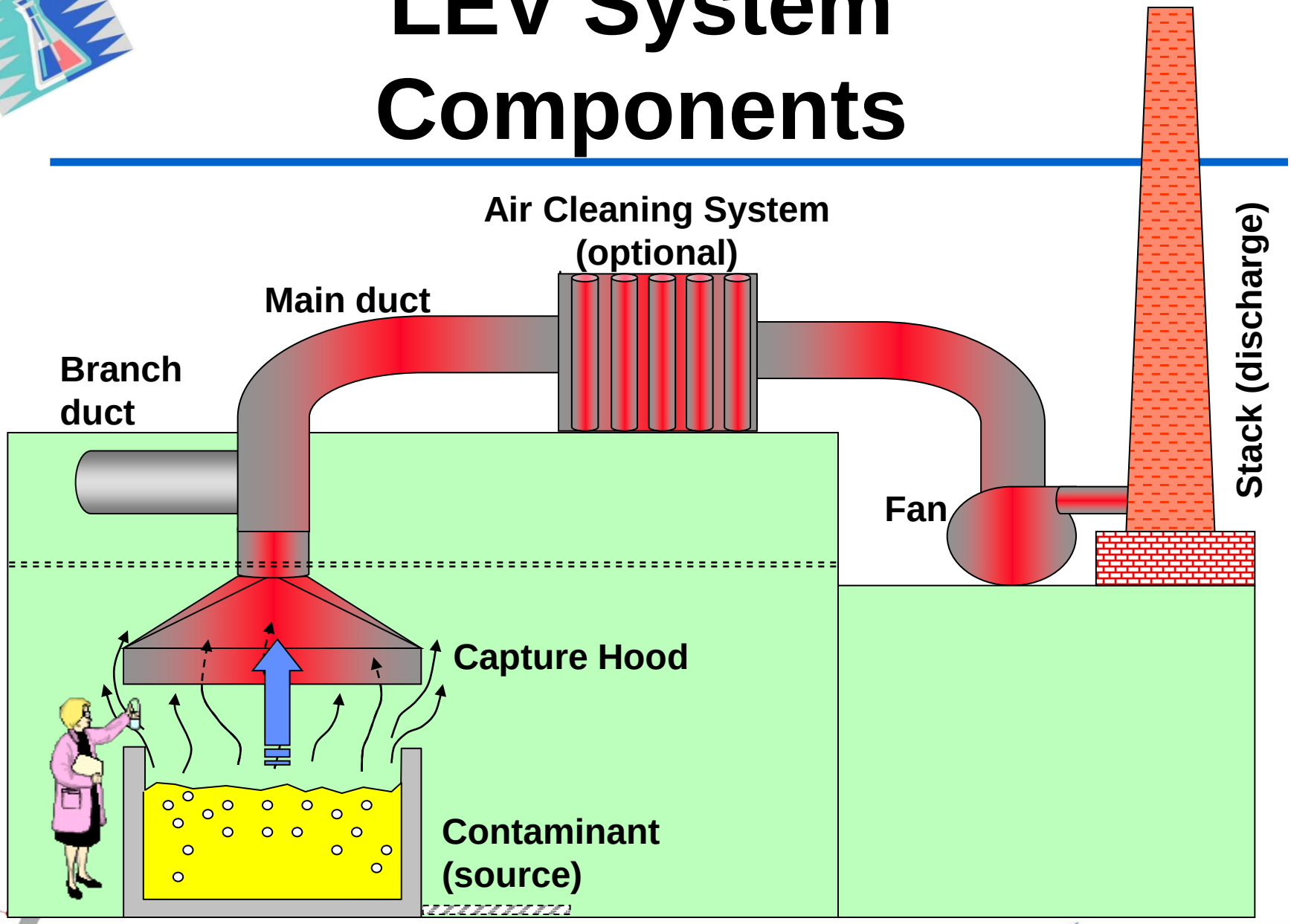
Canopy Hood

Floor Hood

LEV Special Hood Design: Outdoor Vented Balance Enclosure

- **High level of containment**
- **Stable balance readings**
- **Ergonomic design, visibility, comfort**
- **Task specific flexibility**
- **Energy efficiency:**
  - **2’ enclosure = 100 CFM (0.047 m^3/s) air**
  - **6’ hood = 1200 CFM (0.566 m^3/s) air**
  - **1200 CFM (0.566 m^3/s) = $5K/yr.**

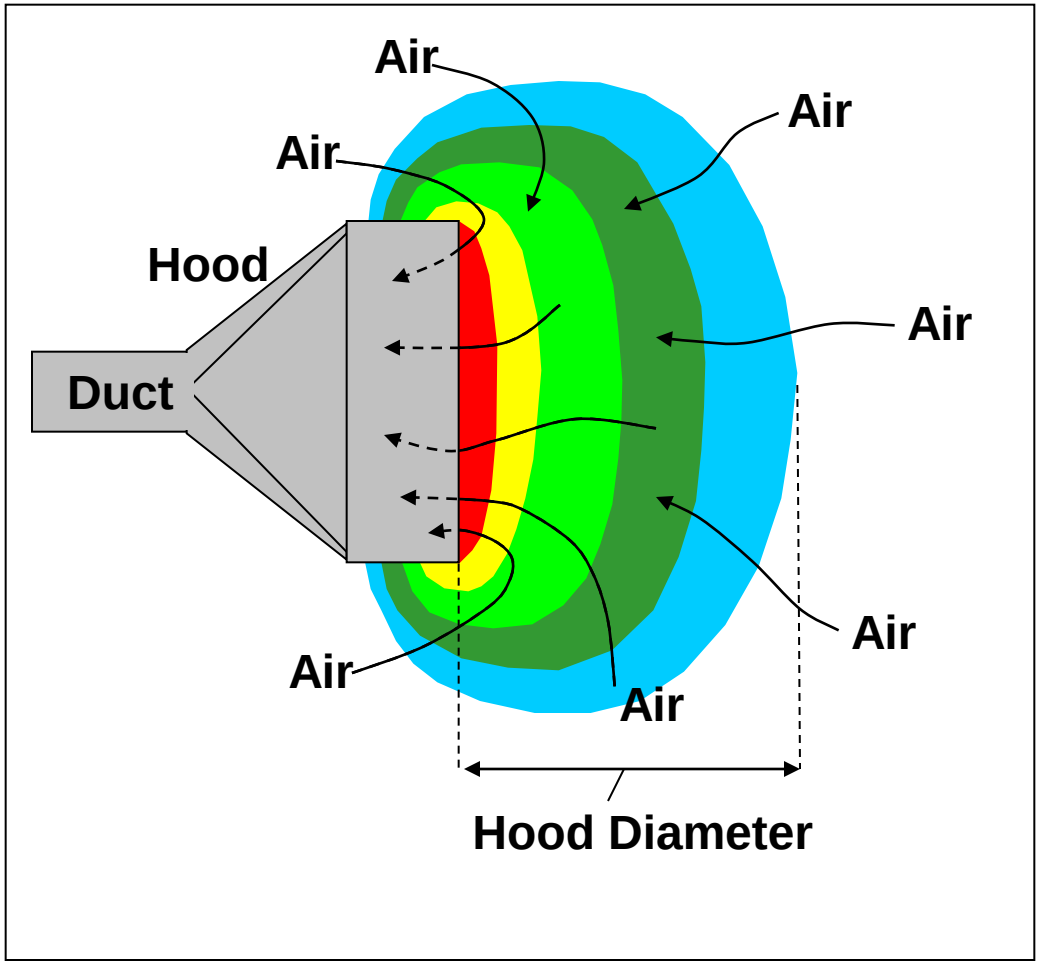
LEV System Components



LEV Hood Capture Velocities

Equal Velocity Zones

% Hood Capture Velocity	
	~100%
	~60%
	~30%
	~15%
	~7.5%



LEV Hood Capture Velocities

Equal Velocity Zones

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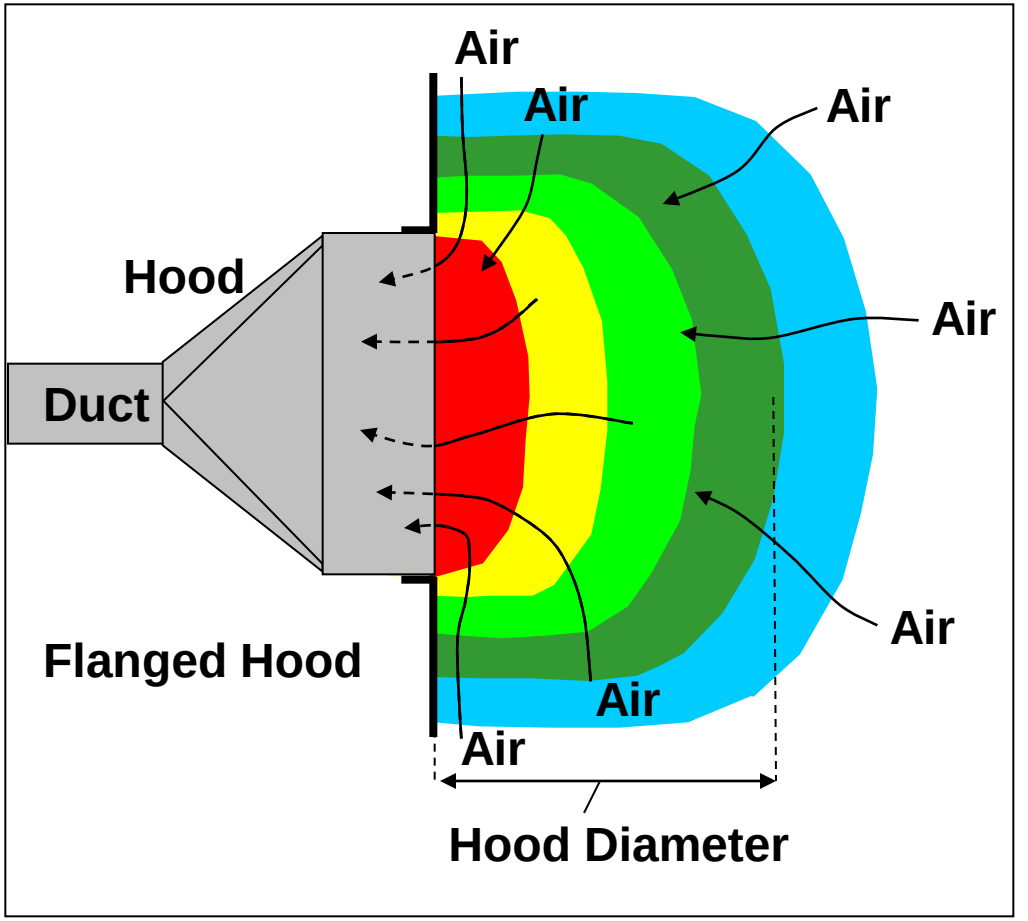
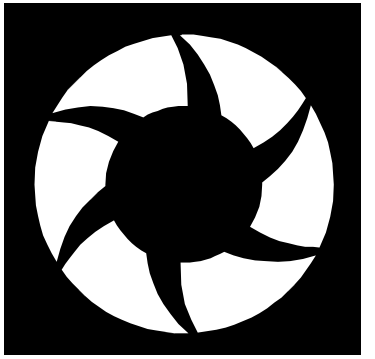
	~100%
	~60%
	~30%
	~15%
	~7.5%



LEV Duct Design



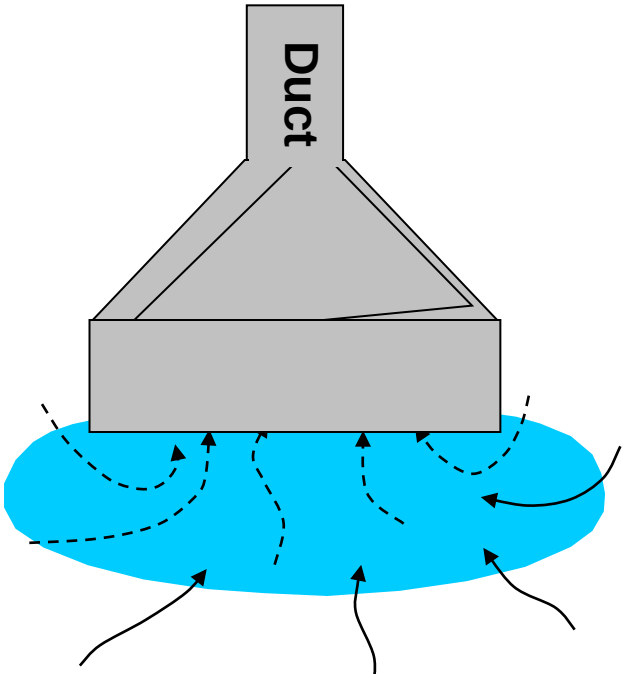
- **Provide adequate capture velocity**
  - **usually 80-120 fpm (0.4 - 0.6 m/s)**
- **Maintain duct transport velocity**
  - **for chemical laboratories ~ 2500 cfm (1.2 m^3/s)**
- **Keep system balanced,**
  - **equalize supply and return air**
  - **match airflows among manifolded hoods**
- **Minimize power consumption**
  - **conserve energy**
  - **save money**

LEV System Losses

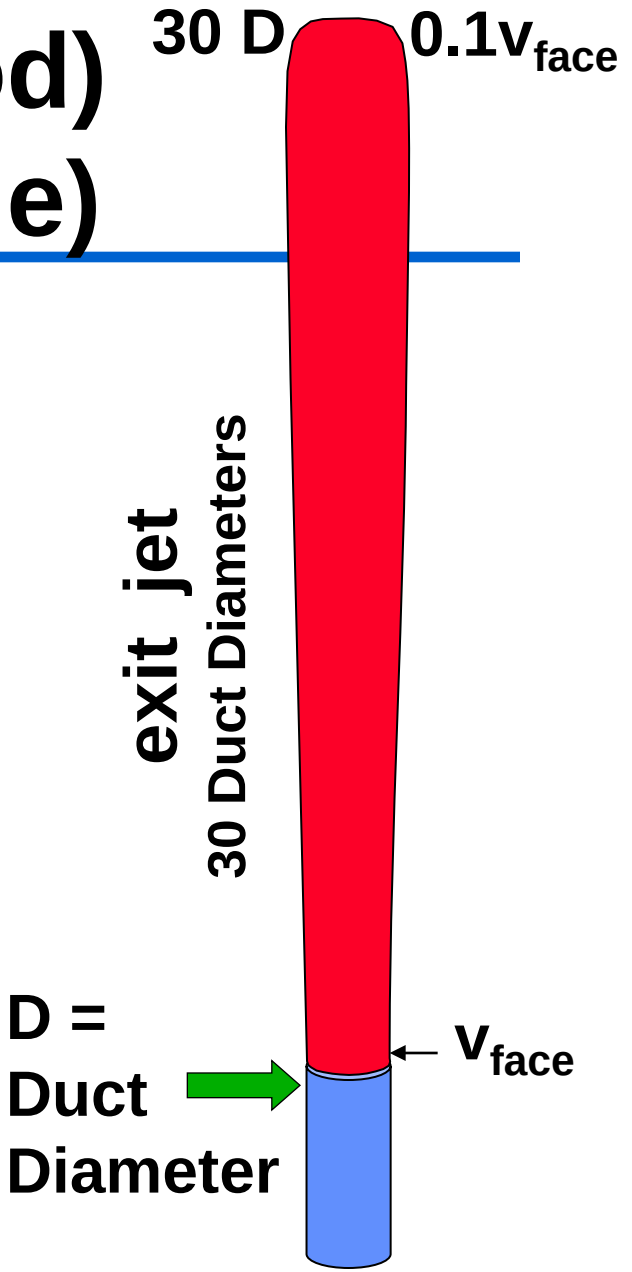
- **Friction Loss (FL):**
  - Rougher surfaces lead to higher velocity
  - FL $\propto LV^2/d$
  - FL units of pipe length
- **Dynamic Loss (DL):**
  - turbulence from elbows or transitions
  - turbulence at hood entry
    - Coefficient of Entry "C_e" measures efficiency of hood entry
  - DL increases with abruptness of elbow or transition
  - DL units of equivalent pipe length or fraction of VP
- **Pressure losses from system devices**
  - fans, air cleaners, etc.

LEV System: Duct Transitions

Flow at Entry (hood) and Exit (discharge)



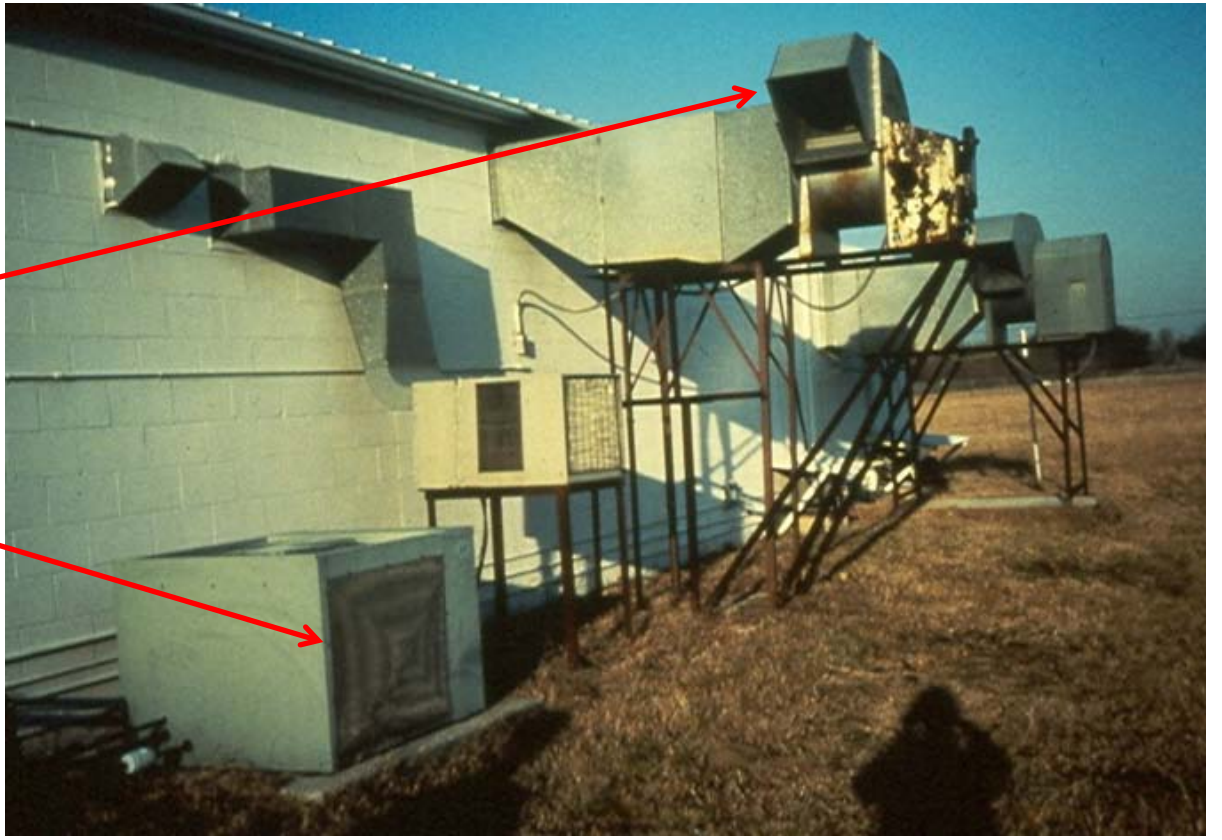
Capture of contaminant is only effective within <u>one (1) duct diameter</u>



LEV Systems: Avoid Exhaust Recirculation

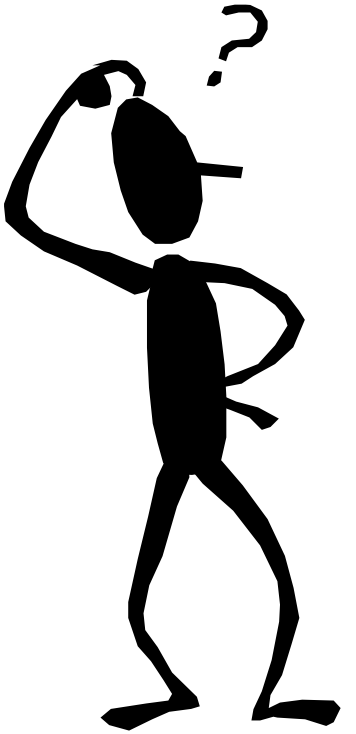
High Hazard Hood Exhaust

Air Intake



LEV Potential Issues

- Insufficient air volume
- Too much air flow
- Wrong location
- Wrong configuration
- Bad/wrong hood design
- Face velocity too low or too high
- Insufficient make up air
- Clogged system
- Noise



Laboratory Hoods

- **Lab hoods & ventilation are the <u>basis</u> of engineer controls.**
  - **But they *must* be:**
    - **properly selected,**
    - **properly located,**
    - **properly used, and**
    - **properly maintained.**

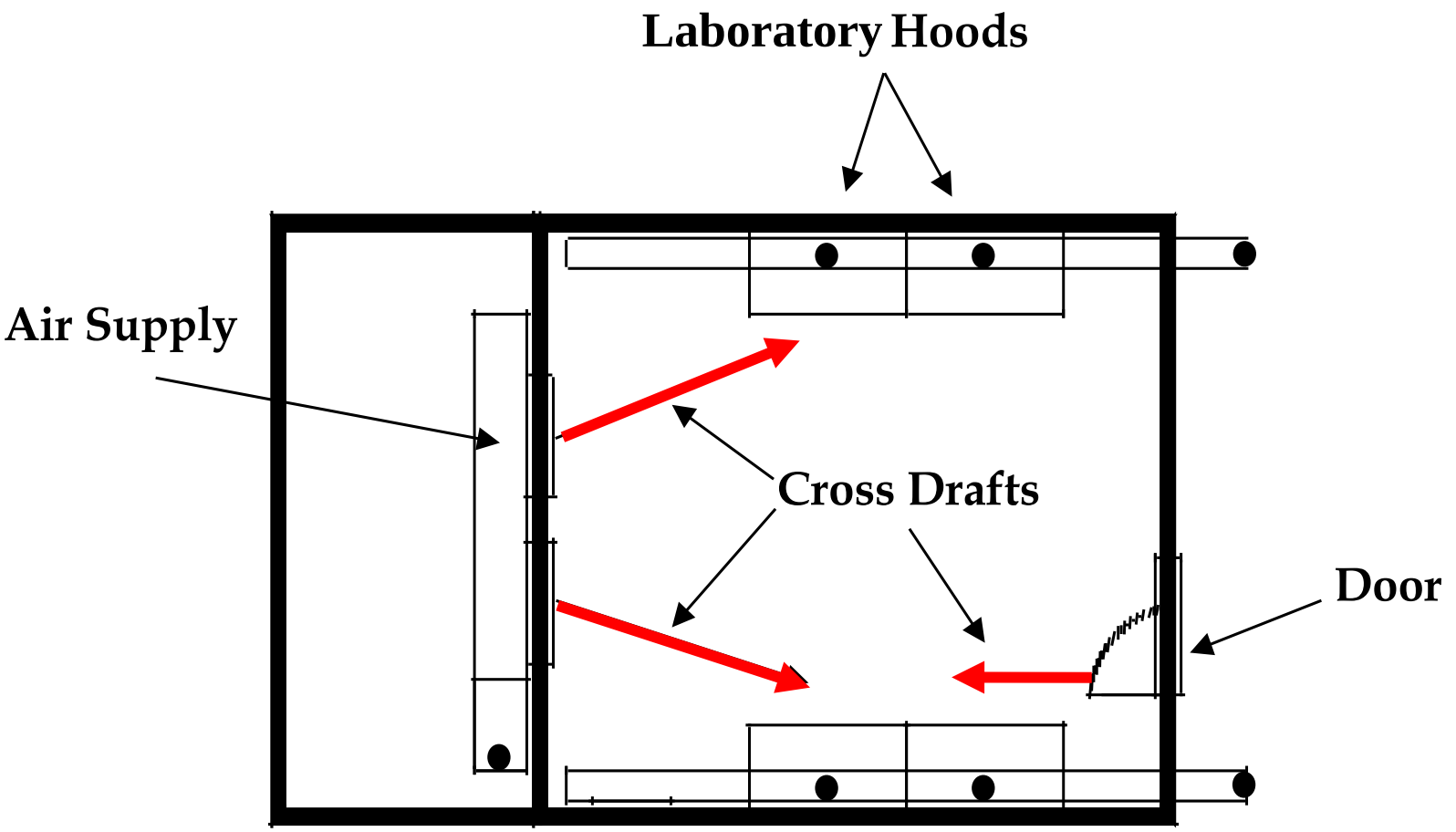
LEV System Design Requirements

- Capture emissions close to source.
- Move contamination away from breathing zone.
- Consider existing air movement when locating hood.
- Minimize air movement in source area.
- Should not interfere with work.

Hood Location Requirements

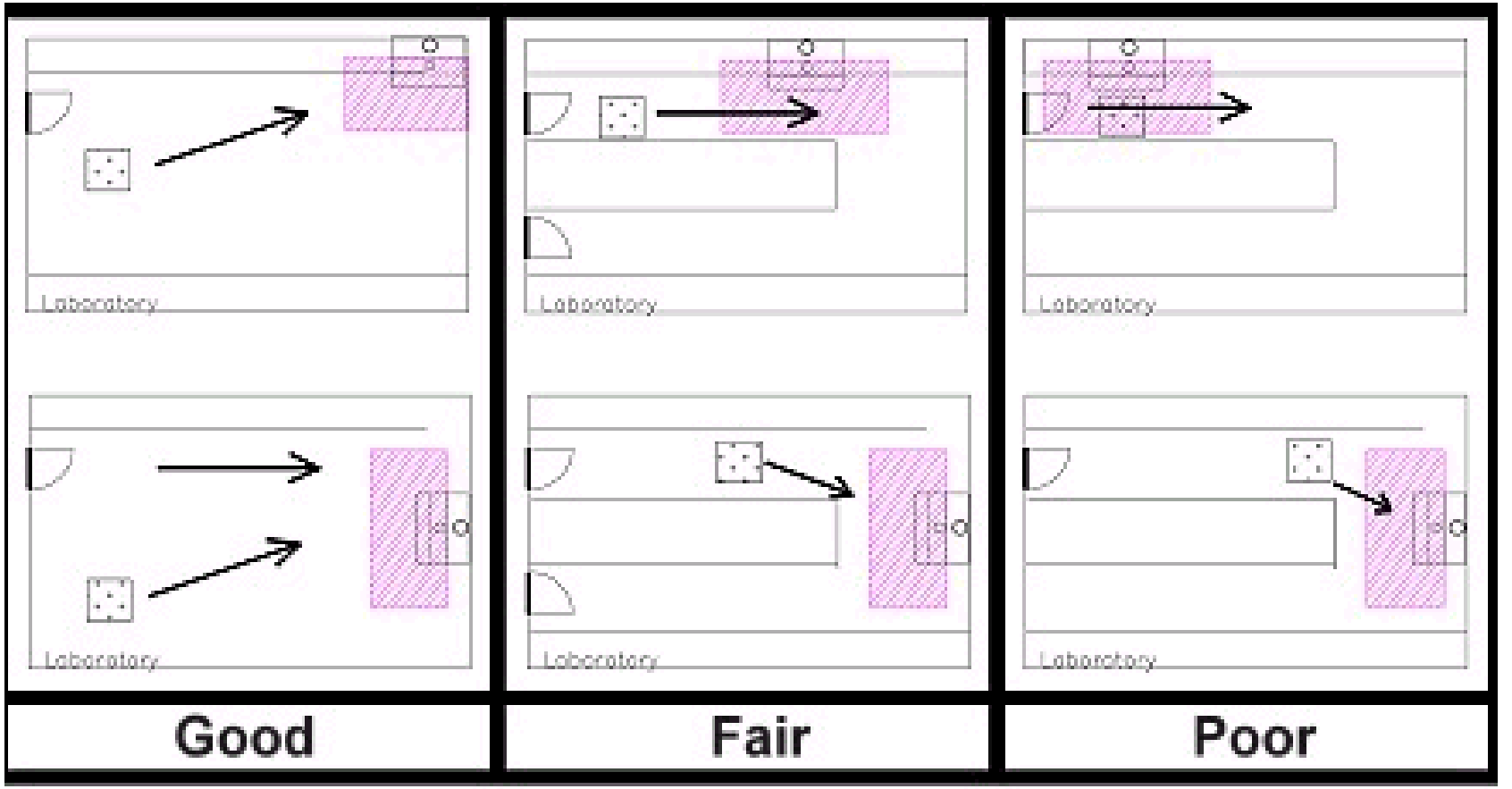
- As near to contamination source as possible
- So contamination moves away from operator
- Minimize cross-drafts
- Don’t place near windows and doors
- Don’t place near air conditioning/heater diffuser
- Doesn’t interfere with other workers
- Locate out of traffic flow
- Place near rear of laboratory

Problem Cross-drafts



Problem Cross-drafts

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



→ Air current or draft caused by door, traffic, air diffuser or other source.

Improper Hood Use

Principles of Hood Design and Operation

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

Hood Design & Operation, cont'd.

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

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

Hood Design & Operation, cont'd.

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

LEV Hood Evaluation

- Face velocity:
  - necessary, but not complete test
  - smoke Tubes
  - smoke Candles
  - incense
  - ASHRAE 110-1995 Test (SF_6)
  - Protection Factors (300-10,000):

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

LEV System Evaluation

- Face Velocity measurement:
  - Anemometer/velometer
    - fpm or m/s
    - directional
  - Hot-wire anemometer
    - fpm or m/s
    - non-directional

Hood Smoke Evaluation: Face velocity *vs.* Containment

- **Hood performance testing evaluates containment of contamination.**
  - **How do we determine containment?**
- **Is face velocity the right value?**
  - **Studies:**
    - **59% of hoods passed face velocity criteria; only 13% of these hoods met tracer-gas standards.**
    - **30% - 50% of hoods leaking excessive levels of contaminants passed face velocity tests.**
    - **lab hoods with face velocities as low as 50 fpm (0.25 m/s) can provide protection factors 2,200 times greater than hoods with face velocities of 150 fpm (0.76 m/s).**

LEV Hood Evaluation

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

Neither of these measurements can guarantee hood capture or containment.

Conclusions

- **Ensuring laboratory hood safety depends on many factors including:**
  - **hood design**
  - **hood use**
  - **lab design**
  - **system operation**
  - **user training**

Acknowledgements

- Tom Smith, ECT, Inc.; Cary, NC USA
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- Ray Ryan, Flow Sciences International, Leland NC, USA; http://www.flowsciences.com
- Knutson Ventilation; Edina, MN USA
- AirClean Inc.; Raleigh, NC USA

Laboratory Ventilation: BSCs and Chemical Hoods

Discussion Exercise

REHAT

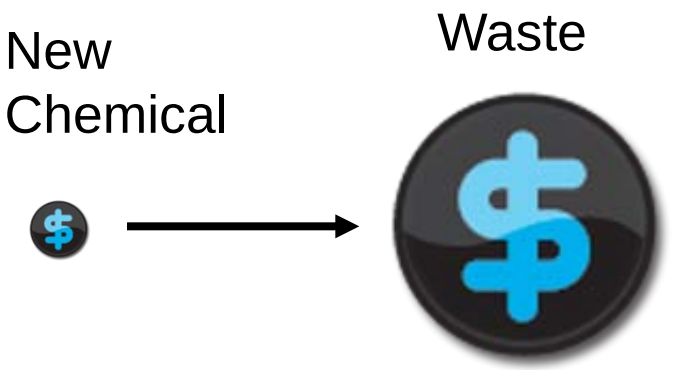
Cradle - to - grave care of chemicals

Receipt → **Storage** →

Use → **Disposal**

Chemical Management is a Best Practice for Safety *and* Security

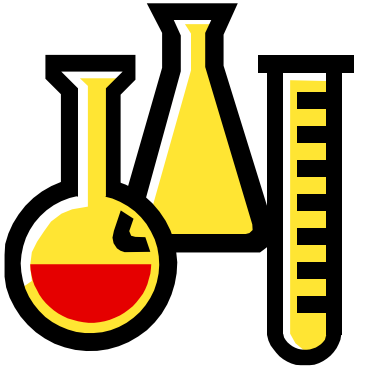
- **Reduces hazardous waste**
- **Reduces cost**
  - **New purchases**
  - **Waste disposal**
  - **More efficient**
- **Improves security**
  - **Insider threat**
  - **Outsider threat**
- **Facilitates environmental compliance**
- **Improves quality of research**
- **Improves quality of lab instruction**



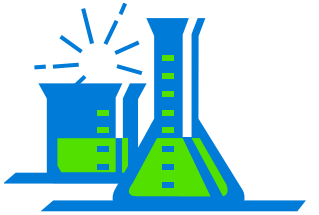
Proper chemical management program has several essential elements

Chemical Management Elements

- Source reduction
- Procedure for chemical ordering and disposal
- Inventory and tracking
- Storage in stockrooms
- Access control
- Recycling of chemicals, containers and packages



Plan experiments in advance!



What chemicals are needed?

How much is needed?

How will the chemicals be handled?

What are the reaction products?

How will the chemical be stored?

How will disposal take place?

Inventory management

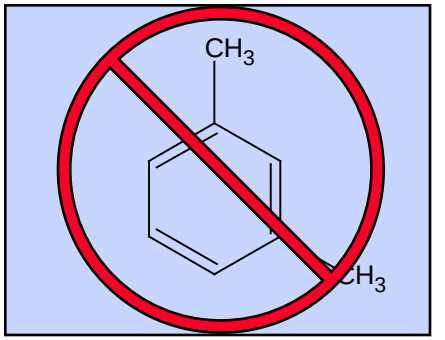
Less is Better !

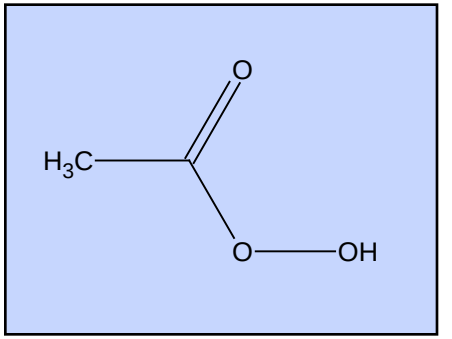
- Order only what you need
- Reduce size of experiment
- It cost less to store
- It cost less to dispose

"Less is Better: Guide to minimizing waste in laboratories", Task Force on Laboratory Environment, Health and Safety, American Chemical Society, 2002.
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=2230&use_sec=false&sec_url_var=region1&__uuid=ef91c89e-8b83-43e6-bcd0-ff5b9ca0ca33

Substitute reagents to reduce waste

- Citrus based solvents for xylene in histology lab
- Peracetic acid for formaldehyde for cleaning kidney dialysis machines
- Non mercury thermometers
- Enzyme and peroxide based cleaners for chromerge (NoChromix)
- When purchasing automated equipment think of chemical waste





Best practice - ordering and stocking chemicals

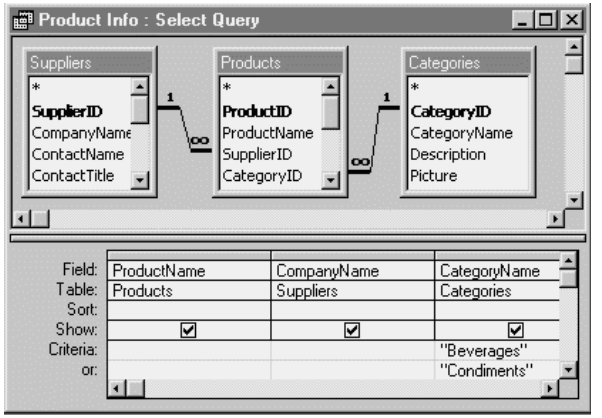
- See if your institution already has it (surplus)
- Order minimum needed (large quantities are not a bargain)
- Check on special storage (refrigeration, dry box…)
- Mark the receipt /open date (unstable chemical)
- Can it eventually be disposed of (rad waste, mixed waste)

Ordering chemicals- chemical inventory

- **Database or Spreadsheets are tools to track the chemical inventory**
  - **Barcoding can be used**
  - **Chemicals can be found easily**
  - **Chemical ages can be tracked**
  - **Chemical standards maintain traceability**
  - **Disposal can be documented**
- **Physical reconciliation**
  - **Assures accuracy of database**
  - **Provides visual inspection of chemical condition**

Inventory and tracking

Database or spreadsheet designs

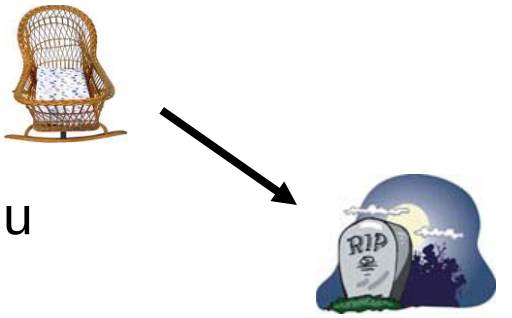


Home made – Access or Excel programs

Freeware – Based on Access or Excel

Commercial – Chemicals and MSDS included

Database helps safely track and report chemical storage and use



Searches and Reports:

- Find an (M)SDS
- Chemical Inventory Search Menu
- Chemical Regulatory Reports Search Menu
- Find Chemical Storage Locations

Transfers, Removal, Verification and Inventory Entry:

- Transfer or Remove a Bar-coded Chemical from the Inventory
- Verify Chemical Inventory Menu
- Add Chemical Inventory
- Chemical Exchange Menu

Procedures, Forms and Links:

- See Inventory procedures, forms and other documents
- See Other Chemical Related Links

Inventory queries

Chemical or tradename search

CAS number search

Ingredient search

Location/organization search

Location owner search

Requester search

Barcode search

Query result for toluene – barcode, location, department, quantity and order date

BARCODE	LOCATION	DEPT	QUANTITY	UNIT	Purchase Date
AQ00600682	NM/518/1111	1725	1	L	10/24/2006
AQ00602185	NM/518/1123	1111	100	mL	11/20/2006
AQ00582298	NM/518/1302	1131	1	L	8/8/2006
AQ00602186	NM/518/1302	1131	100	mL	11/20/2006
AQ00602187	NM/518/1302	1131	100	mL	11/20/2006
AQ00582307	NM/518/1302	1131	4	L	8/8/2006

(M)SDS and Certificates of Analysis may also be included

Chemicals likely to be useful in other labs

ACIDS

Acetic acid (glacial)
Hydrochloric acid
Sulfuric acid

SOLVENTS

Dichloromethane (methylene chloride), Acetone Chloroform, Ethyl acetate, Glycerol, Hexanes Isopropyl alcohol, Methanol, Petroleum ether Toluene, Xylenes

OXIDIZERS

Bromine, Potassium chlorate, Potassium dichromate, Silver nitrate

POISONS

Indicators, Iodine (solid or solution) Metals (powders, dust, shot)
Sodium, calcium, silver, and potassium salts

Excess chemicals are made available to others and can be searched

CHEMICAL NAME	MSDS	QTY	STATE	PURCHASE DATE	OPEN?
DEVCON 5 MINUTE EPOXY KIT	NL203800	2.5 OZ	Liquid	07/25/2001	Not Open
5 MINUTE EPOXY KIT	NL203800	2.5 OZ	Liquid	08/06/2003	Not Open
TOLUENE	OHS23590	500.0 ML	Liquid	03/25/1999	Not Open
TOLUENE	OHS23590	500.0 ML	Liquid	03/25/1999	Not Open

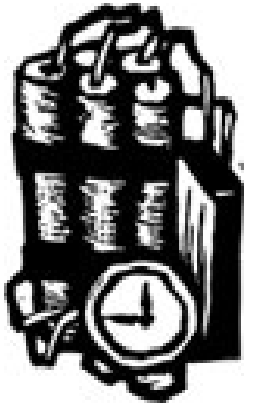
Inventory management

Less is Better !

It's Safer!

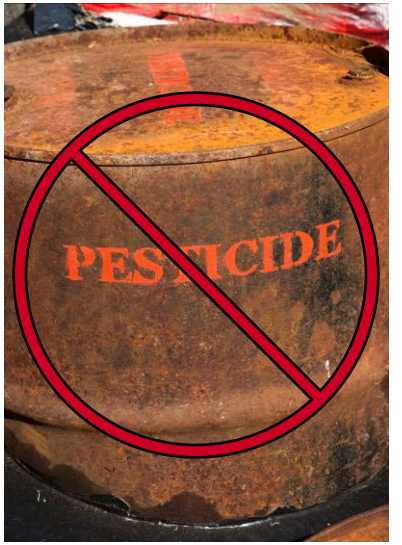
It may be cheaper to order diethyl ether in large containers

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



Inventory management – chemical aging

- How old are your chemicals?
- Some chemicals degrade over time
  - rotate stock
  - label & date
- Chemical assays have expiration dates



Explosives and Reactives

Examples:

- Peroxide-forming - ethers
- Perchlorate-forming – perchloric acid
- Water/moisture sensitive – Na, K, Li, LAlH, flammable metals

Control measures:

- Inventory control
- SOPs, inspections

Inventory management

-R-O-O-R-

Peroxide Forming Chemicals

Even with inhibitors they can become dangerous over time

- **discard or test if unsure**
- **label & date**

when received,
when opened, and
provide expiration date

Peroxide test kits and strips should be available

Peroxide forming chemicals

- Peroxide formation is caused by an autoxidation reaction.
- The reaction is initiated by light, heat, introduction of a contaminant or the loss of an inhibitor (BHT).
- Inhibitors slow, but do not stop peroxide formation.
- Most organic peroxide crystals are sensitive to heat, shock, or friction.
- It is important not to let peroxide forming chemicals evaporate to dryness or accumulate under screw caps.

-R-O-O-R-

Peroxide forming chemicals

Peroxides can explode when exposed to thermal or mechanical shock

Examples: ethers, dioxane, tetrahydrofuran

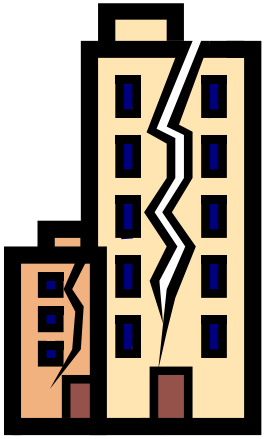
References:

There are excellent websites on peroxide forming chemicals and their hazards, use, storage, and disposal. For example, see:

http://www.med.cornell.edu/ehs/updates/peroxide_formers.htm

Chemical storage

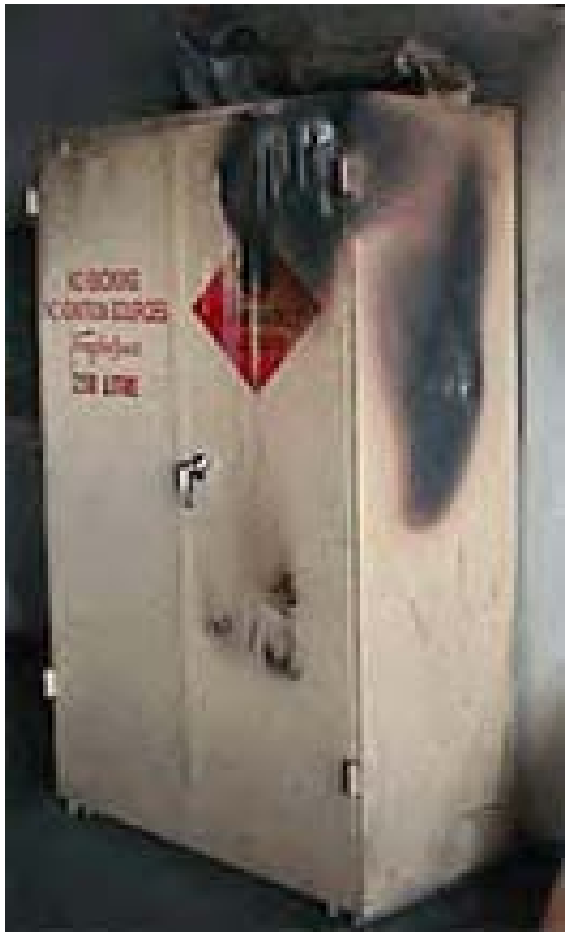
- Protect chemicals during normal operations
- Protect chemicals during unexpected events
  - Floods
  - Tidal waves
  - Earthquakes
  - Typhoons
  - Hurricanes



Chemical storage: Basic concepts

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

Use flammables storage cabinets



Chemical storage: Basic concepts

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

Compressed Gas Cylinders

- Uses
- Types
- Hazards
- Control Measures
  - Inventory control
  - Procurement authorization
  - Training
  - Inspection

Chemical storage: Gas cylinders

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

Improper gas cylinder storage

Damage from Gas-cylinder fire

CSP
CHEMICAL SECURITY
ENGAGEMENT PROGRAM

cal
Y TRAINING

An Accident Waiting to Happen

CSB video: Compressed gas fire

Chemical storage: Good practices

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

Chemical storage: Bad practices

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

Chemical storage: Containers

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

Improper chemical storage

Never use hallways for storage

Safety Hazard!!

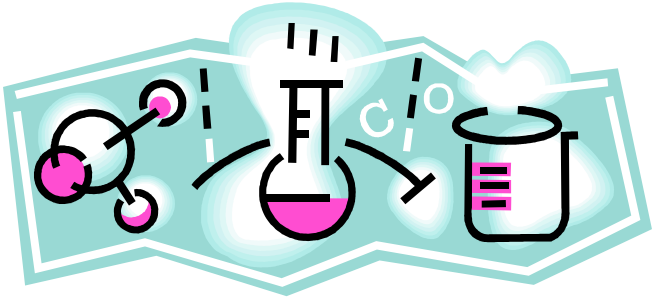
Blocks exit path in emergencies!!!

Chemical storage: Good practices

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

Suggested shelf storage groups: Organics

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



From: “School Chemistry Laboratory Safety Guide,” US NIOSH Publication 2007-107

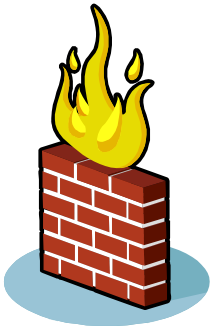
Suggested shelf storage groups: Inorganics

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

From: "School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107

Best practice: access control

- Proper training of chemical handling personnel



- Only trained and approved personnel
  - have access to stock room and keys
  - administrative privileges to inventory and database

- Locked doors and cabinets for controlled substances
  - Radioactive materials
  - Drugs and consumable alcohol
  - Explosives (special handling facility)
  - Dual use chemicals
  - Hazardous waste - high toxicity chemicals

References

"Less is Better," American Chemical Society, Washington DC, 2003, available online:
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