Planning a Safe Experiment

Responsibility for Safety

Each laboratory worker is responsible for his/her safety as well as ensuring that there are no negative consequences as a result of their actions. Thus, each worker must protect not only himself, but others in the workplace, the public, and the environment. In-depth safety planning must precede any hazardous work. Further, many laboratory activities involve materials, equipment or wastes that are regulated, and these regulations must be taken into account when acquiring, storing or using hazardous materials or engaging in hazardous processes. The information contained within the FSU Safety Manual can be used as a blueprint for safe research provided that all involved lab workers are familiar with the nature of the hazards associated with their work, and are trained and supervised accordingly. Research hazards must be evaluated and addressed in the experimental design phase, and a copy of safety procedures for each experiment involving high risk hazards, once developed, should be made available in the lab either as part of the scientific protocol or in a laboratory safety manual (see The Lab-Specific Safety Plan below).

Principal Investigators or supervisors are responsible for establishing and enforcing laboratory safety rules in their areas or for their personnel. Student workers must consult the Principal Investigator or another experienced supervisor about all aspects of laboratory safety prior to engaging in laboratory activities. **Students and employees must be trained in general safety by attending courses offered by EH&S, but must also be trained in the safe handling of hazardous equipment, operations or materials specific to their research and workplace. This training is provided by experienced lab members.** Contact EH&S for assistance in evaluating general laboratory hazards or hazards specific to a given experiment; and to obtain additional resources.

Principal Investigators and supervisors are primarily responsible for ensuring that their employees, students, volunteers and visitors working in the laboratory receive proper training. Training is required for anyone who will work in laboratories with hazardous materials, equipment or processes. **In addition to training that is provided by EH&S, safety training specific to the hazards of each laboratory must be provided by lab supervisors**. See the EH&S training descriptions for information regarding required training; a description of the training courses; or to register for training. One-on-one training sessions or laboratory specific guidance may be requested by contacting EH&S.

EHS maintains records of everyone who attends EH&S training. Records are available upon request.

Research and Plan Ahead

Plan ahead to ensure that you completely understand the experiment, have evaluated the hazards, and have prepared a scientific protocol that is safe to carry out.

- **Become thoroughly knowledgeable** about the processes, equipment and materials used in a given experiment. All experimental designs should be discussed with the Principal Investigator or lab manager to identify potential hazards, to learn how to work safely and how to respond if something goes wrong.
- **Document research** on laboratory hazards so that this information may be utilized in the event of an emergency. Download the SDS or other appropriate sources for hazard information.
- **Discuss experimental design** with the Principal Investigator and other senior laboratory members to address all aspects of safety. Carefully consider each hazardous material, equipment and process and make sure that all questions you have regarding these have been answered. Discuss the use of safety equipment and PPE. Discuss/develop emergency response procedures.

- **Responsibility for Unattended Experiments and Working Alone** – No hazardous experiments should be undertaken when working alone in the laboratory. For low risk experiments, workers in the lab after hours must have permission of their supervisors, who should be made aware of the lab activities that will be performed. Laboratory activities with hazardous materials must sometimes be undertaken at night with no one present. According to the National Research Council as stated in Prudent Practices in the Laboratory, "It is the responsibility of the worker to design these experiments so as to prevent the release of hazardous substances in the event of interruptions in utility services such as electricity, cooling water and inert gas. Laboratory lights should be left on, and signs should be posted identifying the nature of the experiment and the hazardous substances in use. If appropriate, arrangements should be made for other workers to periodically inspect the operation. Information should be posted indicating how to contact the responsible individual in the event of an emergency." All unattended lab operations must have prior approval of the Principal Investigator.

Identify Hazards and Assess Risks

A risk assessment is performed to try to predict what might go wrong, how likely it is to go wrong and how severe the consequences would be. For each hazard, the risk must be mitigated so that the work may be performed safely. Sometimes an agent with a high risk of harm – for example, a high energy laser – may carry a low risk of injury – i.e. the laser beam is completely enclosed within the laser housing. The goal of the risk assessment is to identify each hazard and qualify the level of risk of injury to persons in the laboratory, staff, students, the public and the environment. Each hazard, once identified and assessed for risk of harm to persons or the environment, should be mitigated through administrative and engineering controls, special work practices and the use of protective equipment, taking into consideration what might go wrong in each step of the experiment, removing the hazard to the extent possible, and having secondary plans if something should go wrong.

A risk assessment must be performed for each separate procedure and experiment, and the safety information for work with high risk materials or activities must be incorporated into the lab safety manual or within scientific protocols. To assist with this process, the following guidelines and information are provided.

- **Identify the hazards** – Identify the materials, processes and equipment that may be hazardous. You should look at the suitability and location of the things you use, how tools and equipment are used, and how your activity might affect yourself and others.
- **Evaluate the materials** to be used to determine what harm each agent may cause: identify hazardous nature of chemicals, i.e. physical (explosive, corrosive, flammable, reactive) or health hazard (toxic, corrosive, carcinogenic), hazardous biological materials and radioactive materials. Make sure that you are aware of all possible routes of exposure (inhalation, ingestion, through skin and eyes; injection); the possible effects of a hazardous materials exposure; the concentrations or amounts that are expected to be hazardous; emergency response methods in case of a laboratory accident or materials exposure.
- **Look at the lab activities** that may increase the potential for harm, i.e. weighing toxic materials on the open lab bench; heating or warming chemicals that may give off hazardous vapors; opening volatile chemicals; controlling an energetic reaction; opening an autoclave; aligning a laser beam. Identify methods to control or eliminate the hazard.
- **Evaluate equipment and labware** for hazards before use, for example the use of contaminated needles; working with cutting equipment; aerosolization of hazardous materials when vortexing or when performing flow cytometry; proper syringe transfer of pyrophoric chemicals; the use of

centrifuge tubes that are rated for the g-forces to which they will be subjected. Make sure that you utilize the appropriate equipment and labware for the task, and that all safety mechanisms are in place. Note what kind of maintenance is required for essential equipment and determine if the equipment is working correctly.

- **Evaluate the facilities** to ensure that labwork may proceed safely. For example, the use of compressed gases should be avoided in confined spaces; aisles and workbenches should be uncluttered; emergency "kill" switches may be required to turn off hazardous equipment or electrical circuits; visibility should be adequate; egress must be unobstructed. Make sure that appropriate safety equipment like fire extinguishers and eye washes are available and accessible. Special considerations for location of materials storage; ventilation and shielding should be assessed.
- **Consider increased risk factors** for individuals who are pregnant or who may have health conditions so that they would be more impacted than a healthy worker by the harmful effects of activities or materials. Consider other factors like fatigue or cold that may increase the risk of a laboratory accident. Contact EH&S for guidance related to specific health concerns.
- **Do not underestimate the risk.** Assume that chemical mixtures may be more toxic than the individual components. Assume that a scaled up reaction will increase the risks associated with the hazards.
- **Determine the proper disposal methods** prior to beginning an experiment to ensure that discarded hazardous materials are not spilled or released, resulting in an occupational exposure or a release into the environment.

A Laboratory Hazard Assessment Checklist may assist researchers in identifying hazardous materials or conditions which must be addressed when planning a safe experiment.

Eliminate Hazards or Mitigate Risks

If the risk of injury is high and methods of reducing the risk are unattainable, consider alternative experiments. You should devise control measures to ensure that there is a very low likelihood of a serious worst-case lab accident.

- Can you eliminate it?
- Can you substitute a less hazardous alternative?
- Can you purchase/handle smaller amounts of the hazardous material or use commercially prepared solutions?
- Can you change the way the task is done?
- Is the facility adequate for the experiment?
- What controls may be used to reduce the risk to an acceptable level?
- Will you have to use personal protective equipment? Is it available?
- Have the hazards (and alternatives) been adequately evaluated through research?
- Are regulatory concerns addressed?
- Has the effect on the environment (ultimate fate of materials) been considered?
- Is emergency response equipment available and accessible?

- Have you discussed the hazards with senior laboratory personnel to identify alternatives and to check the efficacy of the safety measures you have in place?
- Have individuals been properly trained regarding all aspects of the experiment and emergency procedures?
- Is there a language barrier that might impede an emergency call?
- Think again about what could go wrong...has each step of the process been evaluated and address for safety?

The following methods of eliminating or reducing risk are used in planning a safe experiment. Identify a combination of safety methods and personal protective equipment (PPE), as described below - including the use of fume hoods and other exhaust equipment, special transfer devices, appropriate glass or plastic ware, personal protective equipment, and special handling protocols - to remove or mitigate the hazard. Make sure that the equipment, methods and PPE are functional and appropriate for the proposed use:

- **Administrative Controls**: Administrative controls are strategies and policies that eliminate or mitigate the risk of harm. These may include personnel policies like training requirements prior to obtaining entry to laboratory areas or class policies for proper attire while performing experiments. Requirements for following workplace safety rules are essential to maintaining a safe workplace. Among these are requirements for good housekeeping, participation in emergency drills, heeding postings and labels, demonstration of knowledge and understanding of hazards and risks, and participation in safety programs and training. These requirements may be made part of administrative controls, for example, if a student grade or employee evaluation is based, in part, on adherence to workplace safety rules. The use of good laboratory design, including identification of proper chemical storage areas, is also part of an administrative approach to minimizing risks. Further, senior lab personnel may require pre-experiment reviews for experiments in which conditions may have changed or which involve high risk processes before work can proceed.
- **Engineering controls**: The use of exhaust systems is essential to protection against a hazardous materials exposure when working with volatile chemicals, hazardous particulate agents and with processes that could make radioactive or biohazardous materials airborne. Other important engineering controls include the use of shielding; equipment guards, monitors and alarms connected to interlock devices; gloveboxes; safety caps; filters; warning lights; barriers and pressure relief mechanisms.
- **Work Processes**: Incorporate work processes that minimize the risk of illness or injury by utilizing exhaust systems; purchase and handle smallest amount of hazardous materials suitable to the experiment; have only necessary materials in the workspace; follow important safety/scientific requirements for labelling and use of appropriate containers; clean up spills and decontaminate before proceeding to the next step; carefully monitor reactions or have shut-down mechanisms in place.
- **Personal Protective Equipment**: The use of PPE is often employed to further reduce risks of injury or illness that are already reduced through other measures. PPE should not be the first or only method of protection except in rare circumstances, for example, when one is working in the field. Generally, engineering controls are employed, along with administrative controls and special work practices, to “engineer out” the hazard.

Prepare the Emergency Response Plan

Devise a response plan to mitigate a laboratory accident. Imagine what might go wrong, and before beginning the experiment or prep work, prepare for these circumstances.

- What might happen if the cooling system or electrical system fails?
- What might happen if the chemical containers break or are tipped over?
- What about visibility? Can it be affected by any facet of the experiment?
- What assistance might be needed for a fire or other emergency?
- Where are the nearest fire extinguisher, safety shower and eye wash, fire alarm and telephone?
- What phone numbers are required?

Before performing laboratory activities, become familiar with emergency equipment and appropriate methods of responding to any accident. Obtain "spill kits" for work with high volumes of concentrated acids, solvents, toxic or flammable chemicals or biohazards. Use the "buddy" system so that a lab worker who is aware of all safety aspects of the ongoing experiment is available to assist in an emergency.

The Lab-Specific Safety Plan

OSHA requires that each laboratory that works with hazardous materials, processes or equipment develop a Laboratory Safety Plan. The Laboratory Safety Plan provides a general outline of laboratory policies and procedures as well as specific safety protocols for high risk operations. The plan may be added as an addendum to the FSU Lab Safety Plan or may be incorporated into laboratory scientific protocols. This plan should be developed by each faculty member to meet the specific needs in his/her laboratory.

The following is suggested list of information to be included:

- Name or Description of Experiment(s)
- Hazardous materials or processes – the lab safety plan should address all aspects of safely handling and disposing of hazardous materials. All personnel must understand the hazards associated with protocols and be able to respond if an emergency arises.
    - Toxicity, reactivity and flammability, other hazard information
    - Amounts and concentrations involved
    - Potential routes of exposure (inhalation, ingestion, injection, skin contact)
    - Engineering controls employed – fume hood, special capping devices, etc.
    - Work practices employed – temperature controls, inert atmosphere employed, etc.
    - PPE required – specifically what types of gloves, goggles and lab coats, specify if flame resistant attire and lab coat is required
    - Signs and symptoms of an exposure
    - Waste disposal procedures
    - Emergency response procedures including equipment locations and spill kits
    - Write specific spill response procedures for hazardous materials and experiments, including emergency contact information, protective clothing, safety equipment,

cleanup materials, evacuation procedures, location of fire extinguishers, waste disposal containers and first aid procedures

- Required Training
- Medical Monitoring if needed
- Registrations/Notifications/Permits/Approvals
- Other Policies and Procedures (University, departmental)

The Lab-specific safety plan is a document that provides details on hazardous materials, equipment and processes that are specific to the lab activities. This plan, therefore, is a document that establishes consistent safety practices for laboratory members.

In addition to a Laboratory Safety Plan, a Safe Operating Procedure (Safety SOP) should be prepared for high hazard experiments:

The kinds of experiments that warrant a Safety SOP involve certain chemicals (high volumes of flammables, corrosives, toxic or reactive chemicals), any amount of highly reactive or pyrophoric chemicals, work with any amounts of explosives, any toxic gas, Class III or Class IV lasers, highly energetic reactions, high heat, high pressure, high hazard equipment, working in confined spaces, potential for low oxygen or oxygen displacement, work with high voltage currents, or other hazardous conditions. A Safety SOP template is available at http://www.safety.fsu.edu/sections/labforms.php

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Additional Information and Resources

- Prudent Practices in the Laboratory. National Research Council, National Academy Press, Washington, D.C. 1995.
- Wood-Black, F. K. "Quantifying Risk – Putting Things into Proper Perspective" J. Chemical Health and Safety Nov/Dec 2002 p. 11 – 14.
- Singley, John A. "Hazard vs. Risk" J. Chemical Health and Safety Jan/Feb 2004 p. 14 – 16.
- Conducting a Clinical Laboratory Risk Assessment
- Five Steps to Risk Assessment
- Risk Assessment at Work
- UCLA sample safety procedures