Chapter 6
Pollution Prevention and Waste Minimization

Is your laboratory a "green" laboratory? "Green" is the design, development and implementation of chemical products and processes to reduce or eliminate the use and generation of substances hazardous to human health and the environment. Since laboratory activities differ, there is no single set of standards for a green laboratory. Observing the following guidelines will help reduce pollution and minimize waste produced during laboratory work.

Green labs are designed to reduce pollution. What steps can you take to may your lab green?

- ✓ Train new personnel in chemical and environmental safety, including methods of pollution prevention and waste minimization used in the lab.
- ✓ Prepare for leaks and spills by using secondary containment (i.e., trays) and by stocking spill control supplies.
- ✓ Review the properties of chemicals in use to understand their hazards (i.e., reading Material Safety Data Sheets) and search for safer substitutes.
- ✓ Assess laboratory air emissions, sanitary sewer disposals and waste generation to understand how your operations impact the environment.
- ✓ Keep caps on carboys and other containers of volatile chemicals.
- ✓ Buy only chemicals in the amounts needed, date chemicals upon arrival, and store chemicals according to their properties (e.g., reactivity, flammability, etc.).
- ✓ Use redistributed (i.e., LABSCAN) surplus chemicals whenever possible.
- ✓ Create and annually review chemical inventories; routinely give usable surpluses to the Safety Department to make those chemicals available to other laboratories.
- ✓ Keep waste types separate and develop a workable system of waste collection.
- ✓ Dispose of waste in a responsible manner, neutralize acids and bases and, where practical, perform in-lab treatment of other chemicals so they do not become a waste requiring commercial disposal.

The methods in this chapter not only prevent pollution, but can also reduce the risk of chemical exposure and accidents.

Call the Safety Department if you have pollution prevention ideas. We can help implement them. We will share successful solutions with others.

This chapter offers suggestions to help you minimize the environmental impact of your laboratory operations.

6.1 Pollution Prevention

Pollution is a byproduct of research. Laboratory workers create pollution when they: generate hazardous waste, allow volatile chemicals to evaporate in a fume hood or discharge certain hazardous materials down the drain. A variety of methods can be used to reduce pollution to the air, water or land. This section will address methods to prevent pollution caused by hazardous chemicals in the laboratory.

EPA defines *pollution prevention* as:
- source reduction
- environmentally sound recycling

Air and water pollution can impact individual health and the health of the environment. For example, it is claimed that particulate emissions from the UW's heating plant increase health problems among those persons with impaired pulmonary function. Run-off from construction sites may cause problems if it enters the lakes through storm sewers. There is also a direct financial impact from laboratory research. It costs over $250,000 annually to properly dispose of laboratory chemical waste through commercial vendors. Each carboy costs about $10 to dispose; bottles of stock chemicals cost approximately $5 to incinerate; and disposal of *one* lecture bottle (i.e., a small gas cylinder) may cost as much as $2,000. When you prevent pollution, you also reduce its human and environmental impact and disposal costs.

In 1999, the Howard Hughes Medical Institute (HHMI) recently led a 2-year collaborative initiative to establish consensus best practices for managing hazardous wastes in academic research institutions. The initiative partnered environmental health and safety professionals and biomedical research scientists from ten major academic research institutions including the UW. A guiding principle of the initiative was a commitment to promote stewardship and responsibility for health, safety and the environment as an integral part of the nation's biomedical research mission (http://www.hhmi.org/research/labsafe/projects/reportcongress.html).

Source reduction includes:
- modifying processes
- improving operations
- material substitution
- product modification

6.1.a Reduce Pollution at its Source

Changing practices and processes to prevent pollution at its source is referred to as ***source reduction***. Source reduction methods include process modification, improved operation and material substitution. Some businesses can prevent pollution by modifying their product, but this method is not as applicable at an educational institution.

Modify Laboratory Processes

Pollution can be prevented or reduced by changing the laboratory process by which the pollution is created. Modern extraction techniques, (e.g., those that use a solid phase or supercritical fluid) minimize waste by using much smaller volumes of organic solvents. Computer simulations and modeling eliminate all environmental impacts when they are substituted for wet laboratory experiments. In the classroom, computer and multimedia simulations often allow students to observe more complex procedures than would be available by a traditional laboratory exercise.

Reduce the Scale of Laboratory Processes. One of the most successful pollution prevention modifications is ***microscale*** work. In microscale work, the amounts of materials used are often reduced to 25 - 100 mg for solids and 100 - 200 µL for liquids compared to the usual 10 - 50 g for solids or 100 - 500 mL for liquids. This often 1000-fold reduction has been brought about by design and material innovations in labware and technological innovations such as PCR. Reducing the scale of laboratory processes not only reduces/prevents pollution, but also has other benefits:

Simple laboratory improvements can prevent pollution:
- minimize the amount of chemicals used
- be neat when using chemicals
- keep volatile chemicals capped and sealed

- ✓ Small scale experiments cost less because they use smaller amounts of chemicals, decrease the amount of needed chemical storage space and reduce chemical waste requiring disposal. Thus, you can then make your research dollars go farther.
- ✓ Small scale experiments usually run more quickly.
- ✓ Heating and cooling is easier with smaller volumes.
- ✓ Less chemicals means chemical exposure is reduced.
- ✓ The degree of risk and severity of accidents, fires or explosions is reduced.
- ✓ The amount of fugitive emissions (evaporative losses) will be reduced

Improve Laboratory Operations

Pollution can be prevented by improving laboratory operations. As seen above, innovative technology can help you redesign laboratory procedures to use smaller amounts of chemicals, reduce waste, prevent fugitive emissions and minimize unnecessary discharges to the sanitary sewer.

Careful and neat operations reduce waste. Take care when weighing or transferring chemicals between containers to minimize spills. Don't take fume hood emissions, sewer effluents or chemical wastes for granted. They are all necessary to safely use laboratory chemicals, but chemical releases and disposal affect the

environment and should be minimized when practical. When it can be done safely, seal and contain processes to prevent the escape of fumes or leaks to the environment.

About 25% of the "waste" chemicals collected have never been used.

Less is Better. The American Chemical Society (ACS) urges scientists who work with chemicals to adopt the motto "Less is Better." A PDF copy of ACS's booklet, *Less is Better,* is available (http://membership.acs.org/c/ccs/pub_9.htm). It is more safe and environmentally sound to buy less, store less, use less and dispose of less. Less reduces risks to you and your colleagues. Less reduces the risk of an accident or fire. Less saves space and money. Less reduces pollution.

Less *is* better! Buying smaller amounts of laboratory chemicals means:
- fresher stocks
- reduced exposures
- reduced emissions
- less surplus to dispose of
- fewer accidents

- ***Buy less***. Approximately 25% of the "waste" collected is unused chemicals. Purchase only the chemicals and amounts that you need in the immediate future. If you need only a small amount, ask another lab if you can borrow from their stocks. There is no such thing as a "large economy size" of laboratory chemicals. A bulk quantity may appear economical, but the cost of disposing of any excess will negate the savings. Don't purchase chemicals speculatively. Smaller containers are easier to handle, less likely to be dropped. Some chemicals age and degrade more rapidly than others, large containers often end up with half their contents becoming waste. Avoid end-of-budget-year buying sprees. Do not accept gifts or samples unless you plan to use all of them in the immediate future. Do not accept more than you need. These practices minimize chemical waste because much of the University's hazardous waste is unwanted surplus chemicals. Unfortunately, because of these unnecessary purchases, tons of laboratory chemicals still with factory seals are shipped to be incinerated each year.
- ***Store less***. Storing excess and duplicate chemicals risks a fire, spill or leak. Some chemicals become reactive or explosive with age. Fugitive emissions from stored chemicals can lead to a harmful exposure. Storage of surplus takes up valuable laboratory space and may be a violation of the fire code (see **4.2.c**). Excess stored chemicals exacerbate a spill, leak or release, and adds risks when responding to a fire. These are all good reasons to buy less, and good reasons to regularly review your laboratory chemical stocks and dispose of surplus. See procedure **On-Site Service 4** in Chapter 7 of this *Guide* for how the Safety Department will help you with a laboratory clean-out.
- ***Use less***. As discussed above, using smaller volumes / quantities of chemicals is safer for you and the environment.

Redistribute Surplus Laboratory Chemicals

One way the EPA measures source reduction is to review the volume of hazardous waste generated from year to year. The redistribution program tries to reduce the volume of unused chemicals being disposed as waste. The Safety Department will deliver these surplus chemicals to your lab for free. When we collect a chemical for disposal, a chemist examines it to determine that it has not degraded and is still useful for research. If so, the Safety Department will redistribute it to another campus laboratory. All redistributed chemicals are in their original manufacturer's container. In many cases, these surplus chemicals still have the manufacturer's seals.

The Safety Department redistributes surplus chemicals between laboratories.

Use surplus chemicals. There are several ways to obtain surplus chemicals. The Safety Department provides an updated list of *LABSCAN* redistributable chemicals on the Safety Department website (http://www.fpm.wisc.edu/chemsafety/). Call the Safety Department to contact the redistribution coordinator with a list of requested chemicals and arrange for delivery to your laboratory. Some laboratories have given

Call the Safety Department for the most recent copy of *LABSCAN.*

Safety standing orders for chemicals they use frequently in large quantities. Tell us if you can use chemicals that are not reagent grade. In some cases, one laboratory's wastes can be used for a procedure that doesn't require a high purity chemical.

Redistribute your surplus chemicals. Redistribution works with chemicals that have not degraded with age. So, please review your chemical inventory regularly and give your surplus chemicals to the Safety Department. This will make your surplus chemicals available for use by other laboratories. See procedure On-Site Service in Chapter 7 of this *Guide* for removal of surplus chemicals.

Call us if you have surplus chemicals that can be used by another laboratory.

A success story. The Safety Department's laboratory chemical redistribution program has been in existence since 1980. About 30% of each *LABSCAN* list is redistributed, which saves the University about $10,000 to $20,000 in the cost of chemical disposal. You receive free laboratory chemicals. We reduce the amount of chemical waste that needs to be disposed of. The whole University benefits!

Control Your Laboratory Chemical Inventory

As described above, a significant amount of laboratory hazardous waste is the result of poor chemical inventory practices. Duplicates are purchased because chemicals are not stored carefully and records of the current inventory do not exist. Labels fall off of older containers creating an unknown that must be analyzed to enable appropriate disposal. Because of undocumented use and poor inventories, researchers are often reluctant to share chemicals, so laboratory shelves often hold half-filled bottles that are eventually disposed of as hazardous waste. Worse yet, some chemicals become unstable, reactive and explosive with age. If you are not monitoring expiration dates and chemical stocks, your safety is at risk.

Many vendors sell laboratory chemical inventory software.

You can reduce these problems by controlling your laboratory's chemical inventory. Keep an inventory of your laboratory chemicals in a card file, computer database or spreadsheet. Some suggestions to having a viable inventory system:

- Place one or two people in charge of purchasing new chemicals and maintaining the inventory; some labs rotate this responsibility monthly.
- Mark or code chemical containers to correspond to an identifier in the inventory database; also, date each incoming container.
- Because of their small size and great number, samples are usually omitted from the inventory, however, make sure samples are properly marked.
- To keep the system manageable, some laboratories do not inventory containers smaller than 100 grams unless highly reactive, toxic or valuable.
- Devise a system of identifying chemical storage areas in your laboratory and mark them; include this location in the database, spreadsheet or card file.
- If you keep a collection of related chemicals that are used by numerous individuals in your research group (e.g., restriction enzymes), keep the inventory of these items taped to the refrigerator or freezer whey they are stored.
- Rotate stock; follow the principle of first-in, first-out.
- Keep track of expiration dates and storage times, especially for peroxide- forming and other degradable chemicals; see Section 4.5.h of this *Guide*.
- Keep track of emptied containers and waste disposal to remove chemicals from the database, spreadsheet or card file.

See the **Chemical Storage and Management** section in Chapter 4 of this *Guide* for chemical labeling guidelines.

6.1.b Where Do Your Chemicals Go?

A chemical *mass balance* is the first step in assessing your lab's impact on the environment.

You purchase and use laboratory chemicals, but where do they go? Chapter 7 of this *Guide* describes chemical disposal procedures, and what happens to waste that is

disposed of in the sanitary sewer or given to the Safety Department. But if you added up all your chemical purchases, and subtracted all the waste you give to the Safety Department, chances are there will be some amounts unaccounted.

One way to assess your laboratory's impact on the environment is to conduct a *mass balance.* Choose one chemical, such as an organic solvent, and account for purchases and disposal. Then try to determine how the rest disappeared. Stored solvents can evaporate, be emitted to the air, and may contribute to air pollution. Poorly capped volatile organic solvents stored in a fume hood can disappear overnight. Does yours? A rotary evaporator will draw solvents into the sanitary sewer. You start your procedure with a certain amount of solvent. How much of it ends up in the waste solvent carboy? Safety occasionally tests building air emissions and sewer effluents, but the irregularity of laboratory operations make a University-wide mass balance difficult.

Reduce Laboratory Air Emissions

One potential source of pollution from laboratories is the emission of volatile chemicals into the air. To prevent chemical exposure of personnel, laboratories are designed to include fume hoods, local ventilation, ventilated cabinets and a specific level of room ventilation. The exhaust of these systems is not filtered or treated in any way. Therefore, you should use these ventilation systems to protect you from chemical exposure, but also use them prudently to prevent excessive / unnecessary emissions to the environment. Evaporation of laboratory organic solvents alone contributes significantly to the University's toxic air releases. It is obvious when a sulfur-containing compound escapes into the atmosphere, but most chemicals do not have such a low odor threshold to indicate their release. Simple laboratory practices can minimize air emissions.

Fugitive emissions are the inadvertent evaporation of volatiles to the atmosphere.

To reduce air emissions, keep containers of volatile chemicals closed.

- Keep containers of volatile chemicals capped; if a cap is not tight, replace the cap or transfer the contents to another container. Keep waste solvent collection containers capped at all times, unless you are adding waste.
- The best container seals have an even rim on the bottle and an appropriate fitting cap with polyethylene or Teflon liner.
- Minimize the amount of volatile chemicals in your lab; order and store only what you need in the immediate future; call the Safety Department to redistribute your surplus (see **On-Site Service** in Chapter 7*)*.
- Do not store chemicals in the fume hood; use an approved ventilated cabinet. These have only a slight negative pressure and are less likely to draw volatile emissions into the air.

Keep laboratory operations using volatile chemicals as closed as safely possible.

- Keep laboratory processes using volatile chemicals as contained as possible.
- Keep the amount of waste solvents in your lab to a minimum. Dispose of carboys by calling the Safety Department for removal. You should call Safety for carboy disposal within three days of it being filled (see **On-Site Service** in Chapter 7*)*.
- If you do not fill carboys within 6 - 12 months, call Safety to have them picked up anyway. Carboys that sit in a lab for a long time tend to become disconnected from their contents log and become a disposal problem.

Do not dispose of any chemical by evaporation.

- Do not dispose of any chemical by evaporation; it is illegal to evaporate hazardous chemical waste for the purpose of disposal.
- Do not dispose of any gas by venting unless told to do so in Chapter 7 or by the Safety Department.

Fume Hoods, Energy and the Environment

Fume hoods are invaluable laboratory safety controls. When you use a toxic chemical in a fume hood, it can protect you from a harmful exposure. Fume hoods are also energy wasters. On average, it costs $2,500 a year to operate a fume hood. This is because it exhausts conditioned air -- warmed air in the winter and cooled air in the summer. Pollution is also a byproduct of energy generation and use.

Wasteful energy use results in unnecessary pollution. Your efforts to conserve energy prevents pollution.

So, to reduce / prevent pollution, we need to conserve energy while insuring safe working conditions. This is accomplished by using fume hoods wisely. Do not use a fume hood for chemical storage; keep it clear for work. Instead, use a ventilated storage cabinet that draws less conditioned air.

If you are involved in the design or remodel of a laboratory, consider local exhaust systems (such as a benchtop exhauster) for routine operations. These systems often provide protection at lower cost, use less energy and make unencumbered workspaces.

Also, do not alter or remove original parts of a fume hood for any reason. Each piece of metal and/or glass is there for a very specific reason and was in place when the fume hood was last certified. Annual certification (see Chapter 4) verifies that the hood is drawing an adequate amount of air from the room to provide a safe environment for our work. If you modify the hood, it may very well fail to adequately protect you.

6.1.c Reduce Laboratory Wastewater Effluents.

Also remember, if a process is connected to a water supply, do not connect it to a sewer or use contaminated or toxic liquids unless an antisiphon or backflow device is included. Do not remove installed devices. These protects your drinking water.

As long as you use a sanitary sewer and follow the **Sanitary Sewer Procedures** in Chapter 7 and Appendix A of this *Guide*, you may safely dispose of a variety of laboratory wastes into the sanitary sewer system. Remember, everything that goes into the sanitary sewer system at the University, goes through numerous treatment processes at the Madison Metropolitan Sewerage District before it is released. Because of the chemical, physical and biological degradation processes in the system, sanitary sewer disposal is often more appropriate than commercial disposal, poses no undue safety hazard and is less expensive. Just remember:

- Make sure containers of liquids are not leaking nor overfilled.
- Make sure any apparatus that drains directly into a sink do not leak or have unnecessary discharges.
- Make sure liquids are stored in trays, other containers or diked areas with no floor drains so that spills are contained.
- Work with others in your laboratory to limit sewer discharges to those in Chapter 7 of this *Guide*.
- Do not dispose of any waste into a storm sewer; most outside drains and sewers are storm sewers that discharge directly into a lake.
- For wastes that are disposed of in the sanitary sewer, consider less toxic substitutes.

We've learned much about toxicity in recent years. Try a less hazardous substitute in methods that traditionally use toxic chemicals.

6.1.d Substitute With a Safer Chemical

One of the most successful ways to reduce pollution is by substituting a chemical with less hazardous properties for a more hazardous chemical. For many laboratory protocols, an environmentally sound alternative exists.

Use non-ignitable liquid scintillation cocktail. One of the UW's more successful pollution reduction practices is the substitution of non-ignitable liquid scintillation cocktail (LSC) for toluene-based cocktails. This change was initiated by the Safety Department in 1990. These non-ignitable cocktails reduce the risk of laboratory fire and personnel exposure to toluene. Additionally, toluene-based cocktails must be commercially incinerated as a hazardous waste while most non-ignitable, water emulsifiable LSC can legally be disposed of in the sanitary sewer.

Search for a safer substitute. Let us know if you find ones not mentioned here.

Other substitutes. In one study, the University of Illinois, Urbana-Champaign's Division of Environmental Health and Safety, explored laboratory waste minimization opportunities (Ashbrook, Peter C., Cynthia Klein-Banay ad Chuck Maier, *Determination, Implementation and Evaluation of Laboratory Waste Minimization Opportunities*, 1992). The following table includes some common chemical substitutes from that study.

Substitution with a safer chemical is one of the best ways to reduce pollution.

Hazardous Chemical	Safer Substitute	Used For
acetamide	stearic acid	freezing point depression
benzene	xylene or hexane	many solvent uses
benzoyl peroxide	lauryl peroxide	some polymer catalysis
carbon tetrachloride	cyclohexane	qualitative test for halides
formaldehyde (formalin)	ethanol	specimen storage
halogenated solvents	non-halogenated solvents	some extractions and other solvent uses
sodium dichromate	sodium hypochlorite	some oxidation reactions
sulfide ion	hydroxide ion	qualitative test for heavy metals
toluene-based scintillation cocktail	non-ignitable scintillation cocktail	studies using radioactive materials

Substitution isn't always ideal. Some procedures don't work as well. Some substitutes aren't as safe as you'd like. Substitution often requires successive trials and evaluations.

Stop using chromic acid solution. Chromic acid solution is a mixture of concentrated sulfuric acid and potassium dichromate, Chromerge® (chromic acid), or chromium anhydride (chromium trioxide). It is used to clean laboratory glassware because it oxidizes most residues and eats away a very thin layer of the glass surface, leaving a new, clean surface.

Chromic acid solution is a strongly oxidizing corrosive that contains a carcinogen.

Chromic acid solution is a dangerous chemical. It is a strong corrosive. It is a strong oxidizer that has been known to react violently and explode when combined with oxidizable materials. It contains chromium(VI), as chromic or dichromic acid, which is a known human carcinogen. Chromium is toxic in other ways to humans, flora and fauna. These properties make it extremely difficult to handle safely.

Stop using chromic acid solution unless you have tried the alternatives and found them to be unsatisfactory.

There are many commercially available alternatives for chromic acid solutions. The Safety Department strongly encourages you to stop using chromic acid solutions unless you have tried the alternatives below and found them to be unsatisfactory. They are listed in groups of increasing hazard. This information is also derived from the University of Illinois study.

Nonhazardous cleaning solutions (safest; try these first)

- Ultrasonic baths (these work well for many labs)
- Alconox or similar detergents
- Pierce RBS-35 or similar detergents
- Biodegradable surfactants

Strong corrosive solutions (hazardous due their corrosivity)

- Potassium hydroxide/ethanol solutions (also flammable)
- Dilute hydrochloric acid

Strong oxidizing acid solutions not containing chromium or other toxic metals (very hazardous; least desirable alternative). Other solutions of strongly oxidizing acids work in the same way as chromic acid solution. Potassium permanganate / sulfuric acid baths are generally not recommended, they are very dangerous and potentially explosive if made incorrectly.

- Potassium persulfate / sulfuric acid (sold commercially as No-Chromix®)
- Aqua regia (mixture of hydrochloric and nitric acids)

At the UW, the cost and time spent on the cleanup and disposal of mercury spills is disproportionately high.

Avoid mercury and its compounds. Like chromium, mercury is a toxic metal that, unlike other corrosive or organic compounds, can't be neutralized or destroyed. As a result, mercury is very difficult and costly to safely dispose.

Mercury and its compounds are used widely in laboratories. Mercury waste from broken thermometers and manometers is far too common at the University of Wisconsin. Although free-flowing, metallic mercury can be recycled commercially for reuse, mercury contaminated thermometers and spill cleanup supplies are expensive wastes.

See Chapter 5 of the *Guide* for details on mercury spill cleanups. Chapter 7 describes mercury disposal procedures.

Anyone who has broken a mercury thermometer or spilled free-flowing mercury knows how difficult and time consuming it can be to clean up the residue. In the extreme case, residual mercury from a spill or careless handling can pose a chronic health risk to laboratory personnel.

To prevent these problems, the Safety Department strongly recommends that you use alternatives to mercury thermometers. These include alcohol (red liquid) thermometers, thermocouples and other electronic temperature devices. Thermocouples are preferred for monitoring the temperature of a water bath where glass thermometers are prone to breakage. If alcohol thermometers and thermocouples are unsatisfactory, consider using Teflon® coated thermometers that will contain the mercury in the event that the capillary is broken.

In many labs, most mercury thermometers can be replaced with non-mercury thermometers.

Due to their toxicity, mercury compounds and solutions containing mercury must be carefully stored and used. Laboratories are encouraged to reduce the amount of mercury they use and mercury-containing wastes they generate. Possible alternatives include:

- If a mercury compound is specified for a procedure, first determine if a less toxic substitute can be used; for example, in most cases copper sulfate can be substituted as the catalyst in Kjeldahl analyses with no loss in total organic nitrogen recovery.
- Reduce the scale of the process to reduce the amount of mercury used and disposed.
- Minimize the volume of waste generated by including precipitation or other treatment methods during the last step. Call the Safety Department for chemical treatment procedures.
- Only buy as much mercury and mercury compounds as you will use in the immediate future.

6.2 Environmentally Sound Recycling

Once you have done what you can to prevent pollution, try to reduce risks to the environment in other ways and follow those practices that have the least impact on the environment. This chapter describes some of these methods.

The Safety Department inspects the UW's commercial recyclers to make sure they use chemical and environmental safety practices.

Recycling is the processing of waste so that it can be used again. While recycling is viable, it should be done in a way that does not harm the environment. For example, distillation of waste organic solvents requires containment to prevent spills and leaks. Controls may be necessary to minimize air emissions and prevent exposure to laboratory personnel. Transport and handling risks are minimized when recycling occurs as part of the laboratory process (e.g., in-process recycling) or near to the point of waste generation (i.e., in the lab or building). Photography and x-ray laboratories have recovered silver from their wastewater for many years. Many recovery systems exist, including in-lab electrophoretic units that are maintained by commercial services.

6.2.a Distill Waste Organic Solvents

In-laboratory distillation of waste organic solvents has been used by several laboratories at the University to recycle waste organic solvents. One laboratory recovers xylene for reuse in tissue preparation; several histology laboratories have successfully recycled their solvents. Recovered acetone and ethanol can be used for rinsing glassware, where technical grade quality solvents are satisfactory. The University of Illinois study and laboratories at other institutions have found that many hazardous waste streams could be successfully recycled. Some candidates include methanol / laser dye mixtures and acetonitrile waste from HPLC analysis.

Because waste organic solvents is such a large wastestream in many labs, distillation and reuse has great potential for preventing pollution.

Modern spinning band stills can produce a very pure product. Their microprocessor controllers make these stills easy and safe to use. Simple gas chromatography can be used for quality assurance of the purified product. Call the Safety Department if you would like to explore solvent distillation and we'll help you get started.

Reduce, reuse, recycle!

6.2.b Commercial Recycling of Laboratory Chemicals

The Safety Department actively recycles metallic mercury, petroleum-based oils from diffusion and vacuum pumps, and uncontaminated lead from radioactive packages. To dispose of these, simply give these wastes to the Safety Department by following procedure **On-Site Service** in Chapter 7 of this *Guide*.

Not all wastes can be recycled. Just as the city has difficulty recycling certain plastics, commercial recycling of laboratory chemicals and wastes is limited by the fact that small scale lab wastes are uneconomical, the lack of markets for certain recycled waste, and the unavailability of environmentally sound recycling facilities.

6.3 Minimize Waste

It may be difficult for your laboratory to minimize its waste. By its very nature, research is often the process of investigating something and throwing the residue away. Unlike large industrial processes, the multitude of irregular laboratory operations are intrinsically more difficult to control. Still, there are things you can do to prevent pollution and minimize hazardous waste.

As noted above, beyond pollution prevention, hazardous chemical waste can be minimized by reusing the waste in another process or by recovering its energy value. Beneficial reuse is exemplified when laboratories use surplus base to neutralize

waste acids (and vice versa). This not only minimizes hazardous waste, but creates a product that can be safely disposed of in the sanitary sewer.

Hazardous waste is also minimized when organic solvents are disposed of via the Safety Department in a waste collection carboy. Most waste organic solvents from the University have a high BTU value and are excellent fuels. To recover their energy, waste solvents are blended with other fuels and used as heat sources such as in the production of cement. Chemical destruction by this heating process, which normally reaches 1650 ºC (3000 ºF), is very efficient. Lime in the cement also neutralizes any acid gases that are produced.

6.4 Reduce Environmental Risks

After you've tried the above pollution prevention and waste minimization methods, there are other things a laboratory can do to reduce environmental risks. Wastes that are neutralized, treated and managed in the laboratory are not subject to accidents and releases that can occur during transportation and handling. Chapter 7 of this *Guide* describes In-Lab Chemical Management, such as neutralization of acids and chemical treatment of toxic chemicals.

For those wastes that cannot be prevented or further minimized, incineration and fuel blending are environmentally sound chemical disposal methods.

The majority of non-solvent hazardous chemical waste disposed by the Safety Department is commercially incinerated. Incinerators reduce environmental risks of hazardous waste by destroying more than 99.99% of the organic constituents. Air pollution control equipment on these incinerators is used to further reduce emissions.

6.4.a Neutralize Waste Acids and Bases

The Safety Department strongly encourages laboratories to neutralize their waste acids and bases for disposal in the sanitary sewer. After neutralization, these wastes can be safely disposed of in the sanitary sewer. Waste acids are very difficult to transport and handle. In-laboratory neutralization and sewer disposal can be done safely and is very efficient. See Chapter 7 of this *Guide* for several neutralization procedures. Appendix A lists neutralizable chemicals and their corresponding procedure in Chapter 7.

6.4.b Chemically Treat Laboratory Wastes

Be responsible. For the waste you generate neutralize acids and chemically treat other wastes (see Chapter 7).

The Safety Department also encourages labs to chemically treat certain chemical wastes in the laboratory. In-lab chemical treatment reduces transport and handling risks, and reduces the cost of collecting, storing and disposing chemical wastes. If you routinely generate wastes that can be treated, include waste treatment as the final step in your procedures. In some cases, the treatment product can be safely disposed of in the sanitary sewer. Chapter 7, Chemical Disposal Procedures of this *Guide* includes methods for deactivation, bleach oxidation, precipitation and reduction to yield a less toxic waste. Chemical treatment procedures are described for:

- Acrylamide solutions (polymerization).
- Chemical carcinogens and mutagens.
- Cyanide salts (oxidation with bleach).
- Ethidium bromide solutions (oxidation with bleach).
- Neutralize Acid 6: Chromic acid cleaning solutions (reduction and neutralization of Cr(VI)) and COD waste.
- Osmium tetroxide (conversion to less volatile form).

Other in-lab chemical treatment procedures can be found in the *Hazardous Laboratory Chemicals Disposal Guide* by Margaret A. Armour, CRC Press, 1991 and *Destruction of Hazardous Chemicals in the Laboratory* by George Lunn and Eric B. Sansone, Wiley-Interscience, 1990.

6.5 Manage Waste Efficiently

In many cases, waste can be minimized, but not eliminated. As mentioned above, waste is a byproduct of research, teaching and testing. However, it is prudent to manage all remaining wastes as efficiently as possible. Resources saved from efficient waste management can be utilized to improve the University's teaching, research and public service programs or they can be reallocated to other environmental protection projects.

The management of chemical waste is most efficient when laboratory personnel keep waste types separate, prudently use the sanitary sewer and normal trash, and help us collect waste efficiently. Thus, the Safety Department collects and handles waste organic solvents in 5-gallon carboys because it is safer and more efficient than collecting such waste in many smaller, potentially breakable, bottles.

6.5.a Keep Waste Types Separate

Keeping wastes separate maximizes disposal options and keeps disposal costs down.

Do not mix different types of wastes (e.g., hazardous and nonhazardous) together except for organic solvents that are collected in carboys as described in procedure **Organic Solvent Collection** in Chapter 7 of this *Guide*. When hazardous and nonhazardous wastes are mixed, the mixture becomes hazardous and the entire volume needs special disposal procedures. When wastes of different characteristics and compositions are mixed, treatment and disposal becomes much more difficult and expensive. A small amount of hazardous liquid waste mixed with a large amount of non-hazardous liquid waste must be disposed of as hazardous waste. Thus, organic chemicals can be incinerated, but mercury waste that has been mixed with organic chemicals cannot be incinerated. Some cardinal principles to observe:

Also keep radioactive, biohazardous and chemical waste as separate as possible.

- Do not place hazardous waste in the normal trash. Appendix A lists some chemicals that can safely be disposed of in the normal trash; follow **Normal Trash Procedures** in Chapter 7 of this *Guide* for those wastes.
- Do not place normal trash, or wastes that can be disposed of in the normal trash or sanitary sewer, in containers of laboratory chemicals or chemical wastes.
- Dispose of organic solvents in the proper carboy. White carboys are primarily intended for non-halogenated solvents suitable for fuel blending; yellow carboys are for the disposal of halogenated solvents that must be incinerated, with no energy recovery. Appendix A lists organic solvents and their appropriate carboys.

6.5.b Safely Use the Sanitary Sewer and Normal Trash

Refer to Chapter 7 for guidelines on normal trash and sanitary sewer disposal.

There are many laboratory chemicals that can be safely disposed in the sanitary sewer or in the normal trash. Proper use of these methods prevents unnecessary handling of these wastes. Chapter 7 of this *Guide* includes specific procedures for using the sanitary sewer and the normal trash.

6.5.c Minimize Chemically Contaminated Labware

One of our fastest growing waste streams is chemically contaminated labware. The procedure in Chapter 7, **Labware Contaminated With Chemicals,** of this *Guide* describes how to dispose of labware. There are several ways to reduce the volume of contaminated labware. First, discard only wastes known to be chemically contaminated as hazardous wastes. If your gloves and benchtop covers were not contaminated, dispose of them as normal trash. For contaminated labware, try to decontaminate it according to the procedures in Chapter 7.

6.6 Review Questions

1. Which of the following is not a method of source reduction:
   a. Process modification b. Substitution c. Recycling d. Improved operation

2. A substitute for benzoyl peroxide for some polymer catalysis is:
   a. Cyclohexane b. Sodium hypochlorite c. Stearic acid d. Lauryl peroxide

3. Less toxic alternatives to chromic acid include:
   a. Detergents, ultrasonic baths and potassium permanganate baths
   b. Detergents, ultrasonic baths, lead chromate dissolved in sulfuric acid and biodegradable surfactants
   c. Detergents, ultrasonic baths, oxidizing agents not containing heavy metals and biodegradable surfactants
   d. Detergents, ultrasonic baths, bleach and biodegradable surfactants

4. Which of the following is not an alternative to an ordinary glass mercury thermometer?
   a. Alcohol (red liquid) thermometer b. Thermocouple
   c. Teflon® coated mercury thermometer d. An incubator

5. Which of the following are waste minimization strategies applied by the University of Wisconsin-Madison Safety Department?
   a. On-site recycling and land filling b. Neutralization and chemical treatment
   c. Off-site recycling and beneficial reuse d. Product modification and substitution

6. Which of the following is not a method to reduce the risk involved in chemical use and management?
   a. Neutralization b. Chemical treatment c. Open burning d. Incineration

7. Items that cannot be disposed of safely in the normal trash include:
   a. A half-full bottle of barium carbonate b. Solvent-soaked silica gel
   c. Glassware containing mercury droplets d. All of the above

8. To reduce the volume of waste that is generated in your laboratory you can:
   a. Take the cap off your carboy to evaporate solvents
   b. Precipitate heavy metals out of solution
   c. Dispose of any quantity of chemical in the sanitary sewer
   d. Heat aqueous solutions until they are evaporated away