The School District of Philadelphia
Office of Environmental Management Services

Chemical Management Plan

Science +Chemicals =A Safer Green Environment

A Guide for Science Teachers within the School District of Philadelphia

June 2009

Dear Educators:

The School District of Philadelphia has developed for you the ***Chemical Management Plan, Science + Chemicals = A Safer Green Environment — A Guide for Science Teachers within the School District of Philadelphia***.

Research shows effective hands-on experiences dramatically enhance a student's educational experience. You, as a practitioner of this hands-on teaching method, know firsthand the value of laboratory time.

We believe you will find the ***Guide*** to be a useful tool to help you implement practices that will reduce your exposure to such incidents. The ***Guide*** will discuss the School District's internal policies on how to purchase chemicals, manage chemicals once they are in your laboratory and how to deal with unwanted chemicals. The ***Guide*** will also provide information on how you can scale down experiments and substitute material without reducing the experience for the student.

If you have any questions regarding ***Chemical Management Plan***, ***Science + Chemicals = A Safer Green Environment— A Guide for Science Teachers within the School District of Philadelphia.***, please do not hesitate to contact the School District of Philadelphia, Office of Environmental Management and Services at 440 North Broad Street, Philadelphia, PA 19130, or Mrs. Francine Locke at 215-400-5213 or Mr. Jerrry Junod at 215-400-6738.

Disclaimer

This document was conceived off of four primary publications:

The ***Laboratory Waste Minimization and Pollution Prevention, A Guide for Teachers in Pennsylvania***, June 2003, by the Pacific Northwest National Laboratory, operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06- 76RLO 1830.;

The ***Safety Guidelines for Technology Education & Elementary Science/Technology Education***, Pennsylvania Department of Education, Bureau of Curriculum and Academic Services, Division of Curriculum and Instruction.

Schools Chemical Cleanout Campaign Lessons Learned Report, January 30, 2009, TechLaw, Inc, for the USEPA.

School Chemistry Laboratory Safety Guide, October 2006, NIOSH, US Consumer Product Safety Commission and CDC.

The following information has been updated as of June 2009, but certain information may still be outdated or no longer relevant. Please use this guide as a tool for further investigation into appropriate processes to minimize laboratory waste and adhere to safe disposal practices. If you are not completely certain what procedures to follow, please contact one of the contacts in this publication.

TABLE OF CONTENTS

1 Introduction

This guide explains how you can minimize the need for chemicals used in your science departments and also decrease the hazardous wastes and other chemical pollution generated by experiments that are performed in classroom laboratories. It is intended mainly for middle and high school science teachers.

Our goal is to make a safe and green environment for our students and faculty, by generating less waste and pollution and save money by purchasing chemicals effectively.

Specifically, this guide will help you:

- ✓ Purchase only approved and necessary chemicals for your curriculum
- ✓ Substitute safer chemicals for hazardous chemicals
- ✓ Properly label, segregate, and store your chemicals
- ✓ Maintain chemical inventories and Material Safety Data Sheets (MSDS) for these chemicals
- ✓ Deal with a large inventory of mislabeled or unlabeled chemicals that were left by another teacher.
- ✓ Communicate the importance of waste minimization to school administrators.
- ✓ Recycle chemicals.
- ✓ Teach students environmental responsibility as you teach them to perform experiments.

This guide deals primarily with chemicals that will be used in a chemistry or biology laboratory in an educational institution. It does not deal with radioactive materials as no school is allowed to possess these materials at any time.

Because this guide is intended for teachers ranging from middle school to high school, not all guidelines apply to everyone. For example, guidance to substitute cyclohexane for benzene would be irrelevant to a middle school science teacher, whose students would never use a substance as hazardous as benzene. Similarly, a high school teacher might not have access to the resources needed to obtain the equipment necessary to do microscale experiments. If a guideline doesn't apply to you, it may give you other ideas. If you feel a guideline may be very helpful but you do not have the resources to implement it, you may want to approach your administration and request the necessary resources.

We realize that, as a teacher, you are subject to many pressures. We don't want waste minimization and pollution prevention to become another burden. It is our intention that this guide will provide you with information to help you deal with important waste minimization issues in the easiest manner possible. In fact, you should find that minimizing waste will simplify other jobs that you currently perform, such as disposing of chemicals and dealing with excess inventory.

2 WHY IS THIS NEEDED?

The United States Environmental Protection Agency (US EPA) and our School District have been completing detailed environmental audits of our schools and other schools in Pennsylvania for over a year. The results of the audits have opened our eyes to the lack of management of the chemicals related to our school science labs.

During the EPA's Schools Chemical Cleanout Campaign (SC3) the notable findings included that:

- schools possessed large quantities of expired chemicals;
- many chemicals were not properly stored;
- most schools had not designated a Chemical Coordinator;
- most schools had not developed a Chemical Management Plan, and;
- most schools did not have the appropriate safety equipment needed to respond to a chemical spill.

In our audit work, we found these similar issues including that chemical purchases were not being managed or controlled, schools were excepting chemicals from private donations without any limitations or oversight, some very hazardous chemicals were being stored at the school which should have never been accepted/purchased, and no Material Safety Data Sheets (MSDS) for the chemicals were on site. We have found numerous instances were chemicals at a school included those that are not appropriate for students under the age of 18. These chemicals included those that are highly reactive, carcinogenic and shock sensitive.

Another trend that we noted was that large chemical cleanouts were being completed every 3 to 5 yrs in the science labs yet the same repeat issues are being identified. Full chemical inventories were being completed but never maintained by the schools. Therefore they are no longer valid and must be redone. This is not only a potential safety issue but also it is a high economic cost to the schools and tax payers.

The handling of the chemical waste at the schools has included the inappropriate practice of disposing of these materials down the drain. Chemicals are not permitted to be disposed down sink drains. This is a violation of the Clean Water Act and local sewer ordinances with the City of Philadelphia.

3 RESPONSIBILITIES

It is the responsibility of schools to ensure that chemicals and their wastes are safely and legally handled and disposed of properly. The school board, superintendent, the district safety coordinator, the administrator (principal and/or department head) and the teacher are all responsible for a safe working environment. The school board, the administration and the instructor have the legal responsibility to provide a safe environment for students to work while they are participating in technology education activities.

School Board/Superintendent/District Department Head

The school district controls budget, curriculum and personnel policy to a major degree. Without district level support, safety program effectiveness will at best be spotty--conducted by dedicated personnel and ignored by others.

A strong comprehensive plan must have involvement and support from the district level administrators. This can be accomplished by instituting a strong chemical management program which includes some of the following elements:

- Enforce that only approved chemicals that are warranted and are safe for our students and staff are allowed in a school setting;
- Mandating current chemical inventories to be maintained;
- Requiring current MSDS for each chemicals stored;
- Demand the proper storage and disposal of all chemicals; and
- Insist on proper labeling of the chemical storage areas.

Your school's administrators can:

- secure necessary funding and other resources
- play an active role in helping you carry out your program (for instance, by interacting with chemical suppliers or tracking waste minimization savings)
- identify other schools and institutions carrying out similar programs that can aid your efforts
- provide special services that will help your program, such as identifying sources of federal grants to apply for.

School administrators may not initially recognize the importance of waste minimization in your activities, or realize how waste minimization can benefit the school. This may simply be because they don't speak the technical language (for example, they may not know why chemicals like carbon tetrachloride are bad for the environment). Or maybe your administrators do not realize the bottom-line savings that a waste minimization program can provide, or how waste minimization benefits the school's community.

However, administrators, like teachers, students, and your community, are concerned about the environment. You may be amazed at the amount of support you receive once they understand the environmental, financial, and community benefits of waste minimization activities.

Individual School Principal and/or Science Department Head

The individual school is the central unit of an educational enterprise. Therefore, the building principal is likely to be the administrator who is most directly responsible for the school's science program. If a specialized supervisor or department head functions with the principal and works directly with teachers, some of the responsibilities for the chemical management program may be delegated.

Your primary role would be to enforce that the chemical management programs is put in place through training of the staff, follow up on the implementation of the program and verification that the program is being followed at all times.

The Teacher

The **major** responsibility for daily chemical management and laboratory safety falls on the teacher. The teacher is the person who directly interacts with the students in the lab and around the chemicals. The teachers have full access to the chemicals and how they are used, stored and disposed. If as a teacher, you have concerns over chemical management you must bring these concerns up to your school principal and/or science department head immediately.

As the facilitator of the program, you need to follow the chemical management program and look to improve the department to the best of your ability. Proper management of chemicals can lead to a green and safe environment for both yourself and the student that you interact with.

4 What are Waste Minimization and Pollution Prevention?

Pollution prevention means **not** generating waste in the first place by reducing it at the source. Waste minimization is a broader term that also includes recycling and other means to reduce the amount of waste which must be treated/disposed of.

A *waste chemical* is a chemical that has no further use. A *hazardous waste* is a chemical that presents a danger to people or the environment. Regulatory agencies determine which chemicals are considered hazardous. Sometimes, specific chemicals are regulated as hazardous substances (e.g., benzene or carbon tetrachloride). Other times, chemicals or chemical mixtures are regulated based on their hazardous characteristics, such as ignitability, reactivity, corrosivity, and toxicity.

Most hazardous waste definitions and requirements are set by the federal government; however, some states have differing definitions and requirements. In Pennsylvania, the Department of Environmental Protection (DEP) oversees the regulation of hazardous waste.

Because this guidance focuses on waste minimization, we won't go into more detail on hazardous waste regulation. However, keep in mind that meeting regulatory requirements is a key part of the proper management of laboratory waste. It is important to be familiar with the requirements covering lab waste developed by agencies such as:

- The City of Philadelphia Fire Department
- The City of Philadelphia local sewer agency
- PennSafe (OSHA does not apply to public schools)
- PA Department of Environmental Protection (DEP)
- U.S. Environmental Protection Agency (EPA)

THE WASTE MANAGEMENT HIERARCHY

There are a variety of methods to deal with the problem of chemical laboratory wastes.

The Waste Management Hierarchy

Best Method---Reduce waste production at the source.

Second Choice---Recover and reuse wastes on-site (i.e., recycling).

Third Choice---Recycle off-site.

Fourth Choice---Treat wastes to reduce volume or toxicity.

Fifth Choice---Dispose of wastes in a manner that protects air, water quality, land quality, and human health and safety.

Last Choice---Landfill a waste.

The waste management hierarchy above shows methods of dealing with hazardous waste, in order of preference. The most preferable option on the hierarchy is to reduce the amount of waste that is produced in the first place. This approach—known as source reduction—means that no one has to deal with the waste at all. This is the cornerstone of pollution prevention.

Unfortunately, not all waste can be eliminated, and the waste that is generated must be dealt with. The second best option for managing this waste includes recycling, refining, or recovering the waste for reuse so that new raw materials are not required and so that waste pollutants never reach the land (e.g., a landfill), the water, or the atmosphere, and resources are conserved.

If that is not possible, the next best option would be to treat the waste to reduce its toxicity and its potential for harming the environment.

The least preferred management method for hazardous wastes (and non-hazardous wastes) is disposal by landfilling or incineration with proper disposal of the residual ash.

While each of these options may be necessary for managing waste at certain times, it is in our best interests to always try to "move up the management hierarchy" with the wastes we generate. At the top of the hierarchy, source reduction should be the cornerstone of our efforts. It is the emphasis of this guide.

5 Why are Waste Minimization and Pollution Prevention Important?

There are a number of reasons.

Waste minimization and pollution prevention are environmentally responsible. By reducing wastes at the source, you are taking the most effective step towards eliminating wastes that would otherwise be released to the environment. Schools are highly visible members of the community, and waste minimization provides the opportunity to set an example for the community, even if a school generates relatively little waste.

Practicing waste minimization and pollution prevention in schools teaches environmental responsibility. By emphasizing the importance of these approaches to your students, you can help instill habits that will be of value the rest of their lives—in the laboratory, on the job, and at home.

Waste minimization and pollution prevention encourage safety in the laboratory. Hazardous wastes can be hazardous to students and teachers, as well as to the environment. If you reduce the quantity of hazardous substances they handle, you reduce the hazard.

Waste minimization and pollution prevention save money. One effective waste minimization practice is to reduce the quantity of chemicals purchased, which in turn reduces the amount of money that is tied up in chemical inventory. Reducing chemical use will also reduce disposal costs, which can run from $6 to $41 per kilogram.

Finally, waste minimization and pollution prevention help ensure schools meet legal requirements. There are federal, state, and even local laws that govern waste disposal. Many schools may be violating some of these laws right now. The best way to comply with these laws is to not generate the waste in the first place.

So how do you minimize waste? Beginning with the next chapter, we'll present some specific suggestions.

6 Purchasing Chemicals

Effective waste minimization begins with effective purchasing decisions. The idea is to buy only what you need, because if you don't buy it, you don't have to get rid of it.

The American Chemical Society estimates that unused chemicals can constitute up to 40% of the wastes generated by a lab. In many schools, unused chemicals have not made it into the waste stream—yet. These schools have an inventory of unused chemicals left over by former teachers or researchers. These chemicals can be a problem for everyone. They may be useless (or even unstable) because their shelf life has expired. Containers may be in poor condition. They may be poorly labeled, illegally labeled, or unlabeled. Unused chemicals can present a safety hazard in the lab and are likely to be difficult and expensive to dispose of.

Chapter 6 will present some specific recommendations for dealing with these inventories. This chapter will tell you what you can do to prevent these inventories from accumulating—preventing damage to the environment, your budget, and your relationship with your successor.

The myth of buying in bulk

All teachers estimate the quantity of a chemical that they will need before purchasing that chemical. Problems arise when these estimates are inaccurate. The simplest way to increase the accuracy of an estimate is to shorten the time horizon; in other words, if you estimate the quantity of a chemical that you will need for a single experiment, that estimate is likely to be more accurate than an estimate of how much you will need for an entire year. If you buy smaller quantities more often, your inventory should shrink.

The problem, many believe, is that it is cheaper to buy chemicals in bulk. When you buy in bulk, you spend less time placing orders, you worry less about shipments arriving on time, and many chemical suppliers will give discounts when a large quantity is purchased.

An important fact to consider, however, is that the cost savings associated with buying in bulk are frequently offset by the costs of disposing of the unused chemicals. The following table presents an example.

The Effect of Disposal Costs

	Package Size	
If 1000 mL are used...	*500mL*	*2500mL*
Unit cost	6.25¢mL	4.2¢mL
Purchase cost	$62.00	$104.00
Disposal cost	0.00	45.34
Total cost	$62.00	$149.34

Actual unit cost	***6.21¢mL***	***15.0¢mL***
If 1677 mL are used...	*500 mL*	*2500mL*
Unit cost	6.25¢mL	4.2¢mL
Purchase cost	$124.00	$104.00
Disposal cost	$13.08	$45.34
Total cost	$137.08	$149.34
Actual unit cost	**8.20¢mL**	**8.9¢mL**

In this example, even though the 2500-mL size costs 37% less than the 500-mL size to purchase, the larger size can cost up to about 250% *more* to use once disposal costs are factored in.

School District Approved Chemicals

The School District of Philadelphia has an "Approved" chemical list. Only those chemicals identified on list of 279 chemicals are allowed to be in a school science department. These chemicals have a known science curriculum need and lower overall hazards for our students. A copy of the Approved Chemical List is in Appendix A.

Teachers, who may have an individual need for a chemical that is not on the approved list, may request "Project Specific Approval". This request would be made in writing to the School District's Office of Environmental Management and Service. The forms for such request can be found in Appendix B of this management plan. Approval will not be given for any chemical which are known carcinogens or have high hazards rankings.

Other Purchasing Strategies

In addition to buying chemicals in smaller amounts, there are other purchasing strategies that can reduce the amount of chemical waste generated.

- Select a chemical supplier who will support waste minimization efforts. Find a supplier who can deliver small amounts of chemicals on short notice and who will accept unopened chemicals that are returned.
- Look for safer greener alternative chemicals to complete the needed curriculum element. Ask suppliers, other teachers, or even look to District Department Head for suggestions. The DEP and EPA are also a source that maybe able to assist.
- Allow only one person to complete all the chemical purchasing at your school. This person will be aware of the "big picture" and may be able to point out purchases that can be consolidated.
- It may help to create a "Required Use List" for the chemicals. Therefore the known use, teacher, and curriculum for that item is known. If it is found that the chemical is not used due to a change in the curriculum or teacher need, then there is no need to further order this item in the future and the current chemical can be placed aside for proper disposal. This can serve to steer

7 Managing Chemical Inventories

Managing chemical inventories effectively can prevent many of the ills that plague environmental managers: unknown chemicals, excessive inventory stocks, and poor use of materials. By managing chemical inventories in a few simple but effective ways, you can avoid many of these problems.

Label Chemicals Properly

Proper labeling is a simple and powerful way to reduce many of the environmental hazards and costs associated with chemicals used in the laboratory. Since science teachers and students are responsible for producing chemicals wastes, they should shoulder the responsibility for identifying the wastes. Mixing unknown or improperly identified wastes can produce dangerous reactions; people have been injured and killed at waste treatment facilities because wastes were poorly identified and packaged.

Consider also the costs of mislabeled or unidentified chemicals on your shelf: the cost of analyzing a chemical prior to disposal can exceed $1,000, by one estimate, many times the original cost of the product. Properly labeling containers also decreases the risk of accidents and injuries, and aids in complying with regulatory requirements such as hazard communication to the local fire department.

Some recommendations for labeling are:

- Establish a policy that requires identifying all chemical containers—including waste containers—and specifying a responsible party.
- Adopt a standard labeling procedure for chemicals and wastes.
- Use labels that are colorfast and permanent.
- Do not use non-laboratory grade containers (ex. Tupperware, empty soda bottles, ketchup containers)

Store Chemicals In A Centralized Place

Laboratories often use a wide variety of toxic, corrosive, reactive and flammable chemicals in small containers. These chemicals should all be stored in a designated, centralized place. Even a small middle school chemistry program should establish a designated chemical storage area.

See Chapter 7 for more data on chemical storage and segregation.

Guidelines for Conducting a Chemical Inventory

The first step in developing a comprehensive chemical health and safety plan is to inventory existing chemicals. This may pose significant risks to the individuals taking the inventory and ample time should be allowed to properly conduct the inventory. Only those who have technical knowledge about the chemicals should be involved in the inventory; students should never be involved! In some cases an inventory may take two people many hours to complete; it's important not to underestimate the amount of time required to complete the inventory. Administrators may not be aware of the time commitment and the importance of an accurate inventory, therefore it is very important to educate them. If you are new to the school and/or a recent inventory has not been conducted you need to be especially cautious. Serious injury can result from touching or moving chemicals that have become shock sensitive or pressurized.

If any chemical container is unmarked, bulging, leaking, rusted, cracked, or has a degraded top, liquid above a solid, or crystals in a liquid, it should not be moved, even for the inventory.

It is best to be cautious! In most cases the inventory will need to be used to generate a disposal list and to determine the quality of the chemicals to be retained. Hazardous waste removal companies require very specific information. Therefore, it is important to include as much information about the chemical to avoid unexpected price changes. For example, anhydrous aluminum chloride is much more expensive to dispose of than is hydrated aluminum chloride. In developing a disposal list it is important to list the proper chemical name, the size of the container and the approximate amount present.

Suggested Procedure:

1. Allow ample time to conduct the inventory.

2. Have a plan to deal with potential explosives if they are found. Will the local or state bomb squad remove the potential explosives? What agencies need to be alerted? What is the procedure for removal of potential explosives? Will the school have to close until the chemical is removed? Notify your local authority (e.g. fire dept.) that you will be doing an inventory, especially if this is the first inventory in several years.

3. Work in pairs and never work alone. It is best if one team does the entire inventory.

4. Be sure the areas in which you are working have adequate lighting.

5. Wear appropriate personal protective equipment. This should include gloves, chemical splash goggles, a lab apron and closed toed shoes.

6. Provide access to a phone, eyewash and a safety shower.

7. Have a written response plan nearby in case of a spill or accident.

8. One person should act as the recorder and the other person should list the chemicals. Be sure to pronounce the chemical correctly; the recorder should read the chemical name after it is recorded to confirm it is correct.

9. Enter the storage area and develop a general feel for the area. Is this a room in which no one has been in five years? Are there obvious vapors; are broken containers present? Are the shelving units secured to the walls? How is the lighting? If above eye level storage is present use a safety step stool or a small

step-ladder to reach the top shelf.

10. Record the room number and the date on your record sheet. Also indicate where in the room the inventory begins. Starting on the top shelf record the name of each chemical, the size of the container, the type of container, the approximate amount of chemical present, the condition of the container (i.e. rust, cracks, degraded top, bulging, liquid above a solid, crystals in a liquid), the presence of spills, defects in the shelving or its supports, corroded wires or gas lines or any other indicator of a hazard present. Do not touch or move chemicals if they are listed as potential explosives or the container appears distorted in any manner.

Serious injury can occur from merely touching the top of a container of picric acid or expired ethyl ether. Use extreme caution not to knock any container to the floor.

11. Be sure you examine all containers and record as much information as possible. For example, if ethyl ether is present record its lot number, expiration date and the manufacturer. **Do not touch the container.** You only want to conduct the inventory once and you want to gather as much information as possible. If the inventory is conducted over several days be sure you mark where you stopped at the end of the day.

12. If kits are present be sure to inventory all chemicals in each kit. Many older kits may contain unlabeled chemicals with only manufacturer's numbers on them. Although kits are particularly time consuming to inventory, each container must be identified. Record the manufacturer, the chemical number, and the size of the container and any information concerning the manufacturer such as phone number and address as well as the kit identification number. Do not ignore the kits; many contain carcinogens such as cadmium powder or toxic chemicals such as sodium azide.

13. If preserved specimens are present, record the preservative used. Contact the supplier to determine if the specimens are capable of outgassing formaldehyde. Many specimens contain some formaldehyde.

14. Be sure to examine all areas in each room including desks.

15. Once the inventory is developed, the next step is to decide if any immediate response is required. Does any chemical present pose a significant risk if not addressed immediately? This is a difficult question to answer particularly if potentially explosive chemicals are present. If you have a chemical health and safety committee or a chemical hygiene/safety officer they should discuss the situation with the principal and the local fire chief.

This inventory procedure was adapted from Chem Info Net. Additional information can be found on their web site, http://cheminfonet.org. Conducting a chemical inventory may be hazardous and those who do so should proceed with extreme caution. A school should consider contracting a licensed Hazardous Waste disposal firm to conduct the inventory and dispose of any hazardous waste.

Track Chemicals From "Cradle To Grave"

An effective chemical tracking system and inventory control is essential to waste minimization. For instance, by tracking chemical purchases and shelf life, you can identify how frequently materials are used, dispose of chemicals as shelf life expires, identify chemicals for exchange with other schools, reduce quantities purchased so that chemicals are completely used before their shelf life expires, and minimize needless waste.

The chemical tracking system should be designed to track chemicals from the time they are purchased through the time when they are used, and ultimately disposed. A tracking system should provide information on who uses chemicals and where chemicals are kept. The "cradle-to-grave" tracking system you develop will depend on the resources you have at your disposal to revise your current inventory control, the demands on your chemical inventory, and the scale of your laboratory operations. A good chemical inventory system will provide the chemicals needed in the right amount with a minimum hassle, and maximize efficient chemical use and distribution.

A cradle-to-grave tracking system includes a centralized inventory space, a file or data management system, and a person assigned to overseeing chemical inventory control and distribution. The inventory control system can be relatively straightforward or very complex, using the latest inventory management methods. Very easy to use inventory systems are available from such vendors as Baker Chem, Flinn, and the American Chemical Society for about $200. Alternatively, many off-the-shelf software packages such as Excel, Lotus 1-2-3, or FoxPro can be used to track chemical inventories. Some inventory system options include

- Always compare new purchasing requests to your current chemical inventory so that excess chemicals in stock can be used before buying more, or ensure that purchasers regularly check the inventory to avoid overstocking chemicals.

- If materials are not centralized, conduct a school-wide inventory to identify where chemicals are located to facilitate sharing, and identify expired chemicals that should be disposed of. Provide a simple monthly listing to chemical users on available chemical stocks, location, and points-of-contact.

- Date chemical purchases and rotate chemical stocks using a "first in, first out" rotation; in other words, use the oldest chemicals first.

- Conduct regularly scheduled inventory audits or review “Required Needs List” to identify chemicals that aren't being used, and use this data when reviewing future chemical purchases to cut down on excess inventory going to waste.

- Regularly "purge" chemicals that are no longer used, if possible, and list them with the local chemical exchange. Also, return expired materials to the supplier, if possible.

Storing Waste Prior To Disposal

Storing wastes should follow many of the same practices used for storing virgin chemicals. That is, wastes should be clearly labeled, they should be grouped and segregated according to type, and they should be tracked. Here are some general suggestions for how to store waste, whether or not it is legally considered hazardous:

- If you know that the waste is hazardous, label the waste with the words "Hazardous Waste," the date, and the type of hazard of the material (corrosive, explosive, etc.). Otherwise, label your waste with the words "Potentially Hazardous Waste," the date, and the type of hazard. A waste label should provide as much information as possible.

- As with all chemical storage containers, make sure the waste storage container is compatible with its contents. Keep it tightly closed.

- Segregate all wastes based on chemical incompatibilities.

- Store so you can inspect it all (e.g., don't pile containers on top of each other). Inspect the waste regularly for damage to containers or leaks.

- Make sure that any people handling the waste are familiar with the hazards associated with it, as well as with the regulations governing waste handling and storage.

Finally, keep in mind that storing waste isn't the end of the story—you need to have a plan in place for disposing of the waste. Even small science programs are limited in the amount of hazardous waste they can accumulate on-site at any one time. Under federal law, if you accumulate over 1,000 kg of hazardous waste, you will be subject to considerable regulation; state and local laws may impose lower limits than federal regulations. See Chapter 6 for more information on waste disposal or contact the School District’s Office of Environmental Management and Services for more information on chemical waste storage and disposal.

8 Dealing with an Existing Inventory of Unwanted Chemicals

If you have inherited a cabinet full of poorly labeled or even unlabeled chemicals from a previous teacher, you are not alone. Many teachers are left with stockpiled chemicals and don't know how to deal with them in a manner that does not present a danger to the environment—or even to themselves or their students.

Old inventories are a common problem. In 1986, a survey was conducted of over 100 secondary schools in Massachusetts. These schools reported that they had 8700 pounds and 500 gallons of unwanted chemicals. Forty-eight percent of the respondents said that chemicals had never been removed from their inventory. A survey of Illinois schools revealed similar problems.

These inventories tend to sit around because it is too much trouble to dispose of them properly. However, the truth is that these inventories are a huge liability—an accident waiting to happen. Dealing with an exposure to a student, teacher, or staff member will be a lot more trouble than safely disposing of the inventory.

Getting Help

The first step in dealing with an unwanted inventory is to realize that stockpiled chemicals are not just your problem—they're the school district's problem and even the city, county, or state's problem. The district and local and regional government have an obligation to help and you will need their help to dispose of the stockpile safely.

Both the EPA and PADEP have a number of programs in place to help schools and individuals dispose of unwanted chemicals and hazardous materials. Our School District has contractors who specialize in chemical waste disposal who assist us regularly with these matters.

With some ingenuity, you may be able to secure other forms of assistance. For example, you may be able to enlist the help of a graduate student, whose time would be funded by a university, to assess and help you deal with the problem.

No matter what your situation, the School District's Office of Environmental Management and Services should be your first contacts in trying to solve your problem.

School District of Philadelphia
Office of Environmental Management & Services
440 North Broad Street
Philadelphia, PA 19130
215-400-5213 p
215-400-4751 f

Disposing of Expired, Unneeded or Non-Approved Chemicals

If you know what a chemical is and can safely and legally dispose of it through your Building Engineer's waste pickups, then do so. But don't expect to be able to dispose of a hazardous or unlabeled inventory yourself. It's a job for professionals—you will probably need to hire a hazardous waste disposal contractor to properly pack and dispose of these chemicals. Again, the School District Office of Environmental Management and Service can assist you and has the licensed contractors who can do the work properly.

Remember that if a chemical is hazardous or you don't know what it is, you can't throw it in the trash or pour it down the drain.

Making Sure It Doesn't Happen Again

So, once you dispose of your inventory, work to keep excess inventory from accumulating again. That's a good policy even if you have an unmanageable inventory. Don't let the problem get any worse. It may also be a good idea to set aside time each marking period and then deliberately search for and dispose of unwanted chemicals on an incremental basis.

Ironically, inventories of dangerous chemicals may accumulate as schools switch to safer chemicals. If you discontinue use of a dangerous chemical, by all means get rid of the hazardous chemical at that time.

9 Proper Chemical Storage

Proper chemical storage controls health or physical hazards posed by chemical compounds during storage in the lab. It is designed to 1) protect flammables from ignition; 2) minimize the potential of exposure to poisons; and 3) segregate incompatible compounds to prevent their accidental mixing (via spills, residues, fires or human error). These guidelines are not only a good management practice but also required by law and fire codes. The City of Philadelphia Fire Department has been working with the School District to help create a safe lab set up for all.

Segregation

Do not store chemicals alphabetically as a general group. This may result in incompatibles appearing together on a shelf. Separate chemicals into their primary hazard class or organic and inorganic families and then related and compatible groups. Separation of chemical groups can be by different shelves within the same cabinet if spill containers are used.

The labels on several manufacturers' chemicals include a Storage Code. This color-coded bar provides a visible guide to storage compatibility by primary hazard class. Some of the groups may be further subdivided. The School District of Philadelphia requires that chemicals be systematically stored into five storage groups:

- **RED:** Flammable. Store in area segregated for flammable reagents.
- **BLUE**: Health Hazard. Toxic if inhaled, ingested or absorbed through skin. Store in secure area.
- **YELLOW**: Reactive and oxidizing reagent. May react violently with air, water or other substances. Store away from flammable and combustible materials.
- **WHITE**: Corrosive. May harm skin, eyes, mucous membranes. Store away from red-, yellow-, and blue-coded reagents.
- **GRAY, GREEN or ORANGE**: Presents no more than moderate hazard. For general chemical storage.

Store incompatible materials separately (e.g., keep flammables in a separate cabinet, away from oxidizers, acids from bases). Using a systematic order for storing your chemicals will not only help avoid accidents, it will make retrieval easier.

Storage

The primary requirements for proper storage include:

- Store chemicals in cabinets and on shelving provided for such storage. Store chemicals in such a way as to reduce the risks of breakage and spills that could release materials into the environment. For example, glass containers should always have secondary containment, such as a heavy gauge plastic tub, in case of breakage. Make sure that the secondary containment material is compatible with the chemical stored.
- Record any spills or leaks and have a plan to respond to them.
- Periodically inspect stored chemicals for signs of leakage, poor storage practices, or any other

- Spill and leak protection should be available in chemical storerooms. Berms, sumps, or even simple plastic bins can be useful forms of protection. If necessary, showers, sinks, absorbent materials, and other sanitary and safety equipment should be readily available for cleaning up a spill.

- Keep chemical storage areas off limits to all students.

- Avoid storing chemicals on bench tops or in fume hoods. Store flammable materials in a Flammable Storage Cabinet. Also do not store chemicals on top of cabinets, and never store any material within 18 inches of the ceiling in sprinklered areas.

- Label all chemical containers, including samples, appropriately with the full name and hazard warning.

- Use secondary containment if the chemicals are stored near a sink or other drain or to segregate incompatible materials (e.g. acids and bases in a corrosive storage cabinet).

The School District of Philadelphia also requires the schools to keep Material Safety Data Sheets (MSDS) on hand and easily accessible for each chemical in your laboratory. Material Safety Data Sheets contain valuable information on chemical handling and storage, physical and chemical properties, transport, disposal, hazards and safety.

The School District maintains the current MSDS for all “Approved” chemicals on the internal server at the following location: XXX

A chemical segregation flow chart should be posted in all chemical storage rooms. A copy of such a flow chart can be found in Appendix C.

10 Conducting Experiment

Waste minimization in the laboratory doesn't necessarily require major changes in the way you run experiments. Some basic efforts to be more efficient and careful with experimental procedures can substantially reduce the amount of waste generated.

Teach—And Practice—Resource-Efficient Procedures

A starting point for waste minimization is being efficient in your use of resources. If you, as a teacher, place emphasis on being sparing with chemical usage or use of other resources (such as water or electricity), then students will be more likely to pay attention to these resources as well. Getting students to think about the environmental consequences of their laboratory activities makes sense in any experiment. Some suggestions for teaching resource-efficient procedures include:

- Have students use solvents and other hazardous materials sparingly.
- Monitor experimental reactions closely and add additional chemicals only as necessary.
- Emphasize water conservation by reducing rinse times where possible.
- Be alert for opportunities to save electricity. For example, don't leave equipment running when it's not being used.

Set Up Experiments With Waste Minimization In Mind

In addition to being just plain careful about chemical use, you can take a number of steps in the design and set up of experiments that will help to minimize waste. Chapter 9 will cover in detail the option of scaling down the size of experiments. Other steps you can take include:

- Pre-weigh chemicals for students. This will take more time on your part, but it will also make lab time more productive for the students.
- Have students work in teams. For example, pairing students can cut the number of chemicals that will be used in half. Pairing also teaches students to work together.
- Alternatively, you may want to demonstrate some experiments yourself, rather than having the whole class perform them.
- Set up a procedure to use spent or recovered solvents for an initial rinse, and save fresh solvents for use in the final rinse only.

Where feasible, include a step as part of the experiment that destroys or inactivates any hazardous products. Chapter 13 will cover "treatment" of hazardous waste materials in more detail. Certain hazardous chemicals such as acids and bases can be easily neutralized as a part of the experiment.

Encourage Students To Research Waste Minimization

Finally, a good way to get students thinking about waste minimization as they run experiments is to have them actually research waste minimization techniques. You might think of including an experiment in your curriculum that actually gets the students to identify ways to minimize use of hazardous chemicals or generation of hazardous byproducts.

11 Scaling Down Experiment

Typically, educational experiments are designed at a macroscale level, with little thought about waste minimization. Most macroscale experiments can be easily scaled down and still achieve the same level of analytical rigor. Experimental quantities can be scaled down by about 50% with little effort or cost, or scaled down to 1/100th to 1/1000th of the original quantities using glassware and experiments designed for microexperimentation. The result—less waste, less student exposure, and fewer chemical purchases.

In upper-level chemistry courses, microscaling complements the use of analytical equipment such as chromatographs, spectrophotometers, nuclear magnetic resonance systems, etc. These systems require extremely small sample quantities for analysis.

Reduced Scale Chemistry

If you cannot convert to true microscale chemistry, try decreasing experimental quantities by a third or half. A 50% reduction in quantities can usually be achieved with conventional glassware. Such scale reductions may require a few trial runs to ensure desired experimental results—a good exercise for students who volunteer for extra credit lab work. (Caution: Instructor supervision is important!)

Microscale Chemistry

Microscale chemistry techniques and equipment can reduce chemical use by as many as three orders of magnitude. Efforts at developing classroom micro experiments for general, organic, inorganic, and physical chemistry courses have been and continue to be successful. Several student and instructor textbooks have been published. Some recommended textbooks are listed in Chapter 15. Two of these books (Ehrenkranz & Mauch, 1993, and Waterman & Thompson, 1993) are specifically intended for high school chemistry classes.

Micro techniques are also being explored and developed in radioactive chemistry and radiochemistry. Most microscale techniques can easily be mastered by beginning students, with proper instruction.

As an example, conventional experiments with solids use 10- to 50-gram amounts, while microscale experiments can use as little as 25-100 milligrams (mg). Similarly, experiments with liquids can be cut from 25-100 milliliters (mL) to 100-200 microliters (pL). Highly accurate density and specific gravity determinations can be achieved using less than 1 mL of liquid and a micropipette, rather than the conventional larger volumetric flask method, requiring up to 30 mL of the solution.

Implementing Microscale

An inexpensive way to achieve an initial level of microscale would be to use flexible, small diameter polyethylene tubing instead of bent glass tubing to transfer gases, using micro pipettes, microburets, and Hirsch filtration funnels rather than the traditional larger size equivalents. (Note: Some of the plasticware may not be suitable for organics.)

To fully retrofit a conventional chemistry lab to microscale, some investment is necessary. Full microscale glassware kits cost up to $110 to $150 (advanced levels) per student (1994 prices). Analytical microscale equipment also adds to the initial cost. Typically, one piece of equipment (e.g., one electronic digital balance or one capillary melting point apparatus) suffices for 15 students.

These costs are typically recovered in nine months to three years (depending on the size and scope of the program). Chapter 14 provides possible strategies for acquiring funding or equipment to convert to microscale chemistry.

The National Microscale Chemistry Center (NMC2) at Merrimack College in North Andover, Massachusetts, offers a wealth of information on implementing mircorscale chemistry in the laboratory. You can visit their web site at http://www.silvertech.com/microscale. Many other colleges are practicing, or are converting to, microscale experimentation in their laboratories and may offer training or auditing of courses using microscale.

12 Substituting Materials

Substitution of hazardous chemicals in the laboratories with nonhazardous (or at least less-hazardous) chemicals is an important source reduction strategy. If you use nonhazardous chemicals in place of hazardous chemicals, you've gone a long way towards avoiding a hazardous waste problem. Substitution can sometimes be done in conjunction with scaling down quantities used in experiments (see Chapter 8), giving you a double savings. Both substitution and scaling down experiments should be considered before such options as reuse, recycling, or treatment. (Remember that, according to the waste management hierarchy, source reduction is always preferable to recycling, treatment, or disposal.)

Substitution of hazardous chemicals with non- or less-hazardous chemicals has been achieved by a number of secondary schools, as well as some high schools and introductory college chemistry courses. These schools have created laboratory curricula that rely on chemicals and compounds that can be purchased at the local grocery store, rather than from a chemical supplier. Below is a table that includes some of the possible substitutes for hazardous chemicals.

Possible substitutes for hazardous chemicals

Procedure	Hazardous Chemical	Substitute
Glassware cleaning	Chromic-sulfuric acid solutions	laboratory detergents, enzymatic cleaners, aqueous solvents
	Alcoholic potassium hydroxide	
Density determination	methanol solution	sugar water
Organic synthesis	chromate ion	hypochlorite ion

	ethyl ether	methyl t-butyl ether
Qualitative test for heavy metals	sulfide ion	hydroxide ion
Molecular weight determination freezing point lowering methods	benzene	cyclohexane
Temperature	mercury thermometers	red or green liquid thermometers
Storage of biological specimens	formaldehyde	ethanol or other preservatives
In-phase change and freezing depression	acetamide	stearic acid point
Qualitative test for halide ions	carbon tetrachloride	cyclohexane
Measurement of vapor pressure- by isotensiscope	carbon tetrachloride	isopropyl alcohol temperature
Acid-base experiments	conventional acids conventional bases	vinegar ammonia

Table from *Less is Better* and Freeman, 1995, pg. 511

13 Alternatives to Wet Chemistry

In addition to substituting safer chemicals and reducing the scale of experimentation, you might also want to consider avoiding certain experiments altogether. While hands-on wet chemistry experience is important to a certain degree, there are good reasons for exploring alternatives such as instrumental analysis, computer simulation, or even videos. One important consideration is that commercial and industrial laboratories are moving away from wet chemistry and towards instrumentation and simulation whenever possible, so it is important for students to gain experiences with these techniques. In addition, of course, these techniques offer a means of minimizing or avoiding some chemical wastes.

Instrumentation

Sample separation, purification, and other new techniques and equipment have advanced significantly in the last decade. However, many of the new instruments can be expensive, and can require users to be rather sophisticated. By and large, these instruments are more applicable to higher-level university science classes than to introductory science or chemistry courses.

Chapter 9 discussed several instruments related specifically to microscale experimentation. In addition, there are a number of other instruments that can perform important laboratory analyses with reduced chemical input requirements. Some of these instruments include:

- ion, liquid, and gas chromatographs El mass spectrophotometer
- IR and UV spectrophotometer II nuclear magnetic resonance (NMR)
- atomic absorption instrument II X-ray diffraction instrument

These highly sensitive instruments can reduce the quantities of analytes required for testing by 10- to 100-fold. For example, NMR analysis requires a 1 mL sample for quantitative analysis.

Again, many of these instruments may be beyond your budget, or may be inappropriate for the scale of your classes. However, keep in mind that just like other technologies (e.g., computers), they may become more affordable and easier to use in time.

Sample Preparation

Another area where alternatives to wet chemistry exist is in the preparation of samples for analysis. Most samples require some extraction and/or concentration in preparation for further analysis. Traditional procedures (liquid-liquid or liquid-solid extraction) are time-consuming and waste substantial quantities of solvents. Solid phase microextraction (SPME) and supercritical fluid extraction (SFE) are two recently developed methods that eliminate the need for solvent to separate analytes. (These methods may not be relevant for high school laboratories.)

SPME is a solventless sample preparation method for analysis of organic compounds by gas chromatograph (GC). This approach replaces traditional methods such as purge and trap systems or liquid-liquid extraction. Essentially, SPME is a modified syringe holding a phase-coated fused silica fiber that adsorbs organic analytes when placed in the water sample. The analytes are then desorbed from the fiber into a capillary GC column at the heated injection port. The equipment is fairly small and reasonably priced, and the fibers are reusable up to 100 times. SPME is particularly cost effective when you consider the savings in solvent purchase and disposal.

SFE uses the unique characteristics of supercritical CO^2 to extract analytes from a sample, fully eliminating solvent use. Because supercritical fluids have lower viscosity and diffuse more rapidly into a sample, it also greatly reduces sample preparation time. The smaller, more recent SFE equipment models may be appropriate for some classroom settings. These models offer microprocessor controls as well as an elimination of moving parts to make maintenance and use easier. A typical extraction takes about 30 minutes at a material cost of about 10 cents.

Computer Simulation/Videos

Again, it is important that students gain laboratory experience in using glassware and equipment. However, due to time constraints in lab courses, and the length of typical introductory experiments, computer simulation may allow students to see a wider variety of experimental results, without generating wastes, and in a much shorter time period. At higher level educational institutions, computer simulation may greatly decrease the amount of chemicals (and wastes) required in research and development by allowing researchers or students to tweak and optimize experiments on a computer instead of repeating experiments again and again at a bench-scale or full-scale level.

A number of computer software vendors are producing chemical reaction simulation software. In some cases, this software is quite elaborate and complicated, as it is oriented towards commercial and industrial applications. In other cases, the software might be useful in the classroom. A good resource for more information (in addition to your local software store) might be a regional or state university, many of which have already started to implement simulation software. In addition, more and more information is being provided on the Internet.

In addition to computer simulations, you might also be able to teach certain experimental principles by using videos—even "home grown" videos.

14 Reusing and Recycling Chemical Resources

After doing as much as possible to minimize waste generation through source reduction, the next most preferable options are recycling and reuse. Although people tend to avoid recovery efforts because of the "costs" involved, chemicals can often be recovered at net costs lower than the cost of disposal. Reuse and recycling can occur at a number of points in the chemical use cycle. Some options include recovering chemicals as part of the experimental process, participating in a chemical swap, and including recovery activities as part of the experiment. Again, some of these options will only be appropriate for larger, more advanced laboratories; others—such as the chemical swaps—may work even if you have a smaller program.

Recovery in Process

Recovery of chemicals can serve as a valuable learning tool for students and can be presented as the final step of a chemistry experiment, or can be an "extra-credit" opportunity for interested students. (Caution: Recovery methods should always be performed under supervision.)

The College of the Redwoods, located in California, has designed a series of "closed loop" experiments where the by-products of one experiment become the reagents/reactants of the next experiment. At the end of the series, the by-products of the final experiment are available for the next set of students to start the process all over again. See the reference list in Chapter 15 for more information on this "no waste" lab manual.

Chemical Swaps

Finding a use for surplus opened containers of chemicals is a good way to avoid having to dispose of them as waste. In many cases, laboratories or other users may be able to use these chemicals even though they have a lower purity. In addition, outside organizations may be willing to accept waste streams from laboratories if they can economically recover the valuable constituents. (Note: waste transport is subject to state/local regulations.) Some things you can do to encourage chemical swaps/waste exchanges:

- Talk with other schools in your area to see if you can set up a simple exchange mechanism for school district.

- Consult the Merck Index to see what types of manufacturers in your area may be interested in your chemicals. For example, artisans may use metal salts for ceramic glazes; auto shops may be able to use distilled solvents for parts cleaning. This is most likely to happen with unused raw material that is properly labeled and in good condition.

When in-house or inter-school exchanges are not possible or too difficult to set up, external surplus exchange services might be helpful. Most exchange services are non-profit; some target educational laboratory institutions, some target industry, and some target both. Services are mostly regional to minimize transportation of potentially hazardous wastes.

Passive surplus exchange services allow generators to "advertise" for free their chemicals and waste materials that may be of use to others. A "catalog" is published every few months, or an on-line database may be available. Items are listed as "wanted" or "available." (You can help close the recycling loop by obtaining chemicals for your lab from the "available" section.) Passive services rely on advertisers and readers to communicate directly to negotiate any exchanges. One such exchange service in Pennsylvania is listed below.

Passive Surplus Exchange Service	Web Address
Pennsylvania Material Trader	http://www.materialtrader.org/

Active exchange services, and/or chemical brokers may be able to find (or provide tips on how to find) market alternatives for reusable chemical wastes. Brokers charge a fee for an exchange, but may offer a free consultation visit to inform you of potential customers for your chemicals. Contact your local DEP Regional Office for more information on waste or chemical exchange services in your area. Remember that containers must be properly labeled and in good condition.

Solvent recovery

If you regularly generate spent solvents, recovery can be very cost-effective, as well as environmentally sound. Spent solvents that are properly segregated (see Chapter 12) can be easily distilled in-house to a high purity that will allow multiple reuse of the same batch of solvent. Many solvents are excellent candidates for distillation, including xylene, methanol, acetone, and toluene. Some exceptions are peroxide-forming solvents, which should not be distilled, and ethanol, which may require a permit for distillation.

In-house, bench-top distillation units ("stills") are commercially available, or can be set up at little or no additional cost with existing laboratory equipment. However, it is important to consult your local fire department before you consider purchasing or setting up a still, since most fire departments have regulations that apply to stills used to process flammables. Alternatively, you may be able to contract with off-site recyclers to recover used solvents, depending on the quantity of solvents you generate.

If you use high-performance liquid chromatography (which tends to generate a substantial quantity of used solvent), you should know that automated, in-line solvent recovery systems are available that make it very easy to recapture up to 80% of high-purity solvents. The recovery equipment is fairly small, is low-maintenance, and requires minimal attention. The recovered solvent can be reused again and again. Such systems are available for a few thousand dollars and can pay for themselves in about one year due to reduced solvent purchases and waste disposal fees.

Metal recovery

Many heavy metals have been largely phased out of school science experiments, although mercury, silver, and others may still be used. Even small amounts of these metals can be successfully recovered in the laboratory, possibly as an educational exercise. For larger quantities, local or regional industries may be interested in metal-bearing wastes for recovery of the metals. In fact, the original suppliers may be interested in taking back such wastes for credit and/or recovery.

A few companies in the U.S. recover and clean contaminated mercury for reuse. It is possible to develop a closed-loop system whereby your mercury wastes are purified and returned to you specifically. These companies provide DOT-approved containers for accumulation and transport. Types of mercury accepted for recovery, recycling, or purification include spill debris, liquid mercury, and mercury in switches, thermometers, barometers, fluorescent lamps, and other items.

15 Managing the Waste Streams

School science laboratory programs will generate two types of waste streams. Those that are hazardous waste and those that are non-hazardous. Hazardous waste is highly regulated by both federal and state laws. We must properly manage and dispose of these waste streams.

Hazardous wastes can not be put down a drain or into the trash.

Determining if a Waste is Regulated as Hazardous

It is the responsibility of the generator of the waste (this would be the science teacher who is conducting the experiment) to determine if the waste is hazardous. Checking to see if a chemical is on one of the lists is simple enough, but deciding whether a chemical or product is a characteristic waste might take a little research. The Material Safety Data Sheet (MSDS) for the material will usually provide enough information to identify characteristic wastes. Occasionally, a chemical or mixture may have to be tested to determine whether it is hazardous.

The disposal options for hazardous waste generated by educational facilities are either *listed* (commonly called “Listed “Hazardous Wastes) in 40 Code of Federal Regulations (CFR) 261 Subpart D, or they are wastes *characterized* (commonly called “Characteristic” Hazardous Waste) in 40 CFR 261 Subpart C as hazardous.

A hazardous waste determination must be made of any chemical waste material generated. (See 40 CFR 262.11).

What Makes Up Hazardous Waste

The disposal of certain chemicals is regulated by federal law: the Resource Conservation and Recovery Act of 1976. This law is frequently referred to by its acronym, “RCRA” (pronounced “rick-rah”). RCRA defines which chemicals are regulated and requires that they be subjected to “cradle to grave” monitoring until they are destroyed, rendered non-hazardous, or buried in a special hazardous waste landfill.

Schools should try to reduce or eliminate as many of their waste streams as possible. If a school is not generating any hazardous waste, the associated disposal costs, potential spills, potential health and safety hazards, and recordkeeping requirements will not be applicable.

A chemical to be disposed of will be a regulated hazardous waste if it exhibits one or more hazardous characteristics (characteristic waste) or because it appears on one of four lists (listed waste).

Characteristic Waste

There are four types of characteristic hazardous waste: ignitable, corrosive, reactive, and toxic. These are referred to in the regulations as “D” wastes. The complete definitions of characteristic wastes can be found in 40 CFR 261.21-261.24 accessible from EPA’s website: ***www.epa.gov***

The following are abbreviated definitions of these characteristic wastes.

Ignitable

There are four reasons a waste could be classified as ignitable:

- ° It is a *liquid* that has a flash point less than 140°F (60°C.) (The flash point is the temperature at which a liquid gives off enough vapor that the vapor will ignite if initiated by a flame or spark.) Examples are ethyl ether, most mineral spirits, ethanol, and gasoline.

- ° It is *not a liquid* and is capable, under ordinary conditions, of causing fire through friction, absorption of moisture, or spontaneous chemical change. Examples are activated carbon, metal dusts, pyrophorics, and matches.

- ° It is an *ignitable compressed gas*. Examples are cylinders of hydrogen, acetylene, and propane, and aerosol cans using flammable gas as a propellant.

- ° It is an *oxidizer*; that is, capable of supporting combustion by contributing oxygen. Examples are oxygen, nitrates, peroxides, and hypochlorites.

Corrosive

• A corrosive waste is a *liquid* with a pH less than or equal to 2 or greater than or equal to 12.5; that is, it is strongly acidic or caustic. Examples are concentrated acids and concentrated ammonium hydroxide.

Reactive

• A reactive waste exhibits one or more of the following properties:

- ° It is *unstable* under ordinary conditions. An example would be any explosive, such as dried picric acid.
- ° It *reacts violently with water*, sometimes producing toxic, corrosive or flammable gases. Examples are alkali metals, acid anhydrides, phosphides and organometallics.
- ° It is a *cyanide or sulfide-bearing waste* that, when exposed to a pH between 2 and 12.5, can generate toxic gases. Examples are potassium cyanide and sodium sulfide.

Toxic

• The characteristic of toxicity refers to a waste from which harmful chemicals would leach if it were disposed of in a landfill. A test, the Toxicity Characteristic Leachate Procedure (TCLP, pronounced *T-clip*), is performed on the waste, and if the resulting leachate exceeds the allowable concentration of any one of 39 substances, the waste is a regulated hazardous waste. The list of these 39 chemicals can be found in 40 CFR 261.24. Examples are absorbent material used to clean up a spill of trichloroethylene, lead-based paint, and electronic equipment containing heavy metals. (It is not always necessary to have the TCLP test performed if you have sufficient knowledge of the waste to accurately predict whether it would pass or fail. For example, you would know that barium chloride would fail the test for barium, but barium sulfate would pass, because it is practically insoluble.)

Listed Wastes

The other category of hazardous waste is listed waste. There are four lists: F, K, U and P:

- F-wastes are mixtures from non-specific sources: for example, solvents used for cleaning.
- K-wastes are those produced by specific industrial sources; schools would not have any of these wastes.

- U-wastes, listed by name, are commercial chemical products.
- P-wastes are also commercial chemical products listed by name, but P-wastes are considered to be “acutely hazardous” and are more strictly regulated.

Most listed hazardous wastes generated by school laboratories would be on the U or P lists. All these lists are in 40 CFR 261.31-261.33 available at: ***www.epa.gov***

We generated Hazardous Waste-Now what?

When a hazardous waste determination has been conducted, the amount of waste generated monthly or stored on site will establish generator status.

To determine a schools status, one must measure all quantities of listed and characteristic hazardous wastes that are:

- Accumulated on the property for any period of time before disposal or recycling;
- Packaged and transported away from your facility;
- Placed directly in a regulated treatment or disposal unit at your facility; or
- Generated as still bottoms or sludges.

It is most likely that a school facility will be a Conditionally Exempt Small Quantity Generator (CESQG) of hazardous waste. CESQGs generate 220 pounds (100 kilograms) or less per month of hazardous waste, or 2.2 pounds (1 kilogram) or less per month of acutely (or P-listed)hazardous waste.

Therefore almost all schools with science labs would be required as a CESQGs (see 40 CFR261.5) to:

- CESQGs must identify all the hazardous waste generated.
- CESQGs may not accumulate more than 2,200 pounds (1,000 kilograms) of hazardous waste at any time.
- CESQGs must ensure that hazardous waste is delivered to a person or facility that is authorized to manage it.
- Written documentation must be kept for three years.

If you generate more than the waste volumes noted above your facility status could be a LQG (large quantity generator), or a SQG (Small Quantity Generator), contact the School District’s Office of Environmental Management and Services for further assistance as the regulation are much more complicated and strict with the high waste volumes generated.

Segregation of Waste Streams

Segregating laboratory wastes during handling, storing, and lab packing is important for safety reasons, for legal reasons, for pollution prevention reasons, and for ensuring the lowest disposal costs. Many of the ideas presented in Chapter 5 on Managing Inventories can also help you manage wastes.

Segregation of incompatible materials in a storage area is critical. Ignitables should be separated from oxidizers or sources of ignition, especially solvents. Acids should be separated from bases, and oxidizing agents from reducing agents. There are also more specific chemical incompatibilities that you might want to consider during waste storage—these can be found in waste management publications or in the references cited in Chapter 15.

Hazardous and nonhazardous wastes should not be mixed together. Likewise, organic and inorganic waste streams should be segregated. For example, if you mix solvents with oils (e.g., from auto shop), you can expect to pay up to five times the disposal cost because the waste is now mixed. Segregating wastes within the same material type is also important, especially in the category of organic wastes.

Waste streams that you can recycle, especially recoverable metals or solvents, should be stored separately. In some cases, segregation will be important to facilitate recycling. For example, halogenated solvents and non-halogenated solvents should always be stored separately, since they need to be distilled separately. In particular, chlorinated solvents (which you might want to avoid using altogether) should not be mixed with non-chlorinated solvent wastes.

Disposal of Hazardous Wastes

Hazardous wastes have the potential to harm human health and the environment. These wastes cannot be put in the garbage or down the drain. They cannot be disposed on or in the ground, or in local landfills, septic tanks, or injection wells, and may not be disposed of by open burning. You may recycle or reclaim these wastes or dispose of them through licensed hazardous waste management firms. **Not complying with hazardous waste regulations can lead to significant fines and penalties for both the school and yourself directly.**

Regardless of quantity, the generator of HW is ultimately responsible for the waste from "cradle to grave", and can be held liable for improper management of HW even though it may have been sent to a "proper" HW management facility using a licensed transporter. The School District's Office of Environmental Management and Services has the proper licensed contractors and they are the only contractors who can package, remove and dispose of chemicals wastes on School District property.

Chemical Disposal Guidelines

When disposing of chemical waste follow these guidelines:

a) Do not transport the wastes from the school property they are currently located on.

b) **DO NOT** dispose of waste chemicals down the drain unless they have been properly treated in accordance with local, state and federal guidelines. In the City of Philadelphia only elementary neutralization is acceptable.

c) Do not use fume hoods to evaporate volatile chemicals.

d) Dispose of wastes by recycling, reclamation or chemical deactivation whenever possible. A hazardous waste transporter will be needed for this step.

e) Avoid stocking over 2.2 pounds (1.0 kilogram) of "P-listed" chemical products. This could help you stay below large quantity hazardous waste generator status. This link will help you identify listed wastes. http://www.epa.gov/epaoswer/osw/hazwaste.htm.

As of May 8, 1990, most hazardous wastes must be treated to meet Land Disposal Restrictions (LDR) prior to disposal in permitted hazardous waste landfills or surface impoundments. **The LDR rule prohibits the dilution of restricted wastes as a substitute for effective adequate treatment.**

Certain wastes, such as heavy metals or pure chemical product, must **NEVER** be discharged to the sanitary sewer in **ANY** concentration. These wastes must be collected and managed as hazardous waste. Contact School District's Office of Environmental Management and Services for specific information.

Since most concentrations in a lab are a 0.1 Molar solution, keep in mind that 0.1 Molar $CuSO_4$ is equal to 6355 mg/L of copper.

You may dispose of chemical waste as outlined below. It is the responsibility of the teachers, principals, administrators, and school district to ensure hazardous waste does not end up in ground water, soil or the atmosphere through improper disposal.

1) **Sanitary Sewer** - Some chemicals (acids or bases) may be neutralized and disposed to the sanitary sewer. This disposal option must be approved by the School District's Office of Environmental Management and Services prior to disposal. Hazardous waste may **NOT** be disposed of in this manner. This includes heavy metals.

2) **Disposal Through a Licensed and Approved Contractor** - A contractor may be used for the disposal of the waste chemicals. Remember that you must keep documentation of your hazardous waste disposal for at least three years. This information must include a waste manifest, reclamation agreement or any written record which describes the waste and how much was disposed, where it was disposed and when it was disposed. Waste analysis records must also be kept when making a determination is necessary. **Any unknown chemicals should be considered hazardous**!

Call the School District's Office of Environmental Management and Services for additional information:

16 In-Laboratory Treatment of Wastes

As a last line of defense in efforts to minimize waste generation, you might want to consider options for in-laboratory treatment of wastes.

An important distinction exists between recycling or reclamation of chemicals and treatment of chemical waste. Reclamation or recycling generally applies to efforts to recover chemicals for re-use—either in the laboratory or elsewhere. By contrast, treatment generally applies to efforts to make waste less hazardous, followed by disposal. While treatment may be a useful activity, you should be aware that the treatment of hazardous waste may require a permit or be subject to regulation.

In the laboratory setting, treatment that occurs as the last step in an experiment is technically not covered by regulation. Therefore, you will be in the best position if you can fold the following treatment options into your experiments directly.

Types of treatment techniques for rendering compounds non- or less hazardous—or in some cases reusable—include:

neutralization	precipitation
separation	degradation
fixation	ion exchange II oxidation

Neutralization of acids and bases is probably the most commonly used treatment method in educational institutions. Neutralization reduces a material's corrosivity (acid or caustic properties) by raising or lowering the pH to a neutral range, between 6 and 9.

In some cases you may need to accumulate wastes before treatment is practical. Treatment of chemical waste outside the experimental process may involve additional regulatory requirements.

Before you implement any treatment methods outside of the experimental process, you should discuss your plans with the School District of Philadelphia Office of Environmental Management and Services.

17 Getting More Information

Here is a list of organizations and publications that may be of help to you as you establish your pollution prevention program.

Organizations

- Pennsylvania Chemical Industry Education Foundation (see page 18), (717) 232-6681.
- The PA Department of Environmental Protection (See the list of DEP regional offices on page 8.)
- U.S. Environmental Protection Agency, Regional Office in Philadelphia serves all of Pennsylvania -(215) 814-5000 or (800) 438-2474
- El National Science Foundation – (703) 306-1234
- II American Chemical Society, 1155 –16th Street NW, Washington, DC 20036
- College Chemistry Programs and Pollution Prevention Programs. Publications: Laboratory Waste Minimization
- American Chemical Society. (1993). Less is better: Laboratory chemical waste management for waste reduction (2nd ed.). Washington, DC: Author.
- American Chemical Society (1994). Laboratory Waste Management: A Guidebook. Washington, DC: Author.
- American Chemical Society (1995). Model Chemical Hygiene Plan for High Schools. Washington, DC: Author. Available on disk: MacOS or MS-DOS.
- Environmental Protection Agency. (1990, June). Guides to pollution prevention: Research and educational institutions. Cincinnati: U.S. Environmental Protection Agency.
- Field, R.A. (1986). Management strategies and technologies for the minimization of chemical wastes from laboratories. Raleigh: North Carolina Pollution Prevention Pays Program.
- Illinois Department of Natural Resources. (1990, May). Waste reduction guide for Illinois schools. Springfield, IL: Author.
- Kaufman, J.A. (Ed.). (1990). Waste Disposal in Academic Institutions. Chelsea, MI: Lewis Publishers, Inc.
- National Research Council. (1983). Prudent practices for disposal of chemicals fromlaboratories. Washington, DC: National Academy Press.

- Jacobson, L. (no date). Children's art hazards. New York: Natural Resources Defense Council, Inc.

- State of Washington School Chemistry Lab/Storeroom Safety Committee. (1984). Who should conduct high school lab/store room cleanups and assure safe disposal? Contact James Knudson, Washington State Department of Ecology, Hazardous Waste Section, (206) 459-6203.

- Task Force on RCRA. (1990). The waste management manual for laboratory for personnel. Washington, DC: American Chemical Society.

- Wahl, G.H., Jr. (Ed.). (no date). Reduction of hazardous waste from high school chemistry laboratories. Raleigh: Pollution Prevention Pays Program, North Carolina Department of Environment and Natural Resources.

Publications: General Waste Minimization

- Freeman, H.M. (Ed.). (1990). Hazardous waste minimization. New York: McGraw-Hill Publishing Company.

- National Renewable Energy Laboratory. (no date). Waste World: Teaching students about municipal solid waste. Municipal Waste Resource Management Program—Project Fact Sheet. Golden, CO: Author.

- National Research Council. (1985). Reducing hazardous waste generation: An evaluation and a call for action. Washington, DC: National Academy Press.

- Tulis, J.J., & Thomann, W.R. (Eds.). (1992). Proceedings: Strategies for Improved Chemical and Biological Waste Management for Hospitals and Clinical Laboratories. Raleigh: Office of Waste Reduction, North Carolina Department of Environment and Natural Resources.

Publications: Laboratory Manuals

- Bergstrom, W., & Howells, M. (1988). Hazardous waste reduction for chemical instruction laboratories. Cincinnati: U.S. Environmental Protection Agency.

- College of the Redwoods. (1989). No-waste lab manual for educational institutions. Sacramento: California Department of Toxic Substances Control.

- Ehrenkranz, D.F. (1993). Chemistry in microscale: a set of microscale laboratory experiments. Dubuque, Iowa: Kendall/Hunt Pub. Co.

- Ehrenkranz, D.F. (1993). Chemistry in microscale: a set of microscale laboratory experiments with teacher guides. Dubuque, Iowa: Kendall/Hunt Pub. Co.

- Flinn Scientific (1994). Spectrophotometer Laboratory Manual. Batavia.

- Hathaway, R.A. (Ed.). (1991). Safety considerations in microscale chemistry laboratories.

Symposium at the 197th national meeting of the American Chemical Society, April 12, 1989, Dallas. Washington, DC: American Chemical Society.

- Mayo, D.W., Pike, R.M., Trumper, P.K., & Fickett, P. M. (1994). Instructor's Manual, Microscale Techniques for the Organic Laboratory. Third Edition. New York. John Wiley & Sons, Inc.
- Mayo, D.W., Pike, R.M., & Trumper, P.K. (1994). Microscale Organic Laboratory with Multistep and Multiscale Syntheses (3rd ed.). New York: John Wiley & Sons, Inc.
- Mayo, D.W., Pike, R.M., Butcher, S.S., & Trumper, P.K. (1991). Microscale Techniques for the Organic Laboratory. New York. John Wiley & Sons, Inc.
- Mayo, D.W., Pike, R.M., & Butcher, S.S. (1989). Microscale Organic Laboratory (2nd ed.). New York. John Wiley & Sons, Inc.
- Pavia, D.L., Lampman, G.M., Kriz, G.S., & Engel, R.G. (1990). Introduction to Organic Laboratory Techniques: A Microscale Approach. Philadelphia: Harcourt Brace College Publishers.
- Pike, R.M. (Winter 1994). Microscale Chemistry - Small Scale, Big Idea. EM Scientist, 3(1), pp. 1-2.
- Szafran, Z., Pike, R.M., & Singh. (1991). Microscale inorganic chemistry: A comprehensive laboratory experience. New York: John Wiley & Sons, Inc.
- Waterman, E.L. (1993). Small scale chemistry laboratory manual. Menlo Park, CA: Addison-Wesley Publishing Co.
- Waterman, E.L. (1993). Addison-Wesley small scale chemistry. Menlo Park, CA: Addison-Wesley Publishing Co.
- Williamson, K.L. (1989). Macroscale and Microscale Organic Experiments. Lexington, MA: D.C. Heath and Company.

Online Resources

- Pennsylvania Department of Environmental Protection, http://www.dep.state.pa.us/. Information on waste minimization, recycling, pollution prevention and hazardous waste disposal in Pennsylvania.
- U.S. Environmental Protection Agency, http://www.epa.gov/. Information on hazardous waste disposal and pollution prevention.
- National Microscale Chemistry Center, http://www.silvertech.com/microscale/ — Web site for Merrimack College's Microscale Chemistry Center, dealing with the use of microscale chemistry as a pollution prevention technique.
- Pollution Prevention in Chemical Laboratory Instruction,

- http://www.pprc.org/pprc/rpd/statefnd/minn oea/pollutio.html— Summary of Laboratory P2 project at the University of Minnesota on P2 in Laboratory settings

- National Pollution Prevention Center for Higher Education, http://www.umich.edu/-nppcpub/resources/ -Home page for the National Pollution Prevention Center for Higher Education (NPPC), which is established to help educators integrate P2 into the curriculum. A good source for readings and curricular materials.

- http://www.ehs.uiuc.edu/— Great resource on laboratory pollution prevention developed for use at the University of Illinois at Urbana-Champaign. Includes "101 Ways to Reduce Waste in the Laboratory."

- http://www.epa.gov/greenchemistry/

Waste Minimization Checklist

The following checklist is designed to help you minimize the amount of waste generated in the laboratory. The list is not all-inclusive, but should serve as a starting point for your efforts.

Purchasing Chemicals

- Develop a purchasing strategy for chemicals and other hazardous materials.
- Purchase chemicals in smaller sizes.
- Standardize chemical purchases across classes or laboratories.
- Designate a single person to be responsible for purchasing chemicals and monitoring inventories.
- Link purchasing requests into an inventory system so that excess chemicals in stock can be used before buying more.
- Find a supplier who will accept unopened chemicals that are returned, or will otherwise support waste minimization efforts.

Managing Chemical Inventories

Institute inventory control

- Conduct a school-wide inventory to identify where chemicals are located.
- Designate a centralized place for chemical storage and another for waste storage, with spill containment.
- Organize your chemical and waste storage systematically to keep like chemicals together.
- Adopt a standard labeling procedure for chemicals and waste, using labels that are colorfast and permanent.
- Designate who is responsible for labeling and inventory control.
- Use tags, bar codes, or some other system to establish a computer tracking of chemicals.
- Use a first-in/first-out policy.
- Return expired material to supplier.
- Perform regular inventory audits to identify chemicals that aren't being used.
- Provide a simple regular listing to chemical users on available chemical stocks, location, and point-of-contact.

Work on spill and leak prevention

- Keep chemicals and waste containers covered to prevent spills.
- Install spill and leak protection in chemical storerooms, including berms, sumps, or even simple plastic containers.
- Anchor storage cabinets to walls and floors.
- Periodically inspect stored chemicals for signs of leakage, poor storage practices, or any other problems.

- Keep a record of spills and leaks and note why they happened and how they can be avoided in the future.

Conducting Experiments

Teach resource-efficient policies

- Use solvents and other hazardous materials sparingly.
- Have students monitor reactions closely and add only what's needed.
- Emphasize conservation of water, electricity and other general resources.

Set up experiments with waste minimization in mind

- Pre-weigh chemicals for students.
- Have students work in teams.
- Demonstrate some experiments rather than having the entire class perform them.
- Use spent/recovered solvents for an initial rinse and fresh solvents for a final rinse.

Include final steps in experiments to destroy or inactive hazardous substances

- Neutralize acids and bases.
- Perform chemical conversions to non-hazardous substances.
- Provide students with the opportunity to research waste minimization techniques.

Scaling Down Experiments

- Reduce scale of experiment (and associated quantities of chemicals) where possible.
- Move to microscale chemistry.

Substituting Materials

Substitute less hazardous chemicals for more hazardous ones

- Use laboratory detergents rather than hazardous cleaning baths (e.g., substitute detergents for chromic acid solutions).
- Use non-halogenated rather than halogenated solvents (e.g., substitute cyclohexane for carbon tetrachloride).
- Use less toxic/hazardous solvents rather than more toxic/hazardous solvents.

Finding Alternatives to Wet Chemistry

- Substitute computer simulations, videos, etc. for actual experiments.
- Use alternatives to solvent-based extraction (e.g., Solid Phase Microextraction or Supercritical Fluid Extraction).
- Use instruments in place of wet chemistry (e.g., chromatography, spectrophotometry, atomic absorption, nuclear magnetic resonance, X-ray diffraction).

Reuse and Recycling

Establish a chemical swap

- Set up an internal surplus chemical exchange.
- Participate in an outside chemical/waste exchange program.

Reclaim solvents

- Filter spent solvent for reuse.Distill spent solvents on-site.
- Recycle solvents via a solvent recycling service.

Reclaim metal-bearing waste

- Identify an outside industry interested in taking metal-bearing waste for recovery.

Segregating Individual Waste Streams

Segregate wastes

- Keep hazardous waste separate from non-hazardous waste.
- Keep organic waste separate from inorganic waste.
- El Keep different groups of solvent separate (e.g., halogenated vs. non-halogenated solvents).
- Keep incompatible materials separated (ignitables and oxidizers; acids and bases; oxidizers and reducers, etc.).

In-Lab Treatment

- Neutralize acids and bases.
- Perform chemical conversions to create non-hazardous substances.

Strategies for the Entire School

Create a Lab or School wide Program

- Create a waste minimization team composed of students, teachers, and administrators.
- Develop a written statement of commitment to waste minimization.
- Perform a waste audit of the school/lab.
- Provide a forum or suggestion box for waste minimization/pollution prevention ideas. CI Set up waste minimization education sessions for students/staff.
- Set up specific reduction goals (e.g., 50% reduction in amount of waste generated per year).

Implement other (non-laboratory) waste minimization/pollution prevention opportunities

- Perform routine maintenance of school equipment to fix leaks, avoid accidents.

- Reduce use of fertilizers and pesticides on school grounds.
- Compost grass and other trimmings.
- Keep school vehicles properly tuned up.
- Maintain air conditioner and heater filters to reduce energy consumption.
- Replace inefficient lighting with compact fluorescent or other energy-smart lighting.