Chapter 8
Chemical Management

OVERVIEW

Many chemicals can be managed safely by schools, depending on staff expertise and the facilities available. Chemicals designated as controlled, regulated or hazardous, however, require special attention through the full cycle of procurement, storage, use and disposal. Management of such chemicals requires a thorough understanding of their chemical properties, potential hazards, and what to do in case of an accident.

The focus of this chapter is on implementing a sound, comprehensive chemical management plan that addresses chemical purchasing, storage and inventory, as well as strategies for minimizing and managing chemical wastes. To ensure such a plan is working effectively requires auditing (and revising if necessary) processes for:

- ordering and receiving chemicals
- storing and handling chemicals
- disposing of chemicals.

CHEMICAL ACQUISITION

Choice of Chemicals

The selection of chemicals for use in school laboratories should be based on several considerations:

- curriculum needs
- value of the laboratory experiences provided to students
- chemical hazards
- likelihood of chemicals being used in multiple activities or classrooms
- maturity, knowledge and skills of the students
- availability of alternative activities and materials
- storage facilities and laboratory equipment available
- environmental considerations and costs related to disposal.

In many cases, nonregulated chemicals that can be bought at the local store can be used as substitutes for more hazardous chemicals. Choosing these less hazardous chemicals often reduces cost of purchase and disposal as well as the hazards associated with use. However, there are many chemicals required in science courses, particularly those in senior high school, that must be ordered from chemical supply houses. When choosing chemicals, consider whether the benefits outweigh the risks, and if they do not, look for safer substitutes.

If an activity that is being attempted for the first time calls for chemicals not on the shelf, schools may wish to borrow rather than purchase the chemicals, particularly if it is uncertain that these chemicals will be used again in the future. If borrowing requires transport between locations, TDG regulations must be observed.

Quantity Ordered

When determining how much of a specific chemical to order, consider the following factors:

- consumption rate
- stability of the chemical (most inorganic salts and dilute acids and bases stocked in schools do not deteriorate with time)
- future use of the chemical
- available storage space
- financial resources.

As a general rule, a “less-is-better” approach to chemical purchasing lowers inherent risks. Buying only what is needed, based on the factors above, also leads to better organization and less costly waste disposal at the end of the year. For less-stable compounds, particularly those that decompose over time, keeping amounts ordered to a minimum will greatly reduce safety and storage concerns and disposal costs. A reasonable shelf life for such substances would be a maximum of three years.

Suppliers sometimes sell large quantities of chemicals at considerable savings. Bulk purchase may be an option with frequently used chemicals, particularly those that are not considered hazardous or are not regulated. However, there are several reasons why such bulk orders may not be advisable:

- adequate storage space may be limited
- curricular changes may occur or teachers may choose different experiments, eliminating the need for the chemical
- initial cost savings from bulk purchasing may be eliminated by added disposal costs if a large amount of the chemical is no longer needed requires disposal.

Receiving Chemicals

Only TDG-trained (Transportation of Dangerous Goods-trained) personnel can receive incoming chemicals. Whenever an order of chemicals arrives, these individuals may follow the steps below or similar school or district procedures.

1. Check the integrity of each chemical and chemical container.
2. Check for WHMIS labelling and presence of MSDSs.
3. Write on each container the date received and the name of the school.
4. Enter information into a chemical inventory.
5. Store chemicals (apply colour coding, if that is the school's practice) and file paperwork.

STORAGE OF CHEMICALS AND HOUSEHOLD PRODUCTS

Storage of chemicals and other products requires thoughtful planning and appropriate facilities. Chemicals purchased from supply companies demand special attention with regard to safe storage. However, in addition to these chemicals, chemical storage areas in schools often contain consumer products, perishables, ice and frozen goods required by school science programs. Vitamins, antacids, detergents, yeast, soda drinks, vegetable oils, meats, dairy products, fruits, vegetables and baking products are a few of the materials that may be found in school science areas.

Some of these products fit into a chemical storage category; others require additional storage space, often in a refrigerator or freezer. Consumer products classified as controlled products should be integrated into the storage scheme used for all other chemicals. According to *Occupational Health and Safety Regulation*, AR 62/2003, materials for activities involving eating or tasting must not be used or stored in any areas used for hazardous chemicals, and therefore will also require an additional storage space outside of the chemical preparation and science laboratory areas. A refrigerator used for storing chemicals cannot be used for refrigeration of "eating" or "tasting" products. Once edible products are stored with chemicals in a refrigerator they are considered contaminated and can no longer be consumed.

CHAPTER 8

Storage Facilities for Chemicals

The hazards associated with chemical use can be greatly reduced by storing all chemicals in suitable storage facilities. An ideal chemical storage area:

- is a separate area outside of the classroom
- can be accessed only by authorized personnel
- has locking doors with a key separate from those used to enter classrooms or preparation areas
- is adequately vented with a continuously running fan to prevent build-up of chemical fumes
- protects chemicals from direct sunlight and extreme temperatures
- has explosion-proof lights, switches and fan motor housing to prevent fires caused by electrical shorts or sparks in faulty switches
- has ground fault interrupter (GFI) circuits installed, especially near sinks
- has ceilings and walls made of gypsum boards or a similar noncombustible material
- has adequate cupboard space for each category of chemicals, as determined by the quantity on-hand and school requirements
- has sturdy, nonmetallic shelves that are securely fastened to the wall or are part of a securely fastened or supported cupboard
- has storage cupboards that are not airtight.

Flammables and concentrated acids may be stored in special cabinets purchased for these types of hazards. Such cabinets are available in metal, plastic or wood. Cabinets made of wood are suitable for bases. Since wood is not suitable for nitric acid, acids should be stored in plastic cabinets. Flammable cabinets are generally metallic but the wood ones are suitable for corrosive flammables such as organic acids; e.g., acetic, butyric, formic. Venting of these cabinets is not considered necessary but depends on air circulation or venting of the room in which they are stored.

The chemical storage area(s) in a school should be large enough to house all of the chemical stock used in the science program as well as the waste chemicals generated through use. A typical senior high school of 800 to 1000 students will require a room with approximately 100 linear metres of shelf space. A junior high school may require 50 metres of shelf space. The space requirements should reflect the science programs offered, including waste generated by these programs throughout the year. Schools offering Advanced Placement or International Baccalaureate courses will require additional space. If a school is unable to accommodate its chemical stores in a facility similar to the one described in this section, it is an indication that the school may need to reassess or reconsider the amount of material necessary to have in storage.

The chemical storage area should be equipped with appropriate safety equipment and supplies, including a first aid kit. See Chapter 3 for more information.

Chemical Storage Schemes

In the past, chemicals in schools may have been stored using a nonclassified system, with products placed on shelves in alphabetical order. Although this arrangement of chemicals appeared to be orderly, it resulted in highly reactive substances such as oxidizing agents and reducing agents being stored together, creating the risk of spontaneous reactions between incompatible chemicals. In some cases, flammable storage cabinets were used to store a variety of hazardous materials without consideration for their compatibility.

The risk of accidents can be greatly reduced by replacing this kind of nonclassified storage system with a scheme that separates incompatible groups and isolates chemicals that present special hazards. The suggested storage schemes that follow can be used as a guideline for safe storage of chemicals in schools. By separating flammable solvents from reactive chemicals, and corrosive liquids from toxicants, these schemes eliminate the risk of spontaneous fire or release of poisonous fumes. These schemes are adaptable to facilities of various designs and to various chemical inventories. Schools may or may not have all of the hazard categories, and some schools may establish other categories to meet their particular needs.

Scheme 1: Grades 1–8 (A storage scheme for limited quantities of low-hazard chemicals)

Scheme 1 provides for adequate separation of chemicals for most elementary and junior high schools up to Grade 8 where small quantities of low-hazard chemicals and dilute solutions are kept on hand. This scheme could also be adapted for Grade 9, but is not adequate for senior high schools. Scheme 2 provides a better model for senior high school use.

Oxidizing Agents	**General**	**Flammable Solids**
Acids	**Bases**	**Flammable Liquids**

Scheme 1 is based on six cupboards but may be expanded to seven or more to provide sufficient space for general storage items. The shelves in these cupboards need to be secure and strong enough to support the weight of all containers placed on them. These cupboards must not be airtight.

In addition to the cupboards shown, a fridge may also be needed to store perishables and frozen products. If the refrigerator is used for storing materials for tasting or eating, it should be placed away from the chemical storage area and not be used for storing chemical and biological specimens. Further information on safe storage of chemicals is included in the storage category notes below.

1. *Acids*

   Keep organic acids (e.g., acetic acid) and mineral acids (e.g., hydrochloric acid and sulfuric acid) on separate shelves. The acid cupboard should not contain any metal fixtures or objects.

2. *Bases*

   This cupboard would shelve household ammonia, sodium hydroxide and other hydroxides. It should not contain any metal fixtures or objects.

3. *Oxidizing agents*

   Peroxides, bleach and nitrates are examples of oxidizing agents. Most peroxides are not recommended for elementary and junior high schools, but hydrogen peroxide would be shelved here. These materials must be kept away from any flammable liquids or solids, as well as materials such as paper or cloth. Ammonium nitrate, if purchased for use in junior high schools, should be stored by itself, as it is a very strong oxidizing agent and is incompatible with most other chemicals.

4. *Flammable solids*

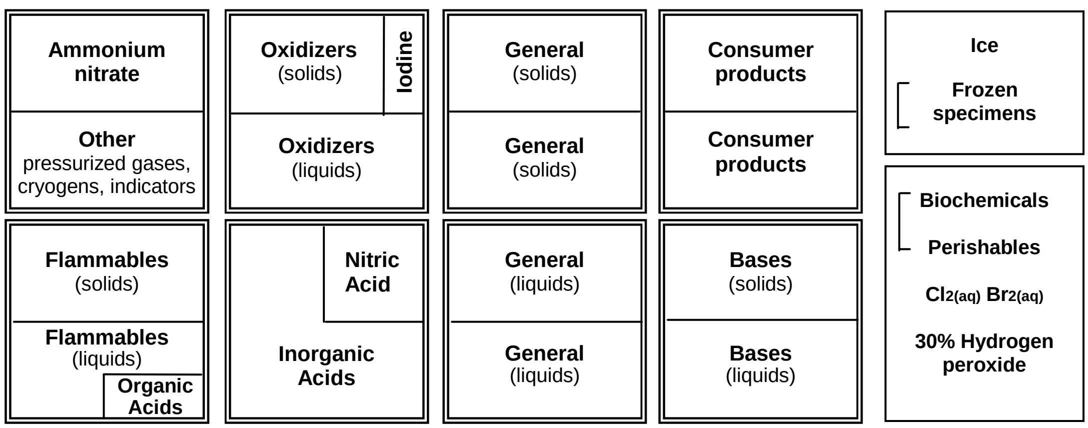
   Flammable solids include metal powders, carbon, charcoal and similar materials. These materials must be kept away from oxidizing agents.

5. *Flammable liquids*
   Flammable liquids such as methanol and ethanol should be stored in a clearly labelled, cool and well-ventilated cupboard, separated from other cupboards by at least a partition. Refer to the *Alberta Fire Code* for regulations governing type, location, labelling, allowable quantities and other requirements for these storage areas. Avoid storing flammable liquids in a fridge, where lights, switches or thermostats can serve as ignition sources.

6. *General*
   This category includes any materials not covered in the other categories, such as Epsom salts, baking soda, starch, glycerin and vitamins.

Scheme 2: Grades 9–12 (A scheme for senior high schools)

Scheme 2 provides for adequate separation of chemicals in schools that offer science programs from grades 9 to 12. The scheme is based on a greater number of chemical categories than shown in Scheme 1 and includes provision for refrigerated storage of some chemicals.



Provide space between chemicals to facilitate access. Avoid storing chemicals more than three deep. If height of the cupboards requires the use of a step ladder or stool, it should have a nonslip surface.

1. Acids

Store organic acids such as vinegar above or separated from mineral acids. Store acid anhydrides with this group. Nitric acid is a strong oxidizing agent and should be isolated as well. It will build pressure over time and should be vented periodically. Parafilm or plastic electrical tape can be placed around lids for storage, to help prevent the escape of fumes. Plastic lids will deteriorate with time and should be replaced when this occurs. This cupboard should not contain any metal fixtures or objects unless coated with special paint.

2. Bases

Store any solid sodium hydroxide above or separated from dilute solutions of sodium hydroxide and household ammonia. Some bases will react with glass containers to form a filmy precipitate, and are best stored in base-resistant plastic bottles. Those that emit fumes should be sealed with parafilm or electrical tape. This cupboard should not contain any metal fixtures or objects.

3. Oxidizing agents

Store nitrates, potassium permanganate and iodine solids above or separated from their oxidizing solutions. Lids on bottles of iodine should be sealed with parafilm or electrical tape. These materials must be kept away from any flammable liquids or solids and materials such as paper or cloth.

Ammonium nitrate is an extremely strong oxidizing agent and is incompatible with most other chemicals. It should be stored away from other materials.

4. General

Inorganic substances such as baking soda, salt and copper sulfate would be found here as well as organic compounds such as glucose, indicators and starch. This category includes any materials not in any of the other categories. Some further separation may be desirable if available storage facilities allow.

5. Flammable liquids

Rubbing alcohol, ethanol, petroleum ether, and indicators dissolved in ethanol would be in this area. These materials should be stored in a clearly-labelled, cool and well-ventilated cupboard, separated from other cupboards by at least a partition. Ideally, flammables should be in a special cabinet manufactured for this purpose.

6. Flammable solids

Flammable solids include metal powders, carbon, charcoal and similar materials. These materials must be kept away from oxidizing agents. Refer to the *Alberta Fire Code*, 1997 for regulations governing type, location, labelling, allowable quantities and other requirements.

Setting Up a Chemical Inventory

A chemical inventory serves as an effective way of tracking chemical supplies. It is also an excellent opportunity for schools to improve safety by recording and organizing information about hazardous materials in the school. Such an inventory is an important part of safety planning because it includes MSDS and TDG data, depends on standardized labelling, and encourages thoughtful ordering and disposal. A chemical inventory provides a consolidated information base for monitoring chemical usage, completing insurance claims, and coordinating waste disposal and recycling to reduce costs. It also allows for an integration of computer support systems and encourages sharing of information through computer networking. Finally, by establishing a system for monitoring chemical supplies on an ongoing basis, an inventory ensures program and support continuity when staff changes.

A computerized or electronic inventory is ideal because it is easy to update as chemicals come in or are removed from stock. The inventory can be stored centrally for easy access, with a copy supplied to the head caretaker and the individual(s) responsible for chemicals and hazardous materials in the school.

An effective chemical inventory will include the following information:

- name of chemical
- quantity of chemical
- supplier
- verification and date of MSDS
- date of purchase
- inventory review date
- hazard classification based on WHMIS requirements
- storage location
- disposal requirements.

For those choosing to track chemicals using a traditional paper-based inventory, a blank template of the sample inventory shown below is included as Appendix F of this document.

Chemical Inventory – Example
Completed by _____________ Review Date _________________

Chemical	Quantity	Supplier	MSDS Mo/Yr	Purchase Date	WHMIS Class	Storage Location	Disposal	Disposal Date (Empties)
Acetic acid (glacial)	4 L	Chem North	Nov-03	Dec-03	E,B	Acid cabinet	WF/I	Feb-04
Ethanol	2 L	Chem North	Jan-03	Jan-03	B, D1,D2	Flammables cabinet	A,WF/I	March-04

Inventory Control

Inventories should be updated annually to reflect product use and curriculum changes. The decision regarding the quantity ordered and stocked needs to take into account consumption rate, as well as the stability of the chemical. See the section Quantity Ordered on page 98 for factors that impact on chemical inventory. As chemicals are used or disposed of from the school site, they should be deleted from the inventory.

An annual check of chemicals on the shelves is a chance to:

- remove chemicals unsuited for the program(s)
- remove excess supplies, including chemicals no longer used because of program changes or activities selected
- remove contaminated, deteriorated and unidentified chemicals
- ensure a current MSDS is available for each chemical (MSDSs are updated by supply companies every three years)
- ensure a WHMIS label is on every chemical container
- confirm chemicals are in their proper location on the storage shelf
- ensure that opened containers are being used before new stock is opened
- visually inspect chemicals on the shelf to ensure they have not deteriorated or been contaminated by moisture or other substances.

Labelling

Proper labelling is one of the most important aspects of an effective and safe laboratory. Labels alert the user to the hazards of the product and provide precautions for its safe use. Therefore, they must present the required information clearly and legibly.

WHMIS Symbols and Labelling Conventions

Purchased stock chemicals kept in the storeroom, as well as materials that are generated in the laboratory, require proper labelling according to WHMIS regulations. WHMIS requires increased information on labels of potentially hazardous materials, often referred to as “controlled products” in legislation.

In terms of labelling and MSDS requirements, the WHMIS definition of controlled product does not include radioactive materials, pesticides, explosives, consumer products or materials covered under Food and Drug legislation; a sufficient amount of information is provided to workers through other means to ensure the safe use of these products. Wood and tobacco products and manufactured articles are excluded from all aspects of WHMIS. Other provincial health and safety laws and regulations cover the hazards of these materials.

WHMIS labelling uses the following symbols to indicate hazards:

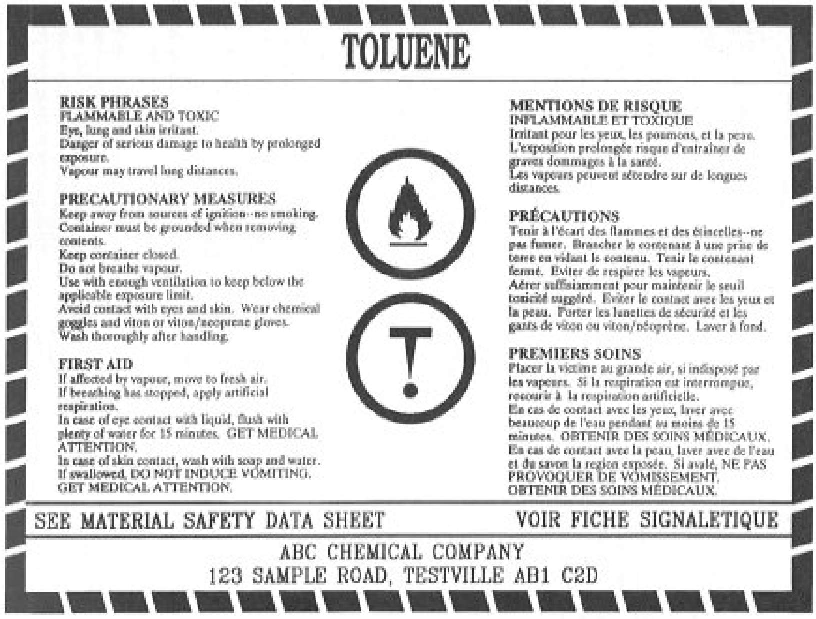
WHMIS HAZARD SYMBOLS		
A	**COMPRESSED GAS**	
B	**FLAMMABLE AND COMBUSTIBLE MATERIAL**	
C	**OXIDIZING MATERIAL**	
D	**POISONOUS AND INFECTIOUS MATERIAL**	
D1	**MATERIALS CAUSING IMMEDIATE AND SERIOUS TOXIC EFFECTS**	
D2	**MATERIALS CAUSING OTHER TOXIC EFFECTS**	
D3	**BIOHAZARDOUS INFECTIOUS MATERIAL**	
E	**CORROSIVE MATERIAL**	
F	**DANGEROUSLY REACTIVE MATERIAL**	

Supplier Labels

These labels come with the chemicals from the chemical supply company. The formal “supplier label” contains seven elements of information inside a distinctly marked border:

- product name and address of the supplier
- WHMIS hazard symbol(s)
- precautionary statements(s)
- first aid information
- reference to the MSDS.

Example of a WHMIS supplier label:



All chemical containers, including the original container, must be labelled in such a way as to clearly identify the contents. There are a few situations where the supplier label may be slightly different from the basic model. This may be the case for controlled products in volumes less than 100 mL and for compressed gas cylinders having curved labels on their necks.

Workplace Labels

These labels are applied at the work site. They are used on controlled products that are transferred from the supplier's containers to work site containers. In the laboratory, for example, transfer containers and reaction vessels containing mixtures, solutions or reaction products must have a workplace label. Workplace labels are also used to replace supplier labels that have been damaged.

This form of label has four components as shown below.

Chemical Name (IUPAC):
Chemical Name (from MSDS):
Safe Handling Information (in point form):
See *Material Safety Data Sheet* for further information.

TDG Labels
During transport, controlled goods must be labelled using the procedures outlined in the *Transportation of Dangerous Goods Act and Regulations*. Transporting vehicles are required to display diamond-shaped placards that indicate the hazard categories of materials being transported. (See Chapter 1 for further information on TDG requirements.)

Consumer Restricted Products and Other Hazardous Materials

Other legislation in Canada requires precautionary labelling on containers of hazardous materials not covered under WHMIS, such as consumer restricted products, explosives, pesticides or radioactive substances. Consumer restricted products are hazardous chemicals that are packaged for consumer use at home or for recreational purposes. Such products include bleach, hydrogen peroxide, mineral spirits, drain cleaners and turpentine. These are not regulated as closely as controlled products. Accordingly, the supplier does not need to supply an MSDS with these products, but will nevertheless provide them on request. As with other consumer products, they have to be clearly labelled and indicate any hazards inherent in the product. When used in the workplace these products are subject to WHMIS regulations, which require that:

- they are correctly labelled
- workers know how to use, store, handle and dispose of them safely.

In some jurisdictions, liability suits have identified lack of proper labelling as a contributing cause of an accident. Careful labelling practices help prevent accidents and protect the teacher and school division/district from assuming unnecessary liability.

WASTE STORAGE AND DISPOSAL

Storage of Wastes and Surplus Chemicals

Surplus chemicals and chemical wastes created in experiments present the same kinds of hazards as stock chemicals ordered from supply companies. Chemical waste from individual experiments should be collected in clearly-labelled containers. With solutions, the water can be allowed to evaporate to leave a solid waste residue. Until each surplus chemical or waste material can be safely removed, it should be carefully stored in the cupboard normally used for that WHMIS classification. Proper waste storage includes:

- attaching appropriate identification and WHMIS labels
- categorizing and arranging waste by WHMIS class
- using a separate section or sections of the storage area, designated with a label stating "For disposal. Do not use!"
- avoiding physical contact between waste groups when wastes are stored
- keeping an inventory of waste materials.

Chemical wastes should be combined for storage according to the categories used by disposal companies. Common categories are shown in the table below, but it would be prudent to consult with your school's selected waste disposal company before beginning your sorting system.

Flammable	– liquids	
	– solids	
Corrosive	– liquids	– acids
		– bases
	– solids	– acids
		– bases
Oxidizers	– liquids	
	– solids	
Substances that react with water emitting flammable gas		
Unknown chemical waste	– liquid	
	– solid	
Mercury compounds	– liquid	
Polychlorinated biphenols		
Aerosols		
Bulk paint		
Oil (waste type 201)		
Glycol (waste type 202)		

Chemical Waste Inventory

Waste disposal records are the last stage in tracking a chemical's history at the school. These records are essential because:

- they are needed to keep the chemical inventory up-to-date, and to remove unnecessary labels and MSDS in cases where the chemical is no longer stocked
- shipping documents for chemical wastes (bills of lading for recyclables and manifests for hazardous waste) must be kept on file for a minimum of two years
- hazardous waste manifests can be useful in tracking and evaluating amounts of waste produced to help determine possible methods of reducing waste/surplus chemicals in the school or school district.

Disposal of Wastes and Surplus Chemicals

Surplus chemical and wastes generated in school activities will both require disposal. Selection of the best method for disposal of each waste will require consideration of the kind of hazard each presents, the severity of the hazard, its concentration, and whether the material is in pure form or part of an inseparable mixture. It also depends on local waste disposal regulations, provincial and federal regulations, and the expertise of school staff. Provincial legislation that applies to waste disposal include the *Waste Control Regulation*, AR 192/96 of the *Environmental Protection and Enhancement Act,* R.S.A. 2000, c. E-12 and Regulation), as well as local or municipal regulations, bylaws or policies regarding sewers, landfills and the environment.

To avoid safety risks, periodically review the school's chemical inventory and remove chemicals that are not being used. Also remove any chemicals that may have been used in the past but are no longer considered appropriate for use. For example, containers of dissection preservative containing formaldehyde should be safely disposed of. The fumes from such containers can combine with those of hydrochloric acid to form bischloromethyl ether, a strong carcinogen at concentrations as low as 0.001 ppm.

Conducting a chemical inventory can help you identify and dispose of unneeded or dangerous chemicals such as the following:

- any chemicals that have deteriorated or become contaminated
- chemicals not utilized in current teaching lessons and unlikely to be used in the future
- chemicals for which MSDSs are not available
- any seldom-used chemical in excess amounts (several containers of the same chemical or unnecessarily large bulk quantities)
- unknown chemicals or chemicals without a WHMIS label
- chemicals that have exceeded their shelf life
- old solutions of formaldehyde or other dissection material preservatives.

The following materials require special disposal procedures:

- substances that are designated as hazardous (regulated) within the *Transportation of Dangerous Goods (TDG) Act*.
- all hazardous wastes, if the school produces a total of 5 kg or more of solid or 5 L or more of liquid hazardous wastes per month
- any containers of unknown substances.

Waste Broker and Waste Generator Identification Number

The three categories of materials listed above must be removed from the school by a licensed waste broker and disposed of by a licensed receiver. A *broker* is a company licensed by the province to pick up and transport controlled substances to a *receiver*, a licensed waste disposal facility. Disposal of waste from a school must be initiated through the school district office and the contract for removal will be between the district and the broker.

School districts may want to investigate a number of brokers in order to select one that best meets their particular needs. For a list of approved brokers, see Appendix G: List of Chemical Waste Brokers. Alternatively, to find a broker in their area, districts may contact the Regulatory Approvals Centre of Alberta Environment: Telephone: 780–427–6311 or Fax: 780–422–0154.

Before hazardous waste can be disposed of, school districts are required by the *Environmental Protection and Enhancement Act*, R.S.A. 2000, c. E-12 to obtain a provincial **waste generator identification number**, which must be provided to their waste broker. To obtain an identification number, districts may contact the Regulatory Assurance Division of Alberta Environment: Telephone: 780–427–5842 Fax: 780–427–1594.

Ecostations and sites designed for drop-off and disposal of household wastes are not appropriate for disposal of school chemical wastes.

Waste Management and Environmental Responsibility

Proper storage and disposal of surplus chemicals and hazardous waste is not only part of science safety, but also an environmental issue. By being environmentally conscious in the day-to-day management of school laboratories and materials, teachers and other school personnel can prevent unnecessary damage to the environment and instill responsible attitudes in students.

Chemical disposal regulations prevent indiscriminate dumping of chemical waste in the trash or down the drain where to do so would create environmental risks. Landfills, once thought of as the dumping place for all manner of materials, are now designated by classes based on their design. These class designations indicate the scope of wastes that a landfill of that design can safely accept. Municipal authorities can provide information on the class of local landfills and the types of chemicals that can be disposed of through regular trash. Similarly local sewer bylaws identify restrictions on materials that can be disposed via the drain.

The disposal column of the Chemical Hazard Information Table in Chapter 9 and the "Chemical Treatment" section in this chapter provide basic information on what chemicals can be disposed of via the drain or trash, and what treatment may be required before this can be done. For all other chemicals, it is best to strive for a "no-chemicals-down-the-drain" philosophy, whereby chemical waste is disposed of by an alternative means that avoids environmental impact. This approach to waste management may require that students and/or teachers place chemical wastes into labelled waste containers on completion of their use. Teacher caution in categorizing waste is needed to avoid placement of incompatible waste together. The waste is then managed in accordance with accepted best practices. In larger schools, the pooling of wastes for disposal through a waste broker may be the best strategy for ensuring safe disposal of many hazardous materials.

CHAPTER 8

STRATEGIES FOR MINIMIZING HAZARDOUS WASTE PRODUCTION

There are several straightforward and practical ways to reduce the volume of chemical waste generated by science classes. Most of the strategies discussed here involve students using less chemicals, which results in less waste generated, less environmental impact and lower waste disposal costs. Other strategies suggest ways to recover chemicals for reuse or to make multiple uses of the chemical.

Microscale Experiments

Traditional practice in school laboratories is for students to perform experiments using gram quantities of chemicals. An alternate approach is to have students carry out microscale experiments in which chemical quantities are reduced to no more than 100 mg (0.1 g). Chemical experiments can be carried out successfully using these small quantities of materials, and many students enjoy the challenge of performing experiments on a miniature scale. When students are planning an experiment to investigate a particular question, they can be encouraged to think about using smaller volumes.

Microscale experiments may require the use of different glassware and equipment, or the use of existing equipment in new ways. Instead of beakers and Erlenmeyer flasks, teachers may use small test tubes or drop plates. Disposable pipettes calibrated to allow delivery of 0.5 mL or 1 mL can be used to deliver chemical solutions. Reaction plates with a series of wells can be used in performing qualitative analysis of inorganic ions. Disposable pipettes in which the stem has been cut short and a small wad of glass wool inserted can be substituted for filter funnels to collect a few crystals by filtration.

Dispensing Chemicals

Teachers will sometimes find it necessary to weigh the relative merits of dispensing premeasured quantities of chemicals to students versus teaching students to measure quantities for themselves. The decision on which approach is best will usually hinge on an assessment of the hazards associated with the chemical. If it is a chemical that is nontoxic and nonhazardous, such as sodium carbonate, then waste generated by students during measurement is not a major concern. If, on the other hand, the substance is magnesium ribbon, it may be more prudent to pre-cut the appropriate length of ribbon for each student to avoid pieces longer than necessary. Advance measurement by the teacher may also help to minimize waste and limit the possibility of spillage when more hazardous solutions are used.

Use of Lab Stations

Setting up activities at specific sites or stations, equipped with appropriate chemicals and supplies, makes it easier to control and manage chemical use by students. This approach helps avoid students having to carry chemicals from one place to another and reduces the chance of spills or other accidents. This approach is particularly beneficial in activities where the chemicals can be reused, as it eliminates the need for providing a separate set of chemicals for each group of students. In activities where probes are used for specific measurements or readings, solutions provided at a station could be used repeatedly as each group progresses through the station. Since students also leave everything behind once they are done at each station, there is less likelihood of chemicals being intentionally mixed by students out of curiosity. This reduces the generation of unknown and unnecessary wastes that are costly to identify and dispose of via chemical treatment plants.

Use of Demonstrations

Although there is educational value in having students perform experiments on their own, demonstrating a chemical reaction to an entire class can be an effective means of achieving an instructional goal and reducing resulting wastes, particularly in cases where the chemicals involved are more hazardous.

Use of Videos and Computer Simulations

These resources can be used to demonstrate reactions or experiments that otherwise would not be possible due to equipment limitations or because they are too dangerous to perform in class. Such visual presentations or simulations of more dangerous reactions avoids associated risks and provides a near first-hand experience for students. These resources can be used either as part of a class presentation or individually, at stations, by students.

Recovery and Recycling

One aspect of good chemical management is to recycle materials whenever possible. Before discarding uncontaminated chemicals or their solutions, consider other activities where these substances might be used. For example, copper sulfate solution produced when teaching students how to make solutions can be used for growing crystals, copper plating or in replacement reactions in the same or other courses. Similarly, crystals grown in one class may be redissolved for use in another because these solutions do not require great purity.

Chemical recovery requires some upfront planning and a space in the lab or chemical storage room where reconstitution can be done. Since most substances used are in solution form, reclaiming the material simply requires evaporating the water. If a recovered substance is stored in a container other than the original, then proper WHMIS labelling is required on the new container.

Distillation of Used Solvents

Recycling solvents requires the knowledge and experience of an expert chemist, as well as the appropriate equipment. Organic solvents such as methanol, ethanol and petroleum ether used in a reaction or as a solvent in chromatography can often be recovered for reuse by distillation. If possible, the distillation apparatus should be set up under a fume hood. The flask should be heated using a water bath (for low boiling solvents such as methanol and petroleum ether), oil bath or heating mantle. The contents of the distilling flask should never be allowed to evaporate to dryness.

Hazardous Waste Treatment

There are several methods of processing hazardous waste to reduce volume and/or toxicity in preparation for disposal. These processes can reduce disposal costs and environmental impact, especially for larger quantities. Since schools may still have chemicals on site that are no longer used or are not recommended for use in schools—for example, heavy metals such as lead—treatment processes for these substances have been included. Their inclusion, however, does not imply appropriateness for school use. Hazardous waste treatment includes evaporation of aqueous solutions and various chemical treatments.

Evaporation of Aqueous Solutions

When solutions contain chemicals not suitable for recovery, the volume of hazardous materials can be greatly reduced by allowing the solution to evaporate under a fume hood or in another well-ventilated area. Transfer the solution to a wide-mouthed container such as an evaporating basin or large beaker for maximum evaporation surface and allow to stand until a sludge remains. This sludge can be transferred to an appropriate labelled container for off-site disposal.

There may be cases where regulations restrict disposal down the drain but allow disposal via local landfill. In such cases, evaporate to dryness and dispose in solid trash.

Chemical Treatment

A number of substances can be chemically converted into an insoluble or less toxic form that may, in many cases, be disposed of by means other than a chemical waste facility. Appropriate personal protective equipment, including eye protection, gloves and laboratory coat, should be worn when performing the reactions. As far as possible, and in all cases where noted, the manipulations should be performed under a fume hood.

These chemical treatments should only be carried out by staff that have knowledge of the chemistry involved, and are experienced in working with chemicals. In all other cases the chemicals—in their original form—should be disposed of through a qualified waste broker.

Neutralization of Acids and Bases
Waste quantities of acids such as hydrochloric acid, sulfuric acid, nitric acid and acetic acid, and bases such as sodium and potassium hydroxides can be neutralized and washed into the drain. First, add the concentrated acids or bases to 20 times their volume of water so that their concentration is reduced below 5%. This should be done in an ice bath under a fume hood using an adequately sized container; e.g., 100mL of concentrated waste will require 2 L of water. Caution: never add water to concentrated acid. Add 5% sodium hydroxide solution or solid sodium carbonate (soda ash) to the dilute solutions of waste acid until the pH is between 6 and 8. Waste dilute solutions of base can be treated with waste dilute solutions of acid or with 5% hydrochloric acid solutions. The neutralized solutions can be washed down the drain.

Precipitation of Heavy Metal Salts
Although heavy metals are not recommended for school use, the process described here is for the benefit of schools that may still have these compounds on their shelves and are looking at discarding them.

An alternative to the evaporation of dilute aqueous solutions of heavy metal salts is to precipitate the metals as an insoluble salt that can be removed by filtration or by allowing the solid to settle and decanting the liquid. The residue can then be disposed of according to relevant guidelines. Specific directions for precipitating lead ions from solution as their silicate is described as well as the modifications needed to use this method for other heavy metal ions. The formation of the silicate can be summarized by the following generalized equation.

Pb^{2+} ( ) (aq) + Na_2SiO_3(aq) → $PbSiO_3$(s)+ 2Na( )(aq)

Add a 0.01 molar solution of a soluble lead salt (e.g., 0.166 g of lead II nitrate in 50 mL of water) to a 0.03 molar solution of sodium metasilicate (0.392g Na_2SiO_3 $9H_2O$ in 50mL of water). Stir well. Adjust the pH to about 7 by the addition of about 15 mL of 2 M aqueous sulfuric acid. Collect the precipitate by filtration or allow the mixture to stand until the solid has settled to the bottom of the container and the liquid can be poured off. Allow the solid to dry, then package and label for disposal.

For dilute solutions of lead salts of unknown concentration, the sodium metasilicate solution should be added until there is no further precipitation. Adjust the pH to a level between 7 and 8 with the addition of 2M sulfuric acid, and allow the solution to stand overnight before collecting the solid by filtration or allowing it to settle and pouring off the liquid. Solutions of cadmium and antimony salts can be treated similarly.

Several other heavy metal salts can also be precipitated in the same way as silicates. The quantities given for lead are also appropriate for 0.01 moles of these metals. The only modification necessary is a change in the pH at which the silicate is precipitated. This includes the Fe (II) & (III) ions, Zn(II) , Al(III), Cu (II), Ni (II), Mn (II) and Co (II) ions, all of which can be precipitated without adjustment of the pH that results from the addition of the solutions of sodium metasilicate.

pH of Precipitation of Metal Ions Using Sodium Silicate

Metal Ion	pH for Maximum Precipitation	Concentration of Metal Ion Remaining in Solution
Iron II	9.5 – 10.0	5 pmm
Iron III	10.0 – 10.5	2 ppm
Zinc II	8.5	< 0.5 ppm
Aluminium III	8.5	< 2 pmm
Copper II	10.5 – 11.0	0.03 ppm
Cobalt II	9.5 – 10.0	0.08 ppm
Manganese II	9.5 – 10.0	0.2 pmm
Nickel II	9.5 – 10.0	0.3 pmm

Similarly, solutions of unknown concentration can be treated with sodium metasilicate solution until there is no further precipitation. Adjust the pH to the required value by the addition of 2 M sulfuric acid or 5% sodium hydroxide solution, and allow the mixture to stand overnight before collecting the solid by filtration or allowing it to settle and pouring off the liquid. After standing in the air to dry, the metal silicates should be placed in a labelled container for disposal. The liquids can be washed into the drain.

Reduction of Oxidizing Agents

Inclusion of this reduction process does not imply appropriateness for school use of some of the compounds identified here. The process is described, however, for the benefit of schools that may have these compounds on their shelves and are looking at discarding them.

Solutions of compounds such as potassium permanganate, sodium chlorate, sodium periodate and sodium persulfate should be reduced before being discarded into the drain to avoid uncontrolled reactions in the sewer system. The reduction can be accomplished by treatment with a freshly prepared 10% aqueous solution of sodium bisulfite or metabisulfite. Specific quantities and conditions for these reactions are detailed in the table below.

Oxidizing Agent Present in Waste Stream	Quantity and Concentration of Oxidizing Agent in Aqueous Solution	Quantity of 10% Aqueous Sodium Metabisulfite	Comments
Potassium Permanganate	2 L of 6%	1.3 L	Solution becomes colourless
Sodium Chlorate	1 L of 10%	1.8 L	50% excess reducing agent added
Sodium Periodate	1 L of 9.5%	1.7 L	Solution becomes pale yellow
Sodium Persulfate	1 L of 10%	0.5 L	10% excess reducing agent added

Treatment of Iodine and Iodine Solutions
Under the fume hood, cautiously add 1 gram of solid iodine to a solution of sodium thiosulfate (2.5 g sodium thiosulfate in 60 mL of water) also containing 0.1g of sodium carbonate. Stir the mixture until the iodine has all dissolved and the solution is colourless. Check the pH and if needed add solid sodium carbonate to bring the pH of the solution to a level between 6 and 8. The solution can then be washed into the drain. A summary of the reaction is:
$I_2(s) + Na_2S_2O_3(aq) + Na_2CO_3(aq) \rightarrow 2NaI(aq) + Na_2SO_4(aq) + S(s) + CO_2(g)$

Solutions of iodine can be dealt with as follows: Stir a sodium thiosulfate solution (4 g in 100 mL of water) containing sodium carbonate (0.1 g) into the iodine solution. Continue stirring until the solution becomes colourless. If necessary, add sodium carbonate to bring the pH to a level between 6 and 8. Treat the liquid for sulfides.

Bromine
Bromine is very toxic by inhalation and causes severe burns if spilled on the skin. It can be reduced to sodium bromide, a much more innocuous substance, by reaction with sodium bisulfite solution.

Under the fume hood, add bromine (5mL) to a large excess of water (1L). Slowly add a freshly prepared 10% solution of sodium bisulfite to the bromine water until all colour disappears. Neutralize the solution with sodium carbonate and wash into the drain.

$Br_2(l) + 2\ NaHSO_3(aq) \rightarrow 2NaBr(aq) + H_2SO_4(aq) + SO_2(g)$

Treatment of Sulfides
Under a fume hood, place 1 mol/L $FeCl_3$ solution (3 times the excess of solution to be disposed of) in a beaker, then add disposal solution with continuous stirring. A precipitate will form. Neutralize with sodium carbonate, a reaction that will release CO_2 gas.

A summary of the reaction can be given as follows:
$2\ Fe^{+++} + 3\ S^{2-} \rightarrow Fe_2S_3(s)$

Allow precipitate to settle and either decant solution or filter. Flush neutral solution down the drain and dispose of the precipitate to an appropriate landfill. If flushing of iron is a sewer concern, then all the material may be evaporated to dryness and disposed of via solid waste disposal.