CHAPTER 9: CHEMICAL MANAGEMENT

Overview

Management of controlled, regulated, or hazardous 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. Ensuring 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 the following 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, non-regulated chemicals that can be bought at the local store can be used as substitutes for more hazardous chemicals (e.g., hydrogen peroxide). Choosing these less hazardous chemicals often reduces the costs of purchase and disposal, as well as the hazards associated with use. MSDSs must be located and added to the MSDS binders. Also, a WHMIS label must be applied on the container.

There are many chemicals required in science courses, particularly in Senior Years, that must be ordered from chemical supply houses. When choosing chemicals, consider whether the benefits outweigh the risks. 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.

There are several reasons why 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 no longer needed requires disposal.

Receiving Chemicals

Once the order has been placed with the supplier, individual school orders are usually delivered directly to each school. Once in the school, the receiving office personnel should immediately contact the science team representative to have the controlled products appropriately and safely transported to the controlled product storage room and entered in the school inventory with all the necessary information from the MSDS.

Whenever an order of chemicals arrives, the science team representative should 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 MSDS.
3. Write on each container the date received, the name of the school, and the initials of the receiving teacher or staff member.
4. Enter the appropriate information into the school chemical inventory.
5. Store chemicals in the proper location.

Removal of Controlled Products

All controlled products that pre-exist WHMIS regulations and signage should be removed from schools. All containers are now made of a polycarbonate composite to reduce the chance of breakage, and are labelled with the appropriate signage.

School inventories must be periodically checked to ensure that the integrity of every container has been maintained. If any containers are damaged or unidentifiable, they should be removed from the inventory and placed on the list for environmental pick-up by a commercial waste broker. Once the product has been identified for removal, the inventory must be changed to reflect the removal. Links to approved waste removal and recycling companies can be found at <www.gov.mb.ca/trade/globaltrade/environ/waste.html>.

Notes

MSDSs for controlled products must be stored for at least 30 years from the moment the MSDS was received. (*Workplace Safety and Health Act* (C.C.S.M. c. 210) Workplace Safety and Health Regulation – Regulation 217/2006)

Storage Facilities for Chemicals

Please refer to Chapter 4 for more information about science facilities.

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

A recommended chemical storage area

- is a separate area outside of the classroom
- can be accessed only by authorized personnel
- has locking doors with a key that is different 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 drywall or a similar non-combustible material
- has adequate cupboard space with doors for each category of chemicals, as determined by the quantity on hand and school requirements
- has sturdy, non-metallic 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

Figure 19 ***Storage Cupboards***

Acids, Bases, and Flammable Products

Flammables and concentrated acids should be stored in special cabinets purchased for these types of hazards. Such cabinets are available in metal, plastic, or wood.

- Wood cabinets: suitable for bases; not suitable for nitric acid.
- Plastic cabinets: suitable for acids.
- Metallic cabinets: suitable for flammables. Venting of these cabinets is not considered necessary but depends on air circulation or venting of the room in which they are stored.

Planning Shelf Space

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

The chemical storage area should be equipped with appropriate safety equipment and supplies, including a first aid kit. See Chapter 4 for more information.

Chemical Storage Schemes

In the past, chemicals in schools may have been stored using a non-classified system, with products placed on shelves in alphabetical order. Although this arrangement of chemicals appeared to be orderly, it may result in highly reactive substances such as oxidizing agents and reducing agents being stored together, creating the risk of spontaneous reactions between incompatible chemicals.

The risk of accidents can be greatly reduced by replacing this kind of non-classified 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 mitigate 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 Early and Middle Years 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 Years schools. Scheme 2 provides a better model for Senior Years school use.

Oxidizing Agents	General	Flammable Solids
Acids	Bases	Flammable Liquids

Scheme 1 is based on six cupboards, but it 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 be clearly labelled and must not be airtight.

In addition to the cupboards shown, a refrigerator may also be needed to store biological supplies. 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 Early and Middle Years 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.
4. *Flammable solids (should not be used in Middle Years schools):* 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.
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: Senior Years Schools (9-12)

Scheme 2 provides for adequate separation of chemicals in schools that offer Grades 9 to 12 Science. 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.

These shelves and cupboards should be clearly labelled.

Suggested Chemical Shelf Storage Plan

Section 1

Halides, Sulphates, Sulphites, Thiosulphates, Phosphates, Acetates, Sulphur

Section 2

Sulphides, Selenides, Phosphides, Nitrides

Section 3

Amides,
Nitrates,
Nitrites

NOT Ammonium Nitrate – ISOLATE IT!

Section 4

Borates,
Chromates,
Manganates,
Permanganates

Section 5

Metals and Hydrides

Store away from any water source.

Store flammables in the flammables cabinet.

Section 6

Chromates,
Bromates,
Iodates,
Chlorites,
Hypochlorites,
Perchlorates,
Hydrogen Peroxide (3%)

Section 7

Hydroxides,
Oxides,
Silicates,
Carbonates,
Carbon

Section 8

- Miscellaneous
- Indicators
  Organics: Oils, Sugars, Starches

Refrigerator Storage

Freezer

- Ice
- Frozen Specimens

Refrigerator

- Biochemicals
- Perishables
- Cl_2, Br_2
- 30% Hydrogen Peroxide

NO FOOD FOR HUMAN CONSUMPTION

Provide space between chemicals to facilitate access. Avoid storing chemicals more than three deep. Controlled products must not be stored above eye height.

Ammonium nitrate is a highly reactive oxidizing agent and must be stored away from other controlled products.

For any product purchased and stored, remember that smaller quantities are safer.

Setting Up a Chemical Inventory

A chemical inventory serves as an opportunity for schools to improve safety by recording and organizing information about hazardous materials in the school. Such an inventory is a necessary part of safety planning because it includes MSDS data, depends on standardized labelling, and encourages thoughtful ordering and disposal. A chemical inventory provides a consolidated information base for monitoring chemical usage and coordinating waste disposal and recycling to reduce costs. It also allows for an integration of computer support systems and encourages the 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 there are 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 electronic chemical inventory system can be purchased from most science supply companies.

A chemical inventory could include the following information:

- Chemical name
- Storage location
- Storage category
- CAS Registry number
- Quantity
- Supplier
- Details related to form and concentration
- Recommended disposal methods
- Hazards
- Inventory control
  - Date added to inventory
  - Amount at beginning of school year
  - Amount remaining
  - Disposal date
- Notes

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

Chemical Inventory – Example

Completed by ____________ Review Date ____________

Chemical	Quantity	Storage category and location	Clarifying details	Supplier	CAS number	Disposal	Hazards	WHMIS classification	Date added	Amount remaining	Disposal date (empties)
Acetic acid	1 L	Acids cabinet	Concentration: 6 moles/L	Chem North	64-19-7	Neutralize	Corrosive, slightly toxic by skin or ingestion; chronic exposure can cause erosion of teeth	E, B	March -13	600 mL	

Inventory Control

Inventories should be updated at least once a year 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" previously in this chapter for factors that affect chemical inventory. As chemicals are used or disposed of from the school site, they should be deleted from the inventory (while remembering to store the MSDS).

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

- remove chemicals unsuited for the planned lessons
- remove excess supplies, including chemicals no longer used because of lesson 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 usually every three years)
- ensure a WHMIS label is on every controlled product 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. Please be sure to include a WHMIS label and supplier label with all products. Refer to Chapter 5 for more information on WHMIS.

Consumer Products and Other Hazardous Materials

Consumer products must be clearly labelled and indicate any inherent hazards in the product. When used in the workplace, these products become subject to WHMIS regulations, which require that

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

Examples of such products include bleach, hydrogen peroxide, mineral spirits, drain cleaners, and turpentine.

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. Proper waste storage includes

- attaching appropriate identification and WHMIS labels
- 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
- storing waste chemicals in separate, appropriate-sized containers for each experiment

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 MSDSs and store them elsewhere 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 chemicals and wastes generated from 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. Depending on municipal bylaws, some chemicals may be safely poured down the sink or thrown in the regular trash. See Chapter 1 for links to some municipal bylaws.

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. **The fumes from such containers can combine with those of hydrochloric acid to form bis(chloromethyl) ether, a strong carcinogen at concentrations as low as 0.001 ppm (1 ppb).**

Conducting a chemical inventory review 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

Waste Brokers

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 board office and the contract for removal will be between the school division and the broker.

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, when doing so would create an environmental risk. 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.

For most 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 requires that students and/or teachers place chemical wastes into labelled waste containers on completion of their use. Caution in categorizing waste is needed to avoid placement of incompatible waste together. The waste is then managed in accordance with accepted best practices.

Strategies for Minimizing Hazardous Waste Production

Most of the strategies discussed here involve students using fewer 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

The 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).

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.

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 non-toxic and non-hazardous, 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 distributing pieces that are longer than necessary.

Use of Lab Stations

Setting up activities at specific well labelled sites or stations, equipped with appropriate chemicals and supplies, makes it easier to control and manage chemical use by students. This approach helps prevent students from having to carry chemicals from one place to another, thereby reducing 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.

Use of Demonstrations

Although there is a strong 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 help to avoid associated risks and provide 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. There are many Internet sites that visually illustrate a demonstration in chemistry or general science that the classroom teacher may feel is beyond his or her level of expertise or the school budget.

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, which is 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 re-dissolved 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. This should not be attempted in schools.

Waste Treatment

There are several methods of processing hazardous waste to reduce volume and/or toxicity in preparation for disposal, including chemical treatments, neutralization of acids and bases, evaporation of aqueous solutions, precipitation of heavy metal salts, reduction of oxidizing agents, etc. See Appendix I for more information. **These treatments should only be carried out by staff who 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.**