

LESS IS BETTER

**LABORATORY
CHEMICAL MANAGEMENT
FOR WASTE REDUCTION**

Second Edition

Prepared by the Task Force on Laboratory Waste Management

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Photos courtesy of Suitland High School, Forestville, MD, (pages 15,17) and National Microscale Chemistry Center of Merrimack College, North Andover, MA, (page 20).

INTRODUCTION

Across government, industry, and academe, this is the decade of source reduction, waste minimization, and pollution prevention. Whatever the terminology, much attention is being paid to the need to reduce waste. Environmental awareness, regulatory requirements, and a desire to maintain good standing in their communities have contributed to increased efforts by laboratories to reduce their generation of chemical wastes. As explained in this booklet, these efforts are suitably rooted in the philosophy that "Less is Better."

A chemical that has no further use is regulated as a waste. The regulation of a waste as "hazardous" is based on a determination by a legislative body or a regulatory agency that the waste material will pose an unacceptable risk to human health and/or the environment if improperly managed or disposed. Federal and state regulations specify that some waste chemicals are "hazardous" by including them on a list, while other wastes are regulated based on exhibiting one or more of certain hazardous characteristics—leachate toxicity, reactivity, ignitability, corrosivity—as determined by specified tests and definitions.

Even though a particular waste is not regulated as hazardous, because of safety considerations it still may be prudent to manage it as if it were one. Due to the variety of the wastes generated in laboratories, prudent management of these chemicals demands considerable expertise and attention. Further, waste that is hazardous must be carefully collected, separated, packaged, labeled, recorded, and disposed of in strict accordance with prescribed federal and state laws and regulations.

This second edition of *Less is Better* explains how you can put a laboratory waste management strategy to use and the benefits of such a program. This material should prove helpful to the broad range of people who deal with laboratory chemicals: bench chemists, business officers, chemical technicians, health and safety personnel, laboratory managers, professors and science teachers, purchasing agents, research directors, stockroom operators, and others. Minimization techniques can be applied to all types of waste streams. However, efforts to reduce laboratory waste are especially important when dealing with hazardous waste streams in order to reduce risks and disposal costs.



The “Economy Size” Myth

Common sense dictates that purchasing decisions for a laboratory should be based on the lowest per unit cost. However, the lowest unit costs typically are available only on larger stock bottles. The end costs of a large volume purchase—including storage, labor, and disposal—make it clear this is not the least expensive option. Further, the purchase of larger quantities poses more risks to personnel and increases potential liability.

Consider the additional disposal costs of purchasing a large container of a chemical. When a large container is purchased, often a small quantity is used and the excess is kept in stock for potential future use. Many researchers begin new procedures and each new phase of an experiment with fresh material dispensed from unopened containers. As a result, partially-filled containers accumulate in laboratories and store-rooms. Traditionally, these surplus chemicals have been removed from a laboratory at the conclusion of a project, when a scientist retires, when someone new takes over a lab, or when a lab is being refurbished.

These partially used containers then are disposed of as wastes. Many of these chemicals will have reached their expiration dates or have labels that are no longer legible. In a laboratory where such surpluses have not been minimized through careful purchase and inventory controls, unused chemicals can constitute as much as 40% of the hazardous waste generated. Many lab cleanouts result in a waste stream composed of an even higher percentage of discarded unused chemicals.

Costs incurred as a result of these excess quantities include analysis, storage, packaging and disposal. The cost of having even a small amount of an unknown chemical analyzed prior to disposal can exceed \$1000—many times the initial purchase price. Disposal costs easily can surpass the purchase price, especially for wastes that are difficult to dispose of, such as those containing toxic metals or dioxin.

To avoid costly surpluses, purchase chemicals in small containers, getting only what you will use in the immediate future. When chemicals are acquired in small packages, less material circulates throughout the organization and smaller amounts require disposal. Thus, purchasing small packages is critical to waste minimization.

As an example, if 300 mL of material are dispensed from a 500 mL container, often the remaining 200 mL are discarded. When 300 mL are taken from a 1000 mL container, the 700 mL balance often remains on a laboratory shelf for many years, never is used in another laboratory procedure, and ultimately is disposed of as a waste. This practice results in higher costs for the materials actually used and additional costs for disposal of the unused portions.

Consider phenol in an example of purchasing a large "economy size" package rather than in a smaller size container more consistent with the immediate need. Assume that the same quantity of phenol will be used in either case and that any remaining chemical will be disposed of as a waste.

Liquid phenol is available in 500 mL bottles at a cost of approximately \$25.00 per bottle and in 2500 mL bottles at a cost of \$65.00 (in 1993 dollars). If 1000 mL are used, the respective cost of phenol used from these size bottles is \$50 (\$0.05/mL) and \$65 (\$0.07/mL). These calcu-

Purchasing-Disposal Economics <i>(in 1993 dollars)</i>		
	Size of package	
	500mL	2500mL
Purchase Price	\$25.00	\$65.00
Unit Purchase Price/mL	\$.05	\$.03
WHEN 1000 mL ARE USED		
Unit Purchase Price/mL	\$.05	\$.07
Estimated Package Disposal Cost	0.00	\$33.65
Total Cost (purchase & disposal)	\$50.00	\$98.65
Unit Total Cost/mL	\$.05	\$.10
WHEN 1300 mL ARE USED		
Unit Purchase Price/mL	\$.05	\$.05
Estimated Package Disposal Cost	\$ 6.73	\$33.65
Total Cost (purchase & disposal)	\$81.73	\$98.65
Unit Total Cost/mL	\$.06	\$.08

lations demonstrate that large container purchases are only economical if most of the chemical is used. In this example, considering only purchase costs, 1 300 mL from the larger bottle must be used before the unit cost of phenol is reduced to the unit cost of purchasing the smaller bottles.

Now consider the disposal costs of the excess material from either of the containers. Waste reagent phenol is classified by the U.S. Environmental Protection Agency (EPA) as a toxic waste. It is corrosive and ignitable or combustible. If ingested, it is a severe health hazard. If absorbed through the skin, phenol can be lethal. If it contaminates drinking water, chlorination in a water treatment plant will convert it to bad-tasting chlorophenols. Because of these characteristics, waste phenol requires costly disposal.

Prior to treatment and disposal of small containers of laboratory waste chemicals by an off-site facility, the spent materials are placed inside a larger plastic or fiber drum called a "lab pack." The drum must meet U.S. Department of Transportation specifications for the transportation of hazardous wastes. Regulations require that inert packing material surround each inside package in order to separate and maintain the integrity of the small bottles and cans containing the wastes and to absorb any liquid released from the inside containers. As a result, the standard 55 gallon lab pack can hold a maximum of some fifteen gallons of material. Since the entire chemical container is packaged in the drum, the greater space required by larger bottles means higher disposal costs.

Federal law requires that lab packs either be incinerated or processed at a facility with a permit authorizing it to treat the materials. Incineration offers more assurance than landfilling that the wastes will not contaminate soil and water, but it significantly increases lab pack disposal costs. Disposal and related costs for incineration of a 30 gallon fiber lab pack holding 8 gallons of chemical wastes might cost \$40.00/gallon today—twice the 1984 cost. The cost (in 1993 dollars) of an average filled 55 gallon lab pack (including its preparation, packaging, labeling, transport, and disposal) is about \$350.00 (\$23.33 per gallon of contained waste based on a 15 gallon maximum capacity).

Regulatory limits on how long a generator may accumulate a waste further increase costs, especially for laboratories because of the small quantities and large variety of chemical waste they often generate. When time limits are reached, drums that are only partially full must nonetheless be sent off-site, and at full-drum prices. Additionally, some waste haulers will have a minimum pickup charge equal to a four-drum price.

A properly prepared lab pack will accommodate about fifty-two 500 mL bottles. At a total cost of some \$350 for the lab pack, 500 mL bottles cost around \$6.71 each, no matter how much waste they contain. A 2500 mL bottle is worth approximately \$33.65 in lab pack space.

Assume that 1000 mL of phenol is used in an experiment. Two 500 mL will be empty and, if properly rinsed, will be clean, and safely can be disposed in the normal trash. The unit total cost of phenol used from these bottles will only be the purchase price of \$0.05/mL. The 1000 mL of phenol used comes from a 2500 mL bottle costing \$65 and the disposal of the partially empty bottle will cost around another \$33.65. The total purchase-disposal cost for the 1000 mL of phenol from the 2500 mL bottle is \$98.65, making a unit total cost of almost \$0.10/mL.

Even if the break-even purchase volume of 1300 mL is taken into account, the larger costs for disposal of the 2500 mL bottle with some remaining phenol makes the total cost greater than using 1300 mL from three 500 mL bottles. When using the smaller size containers, two empty bottles will be cleaned and only the one, still partially-filled 500 mL bottle, will be disposed of. In this last comparison, unit total costs (purchase plus disposal costs) per mL used is about \$0.06 for the smaller bottles and still about \$0.08/mL for the larger container.

These illustrations demonstrate how the favorable per mL purchase price of the larger package can be quickly offset by the disposal costs for that package and its residues. They also exemplify the significant and sometimes unrecognized disposal costs associated with generating hazardous wastes.

Certain chemical wastes, such as peroxides, reactive metals, and explosives require special disposal at a significantly higher cost; packaging, transportation, and disposal cost for these materials may exceed \$40.00/lb. The high costs of disposal of such chemicals makes the purchase of smaller quantities even more desirable.

The illustrations reveal that the lower total cost (purchase, storage, use, and disposal) of purchasing smaller packages of laboratory chemicals makes good economic sense. Some laboratories use a rule of thumb of purchasing the desired amount of a chemical in at least two half-amount containers.

Other Reasons to Make Smaller Purchases

Extended storage of unused chemicals increases the risk of accidents. Small quantity purchases result in fewer unused chemicals being stored and reduce the potential for employee and student exposure to

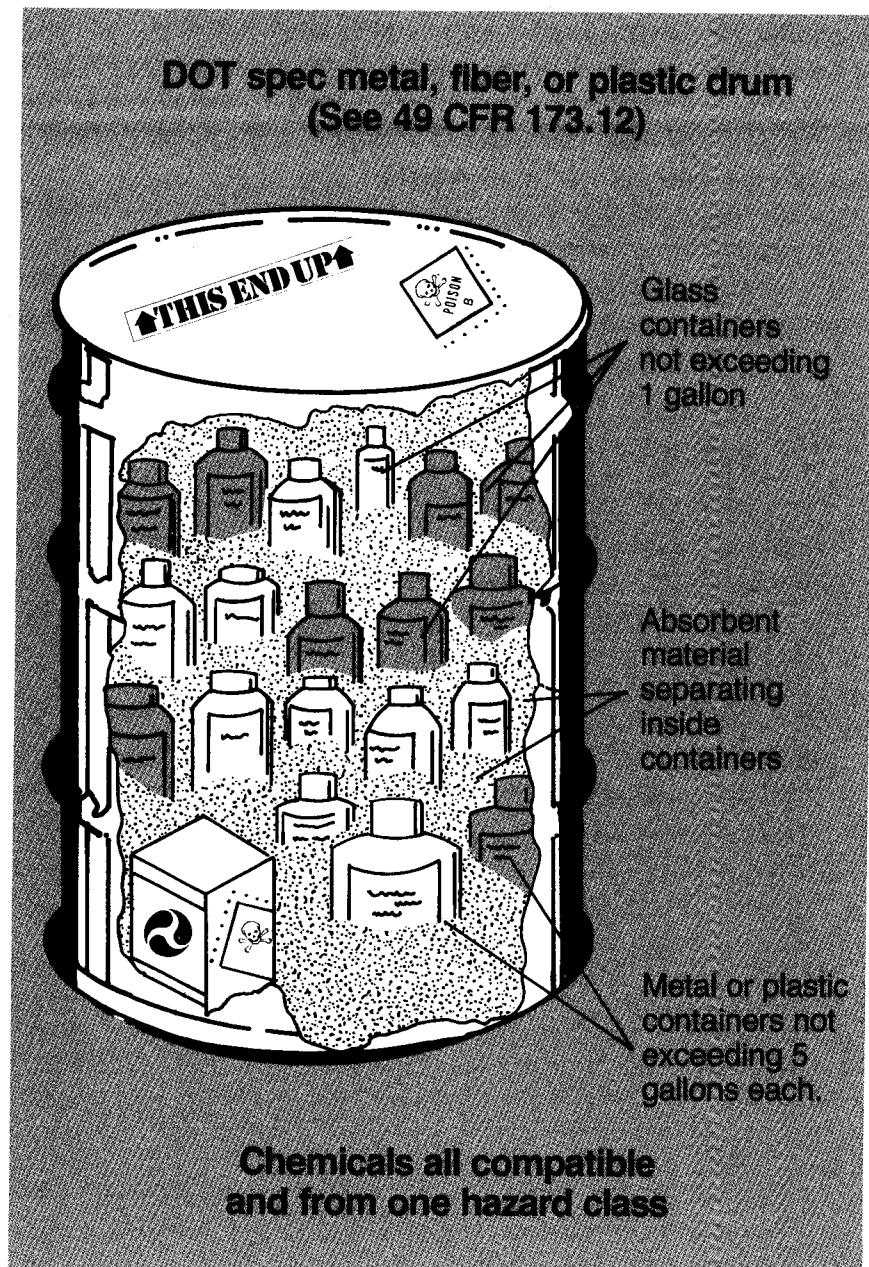


Diagram of Lab Pack

The lab pack is an officially recognized packaging unit by the U.S. DOT. It is the most appropriate way to ship waste laboratory chemicals, as it allows different materials from the same hazard class to be packaged together. The treatment or disposal method to be used will determine the type of outer package and packing materials.

hazardous substances. Small bottles tend to break less often than larger ones. If they do break, there is less spillage, making cleanup safer, easier, and less expensive. Accidents also increase negative publicity and legal liability. Decreased risks of accidents may be reason enough to justify purchases of smaller containers.

Finally, larger containers are less likely to be emptied before their shelf life expires and may require more storage space.

In summary, the purchase of several small containers rather than one large container is generally the least expensive, safest, and most practical way to acquire laboratory chemicals.

**There are many reasons for concluding
that *less is better*:**

- Material taken from a larger "economy size" container can be twice as costly as that drawn from smaller packages.
- Disposal costs per package frequently are at least 25% less with smaller units than larger containers.
- Packages are emptied faster—there is less chance for decomposition of reactive compounds when small containers are used.
- The risk of accident and exposure to the hazardous material is reduced when handling a smaller container.
- Storage and use of large quantities results in higher costs such as additional stockroom planning and design to prevent and control fires and increase ventilation.
- The large "economy size" often requires other equipment—such as smaller transfer containers, as well as funnels, pumps, and labels. Additional labor to subdivide the larger quantities into smaller containers, and extra personal protective equipment also may be needed.

The Tracking of Chemicals

While it is important to purchase chemicals in small packages, comprehensive waste minimization also requires a thorough chemical management system. An optimal system makes efficient use of a purchasing strategy while minimizing interference with teaching and research functions. The system can include information about the kinds, quantities, location, and status of chemicals within a particular laboratory or facility. Tracking a chemical from purchase to disposal can benefit the institution by reducing duplicate purchases. By allowing for redistribution of surplus materials, careful inventory control also minimizes the waste generated from partially-used containers of chemicals that age on laboratory shelves and the accompanying risk of accidents.

A comprehensive approach to chemical management requires substantial information and a modern file or data management system. Some laboratories use data networks, tailored to the needs and resources of the respective facility. The costs of the computer hardware and software needed for such a system have dropped dramatically over the last decade.

A bar code inventory system has proven to be effective at some facilities—particularly when a centralized storage and data management system is utilized. The bar code systems used in chemical management are similar to the Universal Product Code (UPC) systems used in grocery stores. This system allows tracking of the container as it moves throughout the organization. A computer inventory then can be made available to laboratory workers, who may search the database by chemical formula, chemical name, trade name, and location of the container.

There are a number of standard systems that are used in chemical tracking with bar coding, including one approved by the Health Industry Bar Code Council, and "System 39"—which is used by the U.S. Department of Defense. Chemical Abstract Service (CAS) registry numbers are universally accepted for identifying specific chemicals and can be used in such a system.

Tracking purchases with a computer database can provide significant savings by facilitating a storeroom's efforts in redistributing surplus chemicals, preventing the materials from prematurely becoming waste. The

success of such systems depends on the rapid supply of the required materials by the central storeroom to laboratory personnel, the full cooperation of those using chemicals in the laboratories, and the ability to ensure researchers that the surplus chemicals being distributed are of a sufficient quality to meet their needs.

To further reduce costs, link purchasing requests into the computerized inventory system, so that these can sometimes be fulfilled with surplus chemicals. Some major chemical suppliers provide electronic access to their catalogs. Safety information can be added to the inventory system to promote proper handling of chemicals and to aid in compliance with hazard communication and waste management regulations. For example, lab personnel who request a chemical could be supplied with the hazard information contained in its Material Safety Data Sheet (MSDS).

A readily available chemical inventory facilitates the sharing of surplus chemicals (see next section). Many laboratories store unwanted, older chemicals in a facility separate from the main, new chemical storeroom. As they age, these materials, including non-commercial research and development products, become a disposer's nightmare. The older chemicals often have inadequate labels, yet are potentially just what a researcher needs for a special project. An inventory control system allows ready access to these materials, reducing unnecessary purchasing.

Disposal Decision Tracking

A record of materials that must be disposed of as waste can be enlightening. For example, records showing that significant quantities of a particular chemical are discarded on a regular basis indicates that combined purchases and in-house redistribution of the chemical could provide considerable cost savings. Many laboratory workers are surprised to learn how their material use fits into the total chemical management scheme of their organization. This knowledge helps them to become more conscientious in purchasing only what is needed and minimizing waste generation.

Several firms and institutions have expanded the use of a chemical inventory database to include data on the proper disposal methods for chemicals in the system. This system includes data on how chemicals generated by the institution are properly disposed and makes this information available to others responsible for chemical management. The system reduces risks by helping to ensure that hazardous materials are

disposed of with proper precautions, while reducing disposal costs by keeping non-hazardous materials from being placed in the hazardous waste stream.

The Right System for Your Operations

The systems described above may be beyond the current resources of many academic and other small laboratories. The systems, however, can be adapted to the capabilities of such facilities. In some cases, an elaborate inventory can be maintained through access to a central main frame computer. A smaller data system on a microcomputer or a card file system may be appropriate, sufficient, and economically feasible for smaller laboratories.

The effectiveness of any chemical management system, whether it involves a sophisticated computer database or simple handwritten cards, relies on the cooperation of those using it. No one system is best. Each organization must decide what works for it and how to gain the support of the laboratory personnel using the system.

Proper Labelling of Chemical Containers

Labels should be clearly legible and permanent. Proper labelling accomplishes many things, including:

- decreases the risks of accidents and injuries from improper handling or storage;
- allows surplus quantities to be reused rather than requiring disposal because they are unknown;
- reduces the need for analysis and associated costs prior to disposal; and
- aids in compliance with regulatory requirements, such as hazard communication.

In the previous section's discussion, it was noted that a chemical inventory system can reduce waste by aiding in the redistribution of unused chemicals. This section more fully explores how a chemical exchange system can aid your waste minimization efforts.

A laboratory may find that it is managing as "waste" materials that are, in fact, merely surplus quantities of perfectly good chemicals. Both opened and unopened containers of these chemicals can accumulate in laboratories. With containers that have been previously opened, the purity of the chemical may be uncertain. However, these chemicals may be made useable again through simple assay and purification programs.

Often a high degree of purity is unnecessary for certain reactions and uses, and many potential users would be quite willing to accept opened containers of appropriate chemicals. These partially used chemicals should be redistributed rather than left to age, degrade, and eventually become wastes. Through a surplus chemical exchange, these materials become part of the inventory of the entire chemical management system.

Both passive and active chemical exchanges are in operation. In a passive surplus exchange, a brochure or computer database listing available chemicals is made available to potential users. Interested parties then direct inquiries to the central exchange which relays this information to the person in possession of the substance. Any subsequent negotiations are left to the two parties involved. Many passive chemical exchanges concentrate on relatively large quantities of surplus industrial chemicals. In a number of cases, however, laboratory chemicals are being exchanged effectively within a facility. In fact, many laboratories have exchanged surplus chemicals on a voluntary, informal basis for decades.

An active exchange, on the other hand, involves an intermediary who brings together the originator and the potential user. This type of exchange usually is done for a fee and the intermediary may actually take possession of the materials. Such an exchange requires additional time and effort, but can prove to be very effective because of the greater variety and quantity of chemicals made available to potential users.

The most effective surplus chemical exchange programs have proven to be in-house operations. Since the history of a particular chemical is

usually easy to obtain from colleagues, the passive exchange is the most common. The computerized programs that were described in the previous section greatly enhance exchange programs by providing centralized information on the quantity and types of chemicals available in the laboratories.

In-house and passive programs reduce the chance that the operator of the program will end up with chemicals for which there is no use and have to pay for disposal of the materials as waste. Use caution when selecting and dealing with active exchanges operated by those outside of your organization. These exchanges sometimes have been found to consist of little more than a warehouse in which containers of chemicals were being stored without the necessary permit. If the material is improperly stored or disposed of, your institution may be required to pay for an expensive cleanup.

If you accept chemicals from off-site and store them before sending them to the next user, you may be required to obtain a "Treatment, Storage, and Disposal Facility" (TSDF) permit. TSDF permits are very expensive and time-consuming to obtain. There are significant civil and criminal penalties for engaging in covered activities without such a permit.

"Gift" samples of chemicals—whether received from manufacturers, suppliers, researchers, or others—can add to your waste generation, may be expensive to dispose of, and can cause other problems.



Accordingly, laboratories should have a clearly stated policy on accepting such "gifts."

A few manufacturers or suppliers accept unopened containers of surplus chemicals within limited periods of time after the date of purchase. However, this practice does not necessarily solve the overall problem of waste disposal or contribute to waste reduction. The manufacturer may have to dispose of the materials if the costs of handling and purifying the materials exceed the value of the chemical in question.

In setting up an exchange program, it is important to remember that the federal hazardous waste regulations generally prohibit the "speculative" accumulation of chemicals. Accumulation prior to recycling is demonstrated not to be speculative by showing that the material itself is recyclable, that there is a means of recycling it, and that at least 75% of the material accumulated is in fact recycled within a calendar year.

In summary, the exchange of surplus chemicals offers significant opportunities for reducing the amount of waste that is created and requires disposal. Chemical users need to be made aware of the availability and quality of surplus chemicals. In-house and passive systems provide your organization the greatest benefit with the least amount of liability.

As a general rule, laboratory chemicals that have been used in experiments cannot be considered surplus chemicals. The handling of these materials is discussed in the next section.

RECYCLING AND REUSE

In-house recycling and reuse of chemicals offer significant opportunities for pollution prevention—reducing the amount of material requiring waste disposal and the need to purchase new chemicals. Alternatively, recycling may involve sending materials off-site to a company that specializes in their recovery.

In-house recycling provides the greatest control of chemical quality and reduces the potential liability that arises when a material is handled by an off-site recycler. In-house practices may include distillation and reclaiming expensive metals such as silver. Off-site recyclers may handle used solvents. In both cases, the availability of sufficient quantities is often the key to making recycling financially viable. Some reclaimed materials may not be of a sufficient purity to be used again by researchers, but sometimes can be put to use by others. For example, spent acids and solvents can be of use in routine maintenance of buildings.

Some companies that recover solvents will deliver recycled solvent at the same time as they pick up used solvent. However, these companies more commonly serve commercial and industrial operations than they do laboratories.



"Treatment" in the regulatory sense (which generally requires a TSDF permit) refers to techniques applied to a material after it has become a waste. The treatment which a laboratory will find most useful occurs before the material becomes a waste and involves changing the nature of a hazardous material to reduce its volume, toxicity, or both. It is imperative that such treatment techniques become an integral part of an experiment. This is a prime opportunity for researchers to take full responsibility for the material they are using and to prevent the initial generation of a waste, or at least to reduce the hazard of the waste generated.

Among the many treatment techniques available are chemical fixation, oxidation, precipitation, degradation, and ion exchange. Treatment techniques for laboratories are well-documented in the scientific literature, some of which is included in "Suggested Reading" at the end of this booklet. Such treatments should be incorporated and described within normal laboratory procedures, either in laboratory manuals or in the experimental sections of procedures published in the research literature.

A Note of Caution

Though some regulators do not consider a material to be a waste until it has left the lab, it is more likely that a material used in an experiment will be considered a waste once the experiment has concluded. Significant legal penalties may be imposed for undertaking activities regulated as waste treatment, storage, or disposal without a permit authorizing them.

The federal Environmental Protection Agency allows treatment of materials by generators in accumulation containers within the time (90 or 180 days depending on the generator classification) that waste may be accumulated without a permit. However, this policy never has been enunciated in the formal federal regulations and is not consistently followed by EPA regional offices and state regulatory agencies.

When considering recycling, reclamation, and treatment-like activities, it is important to work with your organization's health and safety personnel, its legal counsel, and with the appropriate regulatory agencies to ensure that what you are doing is safe and legal. Remember that states and sometimes even EPA regional offices prohibit procedures allowed by federal regulations. Materials accumulated prior to recycling or reclamation, as well as the residue of the process, generally are regulated as hazardous wastes.

Increased research in laboratory waste reduction techniques has led to the use of smaller quantities of chemicals. Laboratory personnel also have found that they often can use a less hazardous chemical in place of a more hazardous one with the same results. These two techniques often are referred to as "smaller scale" (or "microscale" depending on the amount of reduction) and "substitution," respectively.

Substitution

Some spent glassware cleaning solutions are examples of potential hazardous wastes that can be eliminated through substitution. Chromic acid solution is corrosive (sulfuric acid) as well as toxic (hexavalent chromium) and requires special care in disposal. Alcoholic potassium hydroxide solution is flammable and corrosive. These properties require caution to be exercised, not only when using them to clean glassware, but also when packaging the solutions for disposal and selecting a disposal option. These types of baths frequently can be replaced by one of several alternative laboratory detergents, such asalconox™ or Pierce RBS-35™, that often are highly effective when used properly. When a non-hazardous material can not be substituted, sometimes a more easily manageable hazardous one can be.

Some academic laboratory procedures still specify that the carcinogens benzene or carbon tetrachloride be used as reagents or solvents. These compounds often can be replaced by less hazardous materials. Such substitution results not only in safer procedures, but also in wastes that may be less toxic. Safer substances also are available for a number of other commonly-used hazardous materials. For example, in the standard qualitative test for halide ions, cyclohexane and carbon tetrachloride are equally effective for extracting the halogen. If cyclohexane is used instead of the traditionally-used carbon tetrachloride, the organic layer of the extract is more easily and cheaply disposed of. Qualitative analysis schemes for heavy metals have been developed that replace sulfide ion by hydroxide ion as a central reagent. Both the reagent and the precipitated (waste) product are significantly less hazardous.

In some organic syntheses, hypochlorite can replace chromate ion or other oxidizers, thereby avoiding the problems of disposing of



hazardous waste that contains chromium (VI) and other hazardous materials. In a physical chemistry laboratory, in the measurement of vapor pressure-temperature relationships by isotenscope, isopropyl alcohol is a suitable substitute for carbon tetrachloride. Determination of molecular weight by freezing point depression methods have often used benzene as the solvent. In such measurements, cyclohexane works about as well as benzene and the cooling curves seem no more difficult to interpret than those using benzene.

Reduced Scale

In the analytical laboratory, numerous options are available to chemists who wish to reduce the quantities of hazardous waste generated. Extraction solvents can be selected so as to minimize hazards and increase recoverability. Smaller samples sizes often can be used, thereby reducing the quantities of extraction solvents, derivatization reagents, or both. In one case, a laboratory was extracting 500 mL of highly contaminated sludge with 500 mL of solvents. The laboratory was able to reduce the sample and extraction solvent volumes to 100 mL each while maintaining the desired sensitivity limits. This reduction affected two waste streams in the laboratory—waste hazardous sample material and waste solvent.

When the use of hazardous materials cannot be avoided, carrying an experiment out on a microscale limits the quantity of hazardous waste produced. Small-scale syntheses and analyses not only involve the use of smaller quantities of reagents, but also result in smaller quantities of waste—filter cakes, filter papers, filtrates, and distillation residues. Another impetus to the use of small-scale reactions is the fact that glassware that cannot be cleaned and reused is itself regulated as a hazardous waste if contaminated with hazardous materials.

Many analytical procedures involve hazardous reagents and products that result in hazardous waste. To minimize the hazardous waste problems in such operations, the specific solvent to be used and the feasibility of recycling it must be carefully considered. Even when syntheses must be done on a moderately large scale, the identity and purity of the products formed can be verified on a semimicro- or microanalytical scale using spot plates, chemical microscopy, and if you have the appropriate instrumentation, GLC, HPLC, GC/MS, and NMR.

Many organic and inorganic synthesis procedures have been successfully designed so that the product of one synthesis is the starting material for the next. Multi-step sequences have been designed for a variety of syntheses. When each step is complete, characterizing procedures are carried out on a few milligrams of material. The bulk of the material continues in the process so that no product from the earlier steps is left to be disposed of or to be stored. Even in such sequences, however, there may be filtrates, filter cakes, still residues, byproducts, and other wastes to be disposed of. With judicious planning, the volume of such hazardous materials can be reduced.

CONCLUSION

Pollution prevention and waste minimization are as important to economics as they are to environmental protection and human health and safety. They also are particularly important aspects of education. Emphasizing safety considerations to students and researchers is clearly a responsibility at all levels of an organization.

Every chemical management system—whether in industry, academe, government, or elsewhere—is only as good as the conscientious people using it. The successful waste prevention and reduction programs often are those that are encouraged and supported at the highest management levels. *“Less is Better”* is the guide, and increased protection of human health and the environment, as well as real cost savings, are the benefits. Convincing the public that scientists solve problems and are essential to society starts with *“Less is Better”* management in the laboratory.

Consult with your organization’s health and safety staff, its legal counsel, the most current applicable regulations, and local regulators in developing your own *“Less is Better”* program. This interaction will help to ensure that the program not only reduces waste generation, but also complies with the law and is fully protective of human health and the environment.

Suggested Reading

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The U.S. EPA RCRA (hazardous waste) hotline (800/424-9346 or 703/412-9810) is a good source of free publications.

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