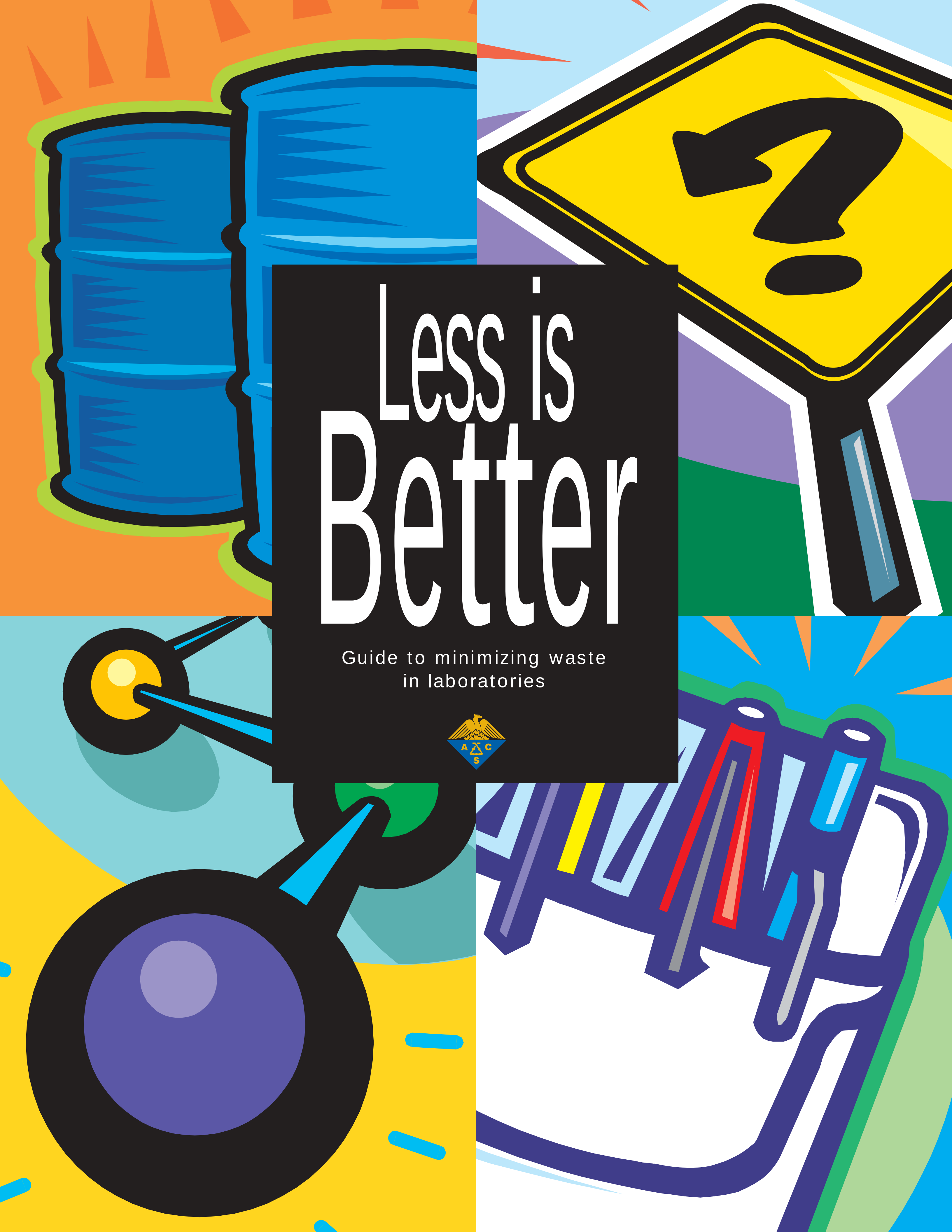

Less is Better

Guide to minimizing waste
in laboratories

Less is Better is a web-based, free of charge document.
No printed booklets have been produced.

Prepared by the Task Force on Laboratory Environment, Health, & Safety.

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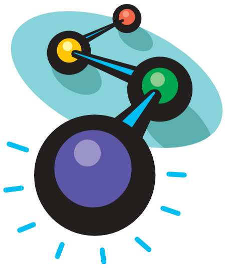


LESS IS BETTER

Across government, industry, and academe, much attention is being given to the need to reduce waste. Increasing environmental awareness, a desire to reduce risks posed to employees and the public, and high disposal costs are directly linked to the efforts of laboratories to reduce their generation of chemical wastes. This work is properly rooted in the philosophy that "less is better".

The American Chemical Society (ACS) originally published *Less Is Better* in 1985. The booklet was developed by ACS's Task Force on RCRA (the Resource Conservation and Recovery Act of 1976) and quickly became a popular guide for minimizing waste in laboratories. Formed in 1981 to help laboratory chemists comply with RCRA provisions, the task force is now called the Task Force on Laboratory Environment, Health, and Safety (Lab EHS). This group monitors and comments on regulatory issues that affect laboratories and provides guidance for complying with federal and state regulations. As a part of this effort, the task force has revised and reissued *Less Is Better.*

Through RCRA, Congress directed the Environmental Protection Agency (EPA) to write and implement regulations concerning hazardous waste management. Because EPA considers waste minimization an essential element of hazardous waste management, it requires hazardous waste generators to have a waste minimization program. By signing a hazardous waste manifest, generators certify that they "have a program in place to reduce the volume and toxicity of waste generated."

In 1990 Congress passed additional legislation referred to as the Pollution Prevention Act (PPA). The act established as a national policy a hierarchy of waste minimization and management approaches with preference for those that provide the greatest protection of the environment:

> *The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.*

The PPA provides guidance for selecting general approaches to pollution prevention and waste minimization, and it is based solely on environmental considerations. The approaches selected by laboratories must be compatible with their educational and operational purposes, economic considerations, and scientific productivity. Many laboratories have found that many of the same pollution prevention and waste minimization strategies used in industry can be successfully applied to laboratory operations.

These strategies are

- better procurement management, especially avoiding overordering of hazardous materials;
- substitution of hazardous materials with less hazardous or nonhazardous materials;
- reduction of scale of experiments and protocols to the minimum size necessary to achieve research objectives;
- redistribution, reuse, and recycling of supplies and reagents;
- improvement of waste segregation to maximize recovery of materials and treatability of wastes; and
- dissemination of information about the benefits and implementation of laboratory pollution prevention efforts.

Less Is Better outlines the practical waste minimization concepts that laboratories adopted early on. These ideas continue to unfold as we enter the 21st century; movements such as *"Green Chemistry"* are taking hold. At the same time, emerging new technologies such as "Lab-on-a-Chip" have the potential to greatly reduce or totally eliminate hazardous wastes generated by laboratory procedures. For more information on Green Chemistry or Lab-on-a-Chip, visit the following sites:

- *Green Chemistry Institute*
- *EPA's Green Chemistry Program*
- Ritter, S. K. Green Chemistry. *Chem. Eng. News,* July 16, 2001; Vol. 79, No. 29, 27–34; *http://pubs.acs.org/cen/coverstory/7929/print/7929greenchemistry.html*
- Borman, S. Let's get small: Lab-on-a-chip devices attract growing interest for a wide range of applications. *Chem. Eng. News,* April 2, 2001; Vol. 79, No. 14, 50–51; *http://cen.acs.org/isubscribe/journals/cen/79/i14/html/7914sci3.html*

This edition of *Less Is Better* discusses strategies for reducing wastes and presents the practical benefits of implementing minimization programs. It will prove helpful to bench chemists, business officers, chemical technicians, health and safety personnel, laboratory managers, professors and science teachers, purchasing agents, research directors, stockroom operators, and others.

Information is organized in the order in which one would be expected to conduct a laboratory procedure:

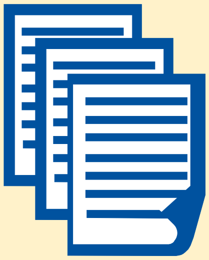
Planning for Pollution Prevention. At the outset of any laboratory operation, one must consider safety, equipment, and final product and chemical waste disposition. Less Is Better strategies include reduction of the quantities and hazards of chemicals used in a given procedure.

Purchasing Strategies and Inventory Control. An efficient, up-to-date inventory system provides information about what chemicals are on site so that unnecessary purchases can be avoided. Most modern inventory systems include hazard and safety information that can be important in planning and implementing laboratory procedures.

Surplus and Waste Chemicals. Plans must be made for disposal, storage, or reuse of excess chemicals once procedures are complete and the desired products and/or data have been recovered. This section focuses on whether the materials can be reused or need to be considered as waste.

Waste Treatment and Disposal. This section addresses how to best handle the wastes. Can the hazards of these excess chemicals be reduced by on-site treatment to minimize risk and disposal costs?

Less Is Better strategies, used at every step of planning and executing a laboratory procedure, mirror EPA's "cradle-to-grave" approach to hazardous waste management.



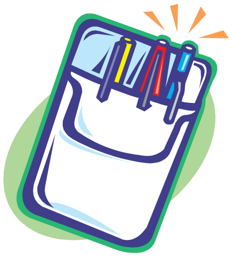
PLANNING FOR POLLUTION PREVENTION

In addition to the chemistry, laboratory personnel need to plan for the proper procedures, equipment, safety, and environmental fate of the products and byproducts generated. They should consult the literature and their colleagues, update methods, and replace particularly hazardous or environmentally inappropriate chemicals with benign alternatives. Where possible, procedures should be scaled down to minimize chemical usage and waste generation.

In recent years, most laboratories have minimized waste generation by substituting less hazardous chemicals for more hazardous chemicals. *Common substitutions* include using less *hazardous glassware-cleaning chemicals, extraction solvents,* and reaction reagents. Substitution of solvents, usually the largest quantity of chemicals used in a procedure, can effectively reduce wastes and hazards. For example, cyclohexane can often substitute for the more toxic benzene. Hydrocarbon solvents may serve in place of their halogenated counterparts. Aqueous solvents are increasingly replacing hydrocarbons as the reaction media of choice. The current literature contains numerous references to these types of substitutions.

Fortunately, modern laboratory instrumentation requires smaller quantities of chemicals than were used in the past to achieve satisfactory analytical results. For teaching laboratories, instructors should plan experiments based on the smallest scale possible. *Microscale* procedures and equipment use smaller quantities of reagents, result in smaller quantities of waste, are safer, and teach careful laboratory techniques. For more information on microscale chemistry, refer to *Laboratory Waste Minimization and Pollution Prevention: A Guide for Teachers* (Chapter 8: Scaling Down Experiments) or the *National Microscale Chemistry Center.*

For more information on planning laboratory procedures with pollution prevention in mind, refer to the *Resources* section.



PURCHASING STRATEGIES AND INVENTORY CONTROL

Even before experiment planning is completed, it is useful to know what chemicals are available in-house. This information may influence decisions and provide a basis for considering chemical substitutions. A chemicals management system is needed to make the best purchasing decisions and to minimize the generation of hazardous waste. An efficient system makes use of purchasing strategies with minimal disruption of teaching, research, and other laboratory functions.

The system should include a chemicals inventory that lists the identity, quantity, and location of each chemical within a laboratory or facility. Tracking a chemical from purchase through receipt, use, storage, and disposal helps reduce inventory and avoid duplicate purchases. Inventory control also minimizes the waste generated from old, partially used containers of chemicals and reduces the chance of accidents with old chemicals. Keeping surplus chemicals can lead to high disposal costs and safety hazards.

Numerous chemical inventory software packages are commercially available, and many allow for customization. Bar code identification has proven to be effective at some institutions, and some suppliers label their chemicals for use with bar code readers, which facilitate periodic inventory checks. Each container has a unique identifier that provides information such as the name of the supplier, date obtained, quantity, price, hazard information, MSDS, location, alternate names, formula, and date to be discarded. Ideally, the amounts of a chemical removed from a container can be tracked so that quantities are always up to date. Although this degree of detailed updating may not be feasible, the flexibility can be part of an overall system. When a container is moved, the new location is entered into the inventory system. When the container is discarded, the chemical is removed from the inventory.

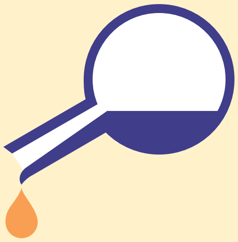
Alternatively, a simplified chemicals management system may focus on chemicals that pose the greatest safety risks, are most difficult to dispose of, or are most likely to be used by other chemists. For example, a system may monitor requisitions to prevent the purchase of hazardous chemicals for which safer substitutes are available. An up-to-date inventory system for the most commonly used chemicals will encourage the sharing of surpluses and ensure that all in-house chemical containers are reviewed. During this process, some chemicals will be discarded because they are outdated, contaminated, in poor condition, or no longer needed. Also, duplicate containers of the same chemical will be found, and their discovery can be the basis for consolidating inventory and establishing prudent storage quantities.

Computer-based inventory systems offer the possibility of linking the search for a chemical with electronic ordering when the desired material is not found on site. Most major chemical suppliers provide electronic access to their catalogs. Persons ordering new chemicals may even operate through a central network that can help identify opportunities to use surpluses from other organizations. The success of such systems depends on quality control, supply availability, and cooperation from the suppliers. Working together, purchasing departments and chemical suppliers can help laboratories minimize chemical risks and wastes.

The “Economy of Size” Myth

Purchasing chemicals in larger containers at an initial lower unit cost, rather than smaller containers, appears to be a good way to save money. However, consideration of the total costs of such purchases makes it clear this may not be the case (see *cost analysis*). When a large container of a chemical is purchased, often a small quantity is taken out for use and the rest is stored. As a result, partially filled containers accumulate in laboratories and storerooms, and the chemicals—many of which have exceeded safe storage time periods or have unreadable labels—are disposed of as wastes. In a laboratory that has not adequately implemented waste minimization programs, unused chemicals typically constitute 40% or more of the hazardous waste stream generated. Costs incurred as a result of these unneeded chemicals include analysis, storage, packaging, transport, and disposal. When labels are missing or unclear, the cost of having even a small amount of an unknown chemical analyzed prior to disposal can far exceed the purchase price of an entire container of the material. Furthermore, long-term storage of unused chemicals increases the risk of accidents.

By contrast, when chemicals are purchased or drawn from the storeroom in small packages, less material circulates throughout the organization and smaller amounts ultimately require disposal. Small-quantity purchases reduce the amount of unused chemicals being stored and the risk of exposure of employees to hazardous substances. Smaller bottles are sturdier than larger ones, so breakage and spill risks are substantially reduced. If bottles do break, there is less spillage, making cleanup safer, easier, and less expensive. The size of the package purchased is therefore critical to safety and waste minimization as well as economy.



SURPLUS AND WASTE CHEMICALS

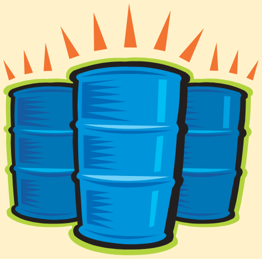
Once an experimental procedure has been completed, unused starting materials, solvents, reagents, byproducts, and even the desired products must be dealt with. Byproducts or contaminated materials that have no further use are most often deemed waste. (Waste management is the focus of the next section.) However, leftover materials may be used in other procedures or by other researchers.

The most widely practiced means of chemical use or reuse in a laboratory is through a "chemical exchange program". Laboratories routinely manage surplus quantities of chemicals. They may be managing surplus materials as waste when in fact they are perfectly good chemicals. Opened and unopened containers of these chemicals can accumulate in laboratories. If a container was previously opened, the chemical's purity may be questionable. In some cases, a simple analysis will confirm purity. However, a high degree of purity is not required for all reactions, and some users might accept opened containers of appropriate chemicals. These chemicals should be exchanged rather than left to become waste.

The most effective chemical exchange programs for laboratories have been in-house exchanges run by large organizations such as government and industrial research centers and universities. The history of a particular chemical can be obtained from colleagues or computerized inventory systems that provide information on the quantities and types of chemicals available.

In-house programs reduce the chance that the operator of a program will end up with chemicals for which there are no uses, ultimately incurring the expense of disposing of the materials as waste. If you choose to participate in a chemical exchange program operated externally, be sure that the outside agency has the necessary permits and insurance, adequate facilities and management, and good references from regulatory authorities and prior customers. Be very careful when accepting surplus chemicals from other organizations. If you accept chemicals from another site and have no likely use for them, a regulator may consider the chemicals waste and your organization a waste storage facility. There are significant civil and criminal penalties for storing hazardous wastes without a permit. Furthermore, chemicals accepted as "gifts" often turn into wastes when they are not used in a timely manner. Disposal costs can be high!

Some manufacturers or suppliers accept unopened containers of surplus chemicals for a limited time after the date of purchase. The manufacturer may not be able to reuse or recycle your returned materials if the costs of handling and purifying the materials exceed the value of the chemicals in question. Still, it is worth pursuing this option with chemical suppliers.



WASTE TREATMENT AND DISPOSAL

Surplus chemicals or byproducts that cannot be used or reused are deemed waste, and the generator must determine whether they are regulated or nonregulated hazardous wastes. Although both types must be managed in ways that protect human health and the environment and limit long-term liability, there are more constraints associated with regulated wastes. Regulated hazardous wastes must be separated, packaged, labeled, recorded, and disposed of in strict accordance with EPA or state regulations. Laboratories that generate nonregulated waste face few regulatory concerns but must be aware of potential liabilities and safety problems related to improper handling and disposal. Because of the diversity of the wastes generated in laboratories, prudent disposal demands considerable expertise and attention.

A summary of EPA's relevant hazardous waste regulations follows. This is a simple overview and in no way should be viewed as a regulatory guidance document. EPA's hazardous waste regulations are online at *http://www.epa.gov/docs/epacfr40/chaptI.info/subch-I.htm.* Most state hazardous waste regulations are online. For a list of state environmental agency Web sites and a summary of hazardous waste treatment without a TSDF (treatment, storage, or disposal facility) permit allowed by states, see EPA's document *Little Known But Allowable Ways to Deal with Hazardous Waste.*

Hazardous Waste Classification

According to *40 CFR 261,* EPA specifies wastes as hazardous if they appear on one of the four lists or exhibit a particular hazardous characteristic. For laboratories, the most relevant listings are those for spent solvents (a portion of the F-list) and discarded commercial chemical products (known as the P- and U-lists). Spent solvents on the F-list are designated by the codes F001, F002, F003, F004, and F005 and include common solvents such as acetone, methanol, methylene chloride, toluene, and xylene. The P- and U-lists apply to unused, discarded commercial chemical products with a sole active ingredient on one of the two lists. Expired or unused laboratory chemicals are often P- or U-listed wastes.

The four hazardous waste characteristics are ignitability, corrosivity, reactivity, and toxicity. Ignitable wastes are generally liquids with a flash point below 140 °F. Nonchlorinated solvent wastes are usually ignitable, and sometimes they are also F-listed. Corrosive wastes are aqueous solutions with a pH ≤2 or ≥12.5. Reactive wastes are unstable, explosive, or water reactive, or they can generate toxic cyanide or sulfide fumes. Toxic wastes contain one or more of 40 regulated toxic constituents (e.g., herbicides, toxic organic compounds, heavy metals) that, when subjected to the toxicity characteristic leaching procedure (TCLP), are likely to leach hazardous concentrations.

In addition to the four federal hazardous waste lists and hazardous waste characteristics, state regulators sometimes include other wastes in their state definition of hazardous waste. Often these wastes (e.g., waste oils and polychlorinated biphenyls) are added in the form of "state lists".

Hazardous Waste Generator Requirements

Once a laboratory determines that it generates hazardous waste, it must identify how much waste it generates each month and accumulates on site over time. This data is used to determine hazardous waste generator status. EPA sets varying requirements for three classes of generators: large-quantity generators (LQGs), small-quantity generators (SQGs), and conditionally exempt small-quantity generators (CESQGs). Often, states define generator status differently and set more stringent requirements. Generators are defined by site; thus, all hazardous wastes from a site (e.g., research center, campus, lab building) are counted together in order to determine generator status. Sites generating ≤100 kg of hazardous waste per month are CESQGs and are subject to very minimal regulation (in most states). Sites that generate >100 kg and <1000 kg of hazardous waste per month are SQGs. Sites generating 1000 kg or more per month are LQGs.

SQGs and LQGs must obtain EPA generator identification numbers and comply with numerous requirements. When waste is accumulating in the laboratory where it was generated, it is said to be in a "satellite accumulation area" (SAA). Such waste is subject to certain accumulation limits (e.g., 55 gal) and must be placed in containers that are in good condition, compatible with the waste, and include a label stating their contents. Once the waste is moved from the SAA, it must be marked with the date and placed in a designated accumulation area with equipment to handle emergencies such as a release or fire. Also, plans for handling such emergencies must be developed and distributed. Waste management personnel must receive RCRA training annually. SQGs can accumulate waste on site for up to 180 days or 270 days if it is to be transported over 200 miles for disposal. LQGs can accumulate waste for up to 90 days.

On-Site Waste Treatment

Laboratories generating hazardous waste have a few options for treating hazardous waste on site without a RCRA TSDF permit:

- *Elementary Neutralization*
- *Recycling*
- *Treatment in Accumulation Tanks or Containers*
- *Treatment as Part of a Process*

In addition, EPA mandates that generators attempt to minimize the volume and toxicity of their waste. Although EPA prefers that generators eliminate waste generation through source reduction, it specifies that when source reduction is not feasible, waste should, if possible, be recycled or treated.

Planning for a laboratory procedure should include decisions about how to manage waste. Recycling, for example, might require careful segregation of wastes during the procedure, not after it is complete. Therefore, an effective waste management process must be established *before* the waste is generated.

Treating hazardous waste on site in ways other than those provided for in the regulatory exclusions subjects generators to extremely high fines (e.g., up to $50,000 per day) and possible criminal penalties (i.e., incarceration). Before treating hazardous waste on site, laboratory personnel must be absolutely sure that the treatment is allowed without a permit by their state hazardous waste regulators. They must also ensure that they have proper procedures, equipment, and skilled employees to conduct treatment safely and effectively on site.

On-Site Disposal

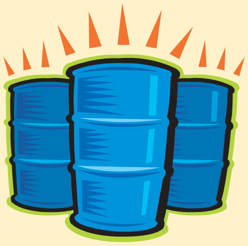
Disposal of laboratory waste on site is not typically a viable option and is not usually considered to be in line with the Less Is Better strategy. Disposing of laboratory wastes by placing them on or in the land or evaporating them to the atmosphere is almost always considered unacceptable. In very limited cases, laboratories may be permitted to dispose of certain *wastes down the drain.* Before disposing of any wastes on site, laboratories must consult with regulators and carefully consider the consequences of their methods.

Off-Site Disposal

Most laboratories ship hazardous waste to permitted TSDFs. Hazardous waste shipped off site must be accompanied by a hazardous waste manifest (shipping paper) and transported by an EPA-permitted transporter. To avoid potential future liabilities, lab managers should ensure that their waste is delivered to a reputable permitted TSDF. To ensure safety as well as economical and environmentally sound disposal options, waste must be carefully segregated before off-site disposal. For example, spent nonhalogenated solvents may be accumulated separately and sent off site for fuel blending rather than incineration. In some cases, spent solvents (e.g., methylene chloride) can be segregated and sent off site for recycling. Certain treatment or disposal options such as fuel blending and recycling are sometimes better for the environment and less expensive than hazardous waste incineration.

Waste Generation Records

Regardless of how a laboratory chooses to treat or dispose of its waste, a look back at waste generation records can alert an organization to options for changes in its chemicals management plan and enhancement of the Less Is Better attitude. For example, the record might show that various quantities of a single chemical are being discarded from many different projects. Combined purchases and in-house distribution could provide considerable cost savings on such a chemical. Many laboratory workers may be surprised to learn how their material fits into the total chemicals management scheme of their organization, and thus they can make better decisions about purchasing and how to minimize the waste that is generated.



CONCLUSIONS

The Less Is Better philosophy for chemicals management can help to minimize the generation of hazardous wastes that might adversely affect the environment, reduce the risk to laboratory personnel, and enhance the safety practices of laboratories through advanced planning.

Today's responsible chemist must have an understanding of the ultimate fate of each chemical being used in an experiment or process. Chemists are in the best position, through their education and practice, to know whether a chemical poses any risk to humans or the environment after it leaves the laboratory bench.

The ACS Task Force on Laboratory Environment, Health and Safety hopes that implementation of Less Is Better concepts will improve chemical safety and environmental protection. We believe that our recommendations can become a part of the plans and procedures used in every laboratory. By using Less Is Better practices, chemists and their supervisors will more effectively address the government regulations that have been established to prevent risks to personnel and the environment.

RESOURCES

- *Laboratory Waste Minimization and Pollution Prevention,* A Guide for Teachers; *Pacific Northwest National Laboratories* and *Battelle Seattle Research Center,* March 1996.
- *Laboratory Waste Management: A Guidebook;* American Chemical Society: Washington, DC, 1994.
- *National Research Council. Prudent Practices in the Laboratory, Handling and Disposal of Chemicals; National Academy Press:* Washington, D.C., 1995.
- Task Force on RCRA. *The Waste Management Manual for Laboratory Personnel;* American Chemical Society: Washington, DC, 1990.
- Little Known But Allowable Ways to Deal with Hazardous Waste (EPA 233-B-00-002); EPA Small Business Ombudsman, 2000; *http://www.epa.gov/sbo/.*
- *Handbook of Chemical Health and Safety;* Alaimo, R. J., Ed.; Oxford University Press: New York, 2001; pp. 391–397.
- 101 Ways to Reduce Waste; *http://www.ehs.uiuc.edu/ ~chem/pdf/WM01.pdf.*
- *Environmental Management Guide for Small Laboratories* (EPA-233-B-00-001); EPA Office of the Administrator, May 2000.

APPENDICES

Glassware Cleaning

Some glassware cleaning solutions pose health and safety concerns and are regulated hazardous wastes upon disposal. For example, chromic acid and alcoholic potassium hydroxide are sources 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. Although such materials are effective for their intended purposes, they add to a laboratory's hazardous waste stream and should be replaced by one of several equally effective proprietary laboratory detergents.

Extraction Solvents

Some academic laboratory procedures still specify benzene or carbon tetrachloride as reagents or solvents. These compounds often can be replaced by less hazardous materials that are safer to use and result in wastes that may be less hazardous. 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 traditional carbon tetrachloride, the organic layer of the extract is less hazardous and more readily disposed of.

Economy of Size Myth—Cost Analysis

As an example of the advantageous economics of a small-size purchase, consider xylene. The per-liter purchase price of certified ACS xylenes sold in one-liter bottles is nearly twice that of four-liter bottles. Even if you don't need four liters, it is tempting to purchase a larger bottle.

Let's assume that you need two liters of certified ACS xylenes in your laboratory. You can purchase a four-liter bottle of xylene for slightly more than the cost of two one-liter bottles. It is easy to justify this additional expenditure because surely you will need more xylene sometime in the future and you will have it on hand to use without the hassle of purchasing paperwork and waiting for delivery. And if the four liters are eventually used, you will have wisely paid nearly half the price of four one-liter bottles. How thrifty you are!

This pattern of unit pricing—small containers are relatively more expensive than larger containers—is very common in the marketplace. We make similar purchasing decisions nearly every day. The problem with using this reasoning for purchasing the "large economy size" of laboratory chemicals is that every scientist in every laboratory can use this rationale for nearly every purchase. However, this type of purchase commonly is *not* cost-effective. Buying the larger bottle results in thousands of bottles of partially used chemicals. Look around. It may be hard to admit, but the vast majority of these partially used bottles will not be used. In many organizations, these containers will eventually need to be disposed of as hazardous waste.

Another cost that is rarely considered is the small additional purchase price multiplied a thousandfold by other, similar purchases that result in assets that are either tied up in inventory or forever lost because of excess that isn't used. There is no convenience in finding degraded and unusable aged chemicals in the laboratory. All partially used containers demand space, safe storage facilities, and the overhead costs of maintaining them. Now add the risks of fire, breakage, spills, and exposure of personnel to toxic chemicals. That four-liter bottle isn't thrifty after all.

Consider just disposal costs. Xylene is a flammable liquid. Many laboratories dispose of laboratory chemicals in their original container, which is placed into a "lab pack" (an overpack container, usually 5 to 55 gallons in size, into which smaller containers of laboratory chemicals are placed). Although packing, transport, and disposal costs vary by locale, disposal firms usually charge both a per-pound fee and a per-container fee for each bottle or laboratory chemical waste. In the table below, we use $3 per pound plus $10 per container to handle, document, pack, transport, and incinerate that partially used four-liter bottle of xylene into a lab pack. The per-container charge recognizes that every container, no matter how large or small, must be sorted, documented, and packed. The per-pound cost may be thought of as the cost to transport and incinerate the waste.

Note that additional charges are incurred for the disposal of partially used containers that are reactive, potentially explosive, or have missing or unrecognizable labels. This is not an uncommon situation for older laboratory chemicals.

Consider the total-cost example of certified ACS xylenes as outlined in the table below. The 2001 purchase costs of certified ACS xylenes are used in the table. Indeed, the unit purchase price of the four-liter bottle is half that of a one-liter bottle, but the cost of purchase plus disposal is more for the four-liter bottle than for two one-liter bottles from which the contents are consumed. Disposal of a partially used four-liter bottle can be nearly a third of the original purchase price!

Package size	**1 L**	**4 L**
Purchase price	$42.49	$93.72
Unit purchase price per mL	$0.04	$0.02
When 2000 mL are used		
Unit purchase price per mL used	$0.04	$0.05
Disposal costs	$0.00	$29.80
Purchase plus disposal costs	$84.98	$123.52
Purchase plus disposal unit cost per mL used	$0.04	$0.06

Purchasing small containers has other benefits. Packages are emptied faster, so there is less chance of chemical degradation. Frequent purchases and rapid inventory turnover mean that supplies are fresh. In contrast, larger sizes often dictate additional costs and equipment, such as transfer containers, labels, funnels, and pumps. Labor may be required to subdivide the larger quantities into smaller containers, with the commensurate risk of spills, chemical exposure, and the need for personal protective equipment.

The other costs of partially used containers mentioned above—inventory, storage, fire, spills, and the like—are more difficult to quantify. However, these are very real costs that, if considered in the above table, would result in an even higher total unit cost for the larger, four-liter bottle.

For many reasons, less is not only better; it is less risky and less expensive.

Elementary Neutralization

EPA and most state authorities clearly allow elementary neutralization (i.e., pH adjustment) of hazardous wastes without a permit (40 CFR 264.1(g)(6) and 270.1(C)(2)(v)). Elementary neutralization units (as defined in 40 CFR 260.10) may be used to neutralize corrosive (D002) wastes without any worry about meeting RCRA permitting requirements. Two important points to remember are that elementary neutralization refers only to pH adjustment, and neutralized waste should be discharged down the drain only if it meets all applicable discharge standards (i.e., local, state, and EPA limits). In ideal cases, the result of this in-laboratory neutralization is a nonhazardous, nonregulated product that can be discharged into the sanitary sewer. However, whether disposal of neutralized wastes down the drain is allowed depends on the nature of the waste and regulations imposed by the wastewater authority.

Recycling

Although EPA considers recycling a form of treatment, it does not require recyclers to obtain a TSDF permit. In *40 CFR 261.6 (c)(1),* EPA states that "the recycling process is exempt from regulation." Generally, laboratory waste streams that are generated in larger quantities provide the greatest opportunity for recycling. For laboratories, spent solvents are often the hazardous waste most generated and, fortuitously, the hazardous waste most amenable to recycling. Precious metals are the second most likely materials to be recycled in a laboratory.

Treatment in Accumulation Tanks or Containers

Generators may treat hazardous wastes in accumulation tanks or containers without obtaining a RCRA TSDF permit. EPA clearly states this exemption in its *Federal Register* notice issued March 24, 1986 (51 FR 10168) as well as in subsequent FR notices and interpretive memos. For laboratories, treatment is more likely to occur in a container than in a tank. Containers in which treatment occurs must be managed in compliance with EPA's container management standards in 40 CFR 265, Subpart I. EPA rules do not limit the methods of treating hazardous waste in a container. All treatment procedures should be safe, environmentally sound, and chemically practicable. Examples of treatment in accumulation containers include precipitating heavy metals from solutions and oxidation-reduction reactions. Remember, treatment residues usually still require management as a hazardous waste.

Treatment as Part of a Process

(This is not technically hazardous waste treatment and is not condoned by mention herein.) Many laboratories have, over the years, questioned when materials waste must be designated as hazardous wastes. Strictly speaking, most regulators believe that once a waste is generated, it must be managed as hazardous waste if it is on one of the lists of hazardous wastes or exhibits one of the hazard characteristics. Some regulators and laboratory organizations have discussed options to allow materials to be deemed a waste only after they have left the laboratory. The point at which a material is declared a waste is important because it can then be treated only in ways that are allowed by EPA. Before declaring a material a waste, a laboratory can analyze, experiment with, react, or treat a chemical without regard to EPA's hazardous waste regulations. This type of treatment has been referred to as "treatment as part of the process" since researchers often add an extra step to a procedure in order to render a byproduct nonhazardous. As with most laboratory processes, this last step treatment would be small-scale and pose a minimum of risk to personnel and the environment. Furthermore, safety may be improved since the person most familiar with the characteristics of the wastes typically carries out treatment. Still, from a regulatory perspective, this can be a perilous way to treat waste in the laboratory, because establishing when a material becomes a waste is controversial and open to interpretation. Before undertaking treatment as part of the process, laboratory managers are advised to consult with regulators.

Disposing of Laboratory Waste Down the Drain

Laboratories that discharge wastewater to a septic system or directly to surface water are well advised to limit the discharge of pollutants to the maximum extent possible. However, laboratories discharging wastewater to a publicly owned treatment works (POTW) or possibly to an on-site permitted treatment plant may be able to dispose of certain wastes down the drain. Laboratory wastes, even those typically considered hazardous, are not regulated by EPA hazardous waste regulations when they are discharged to a POTW because of the "domestic sewage exclusion." According to EPA regulations and most state regulations, wastewater discharges to a POTW are excluded from the definition of solid waste and, therefore, are not regulated hazardous waste (40 CFR 261.4(a)). Still, laboratory personnel must consider federal, state, and local water pollution control regulations before discharging wastes down the drain. Regulations governing wastewater discharges to a POTW are sometimes referred to as "pretreatment standards." EPA's National Pretreatment Standards, found in *40 CFR 403.5,* prohibit *all* users from discharging many types of pollutants, including flammable liquids, corrosive liquids (pH <5), solid or viscous materials, chemicals with high biological oxygen demand, and petroleum oils. Additionally, most POTWs have local sewer ordinances, which usually set more stringent standards. It is up to laboratory personnel to compile the federal, state, and local standards and ensure that their wastewater discharges comply with all three sets of standards.