Hazardous wastes in academia

Colleges and universities are trying to develop ways to manage hazardous wastes

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As do many industries, colleges and universities encounter thorny problems in dealing with hazardous wastes. Industry and academia alike are saddled with the rising cost of waste management and face perpetual liability for costs of waste cleanup. Unlike many industries, however, colleges and universities generate small amounts of waste, most, but by no means all of which is generated in laboratories; almost every operation contributes a certain amount. The wastes consist of nearly every hazardous chemical listed by EPA, including hydrochloric acid, methanol, polychlorinated biphenyls (PCBs), and newly synthesized compounds of unknown toxicity. Moreover, their composition changes with each new research project and experiment.

Liability and cost

An example of academic institutions' perpetual liability is found in a legal proceeding that listed four universities among the parties responsible for cleaning up a Superfund site in Seymour, Ind. In addition, at least one university has an old abandoned disposal site on the Superfund National Priority List (*1*).

One institution experiencing problems with the dramatically rising costs of hazardous waste management is the University of Illinois. In 1977, the university spent $2000 to dispose of 100 drums of waste chemicals. By 1982, the cost of disposing of 265 drums had risen to $46,000, an 87% annual increase in the cost of packaging, transporting, and disposing of the wastes in a landfill. Additional costs are incurred because of the need for adequate space to store waste chemicals pending disposal and because waste chemical management workers must segregate wastes to facilitate disposal (*2*). At the Davis campus of the University of California, total costs of the hazardous waste management program increased by 113% in five years (*2*).

We believe that all academic institutions, regardless of size, should develop chemical waste management systems. The environmental benefits of proper management of small quantities of waste chemicals may not be significant in comparison with those derived from managing the larger quantities generated by industry, but there are substantial benefits to be realized in training students in proper management techniques when they begin to work with chemicals. This article explains how colleges and universities are coping with their chemical wastes and discusses what the future holds for hazardous waste management at academic institutions.

Heterogeneous wastes

Collectively, academic institutions generate less than 1% of the nation's hazardous wastes (Figure 1) (*3*). Yet the totals at individual institutions can be surprisingly large. The University of Illinois at Urbana-Champaign disposed of 27,500 kg of waste chemicals in 1984. The University of Wisconsin–Madison generates 36,000 kg/y of chemical wastes. Indeed, hazardous wastes are a problem for any school with a laboratory, regardless of size (*4*, *5*). In 1983, 78 high schools in Minnesota generated an average of 40 kg each of hazardous wastes (*6*).

The hazardous wastes generated in academic institutions can best be characterized as heterogeneous. A list prepared by the University of Minnesota in 1981 enumerates 1350 frequently used chemicals that can be designated as hazardous wastes (*7*). At the University of Illinois, 2104 chemicals and chemical mixtures, collected in 7300 containers, were disposed of last year.

Containers typically hold gram to kilogram quantities of wastes, the composition of which often is unpredictable (*8*). New Mexico State University approached this problem in the following way: On the Part B permit application for its storage facility, required by the Resource Conservation and Recovery Act (RCRA), the university described its wastes by naming every item on EPA's list of hazardous chemicals (*9*). Actually, certain general patterns in the nature of many academic institutions' wastes can be seen. For instance, un-

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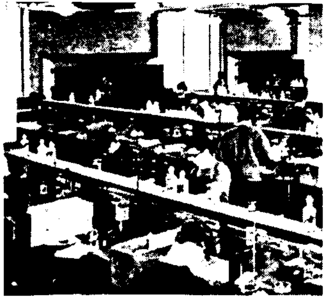
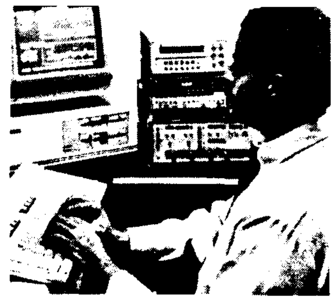
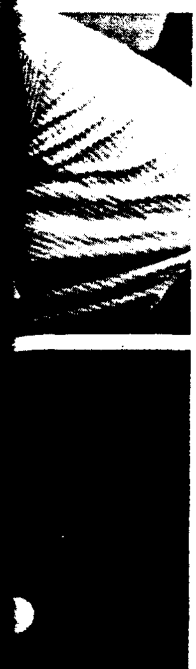






Elements of waste chemical management programs

Minimum requirements:
- Collect hazardous wastes, separate from normal trash
- Transport to an on-site storage facility
- Prepare waste chemicals for disposal
- Store safely pending disposal
- Obtain funds for transport, treatment, and disposal

Additional elements, which are highly desirable or may be required by law:
- Permit for storage for more than 90 days
- Education and training of all those producing and handling waste chemicals
- Analytical support
- Facilities and permits for on-site waste treatment
- Computerized record keeping
- Consultation support to laboratories regarding proper handling and disposal methods to provide laboratory workers with information on the proper handling and disposal of waste chemicals

ke those from most industries, spent rganic solvents account for the largest ortion of hazardous wastes generated y academic laboratories (*10*).

Requirements for waste stream analsis have bedeviled university hazardus waste managers, partly because ich analyses are potentially more exensive than the actual disposal of the aste. Expenses can be high if, as ome have suggested, each container is alyzed to verify its contents. Some alysis of unlabeled waste is necesry, but it is unlikely that the detailed alysis—in some cases by gas chromaography–mass spectrometry—required y permit writers from EPA or state gencies is necessary to determine a roper method of disposal (*11*).

Treatment and disposal facility operars, who interpret regulations with reat caution, often review lists of astes to be disposed of without regard or the quantity involved. For example, e disposal of 50 mL of waste acetone ould receive the same attention as 50 al. Moreover, because of the variety f containers and classes of hazards inolved, the treatment and disposal of boratory wastes is a high-risk, lowrofit business; willing disposal conactors are difficult to find.

In addition to the heterogeneous nate of the waste stream, there are other nusual aspects of managing waste chemicals from academic facilities. Educational institutions are usually open to the public, so it is difficult to restrict access to areas in which hazardous materials are used and stored. Intersecting public roads and noncontiguous boundaries between university property and other land, which are typical of educational institutions' layouts, make interpretation of the regulations difficult and compliance with the law costly. For example, many academic institutions transport waste chemicals along city streets—often for only a few blocks—without EPA manifests and without the packaging required by the Department of Transportation (DOT).

Moreover, the need for a well-designed chemical waste management program is not always apparent to academic administrators, especially when the disposal of chemical wastes has not previously been perceived to be a problem. Many researchers believe that the chemicals with which they work are not hazardous or that the substances are easily rendered nonhazardous before they are discarded. These researchers also believe they have the expertise to dispose of their chemical wastes properly. According to this reasoning, there are few waste chemicals generated, and a good control program can be set up with relative ease.

A more typical situation, however, is that if a chemical disposal service is available, clean-outs of laboratories and storerooms are prompted, and waste chemicals start accumulating in much larger quantities than expected (*12*). Reducing the improper discarding of chemicals in sewers and dumpsters also may add to the large amounts of wastes suddenly requiring disposal.

Some solutions

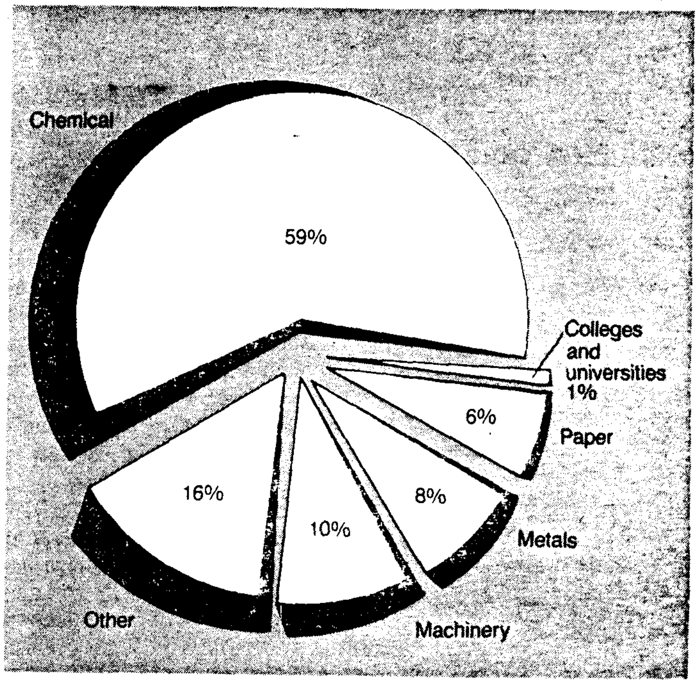
Hazardous waste management strategies for academia are no different from those used by industry. In practice, however, academic producers rely on landfills more heavily than industry does. Academic institutions frequently use the labpack, a 55-gal drum filled with liquid- and solid-waste containers surrounded by absorbent material. These labpacks are usually disposed of in a secure landfill. This method is the most convenient and, if the potential for future legal liability is not considered, the least costly.

Academic institutions are beginning to adopt alternative management practices because of the rapidly escalating cost of sending labpacks to landfills. Other factors responsible for the new approach include regulations that restrict the use of landfills, the fear of future liability, and the availability of other options that are more desirable from an environmental and safety standpoint. A review of the efforts of several institutions illustrates the benefits of several approaches.

Waste reduction. Waste reduction is the most attractive answer to the problem of hazardous waste generation (*13*). This approach encompasses two basic options: the purchase and use of smaller quantities of chemicals and the substitution of less hazardous chemicals in laboratory work. The best results are achieved at the point of generation of wastes, because the user is the person most familiar with the required quantities and properties of chemicals used.

The amount of wastes generated in laboratory course work can be reduced. According to a recent survey by the American Chemical Society (ACS), 116 of 155 academic laboratories ran experiments using smaller amounts of chemicals to reduce hazardous waste generation (*14*). One example is microscale organic laboratory courses, such

FIGURE 1
Hazardous waste generators[a]



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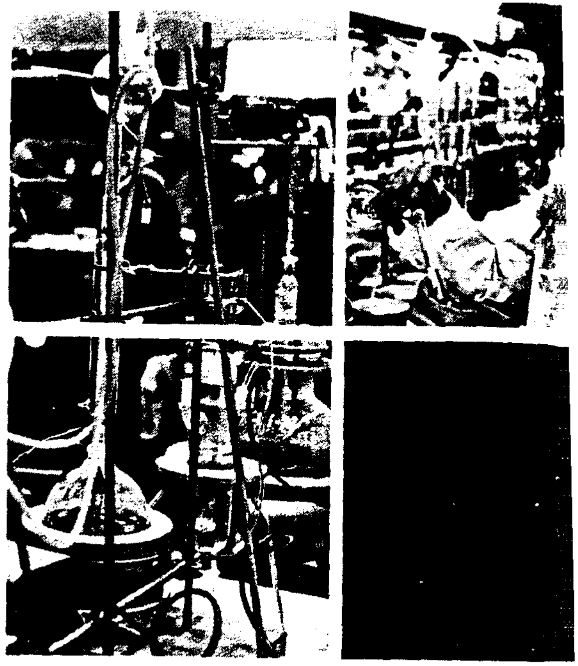


as those taught at Bowdoin College (*15*), in which extremely small amounts of chemicals are used. Such efforts not only reduce quantities of hazardous wastes, but they are safer and more economical.

The use of less hazardous materials is encouraged at the University of Wisconsin, where premixed chromic acid cleaning solutions are no longer readily available from the chemical supply stores; nonchromium alternatives are offered instead. Constraints on the acquisition of certain chemicals, however, can be expensive to administer and are seen as a burden to teachers and researchers. Also, the use of less hazardous materials does not necessarily reduce the amount of waste, although it might simplify waste handling.

Wastes generated in colleges and universities

Major laboratory wastes:
- spent solvents
- spent acids and bases
- unwanted stock chemicals

Minor laboratory wastes:
- spent toxic metals
- degraded stock chemicals
- contaminated laboratory apparatus
- chemicals that react with air or water
- potentially explosive chemicals
- cyanides and sulfides
- pesticides
- polychlorinated biphenyls
- small gas cylinders

Source separation. Once waste chemicals are collected, their amounts can be reduced by segregating wastes according to their properties. Flammable liquids can be combined in 55-gal drums for incineration, rather than placed in labpacks, which are limited by DOT regulations to 15 gal/drum of waste. This approach not only reduces the amount of chemicals disposed of in landfills and the cost of such disposal, but substitutes a more desirable disposal method.

The segregation of chemicals also allows the removal of nonhazardous chemicals from those that must be disposed of as hazardous wastes. These simple, logical procedures often are not carried out because of shortages in the amount of staff available or because of inadequacies in storage and handling facilities.

Such materials as aqueous solutions of heavy metals can be evaporated to reduce their volume. Southern Illinois and Iowa State Universities have used this method with good results (*12, 16*).

Recycling. Interlaboratory recycling of unwanted bottles of stock chemicals has been successful at the University of Wisconsin and other schools (*17*). To make such a program work, criteria for suitable chemicals must be established, storage space must be made available, and the availability of the chemicals must be publicized. The financial benefits, more than $20,000 annually at the University of Wisconsin, come much more from avoiding chemical purchases than from saving on chemical disposal costs.

Reclamation. With the possible ex-

National Research Council recommendations

Some changes have been suggested for EPA regulations that cover academic laboratories and other such generators of small quantities of chemical wastes. They appear in "Prudent Practices," published by the National Research Council (*20*).
- Encourage consistency and integration among federal, state, and local regulations and uniformity with EPA rules as states assume regulatory authority.
- Reduce the detail required for waste characterization, reporting, shipping, and disposal by describing wastes according to seven classes of waste.
- Create a special uniform manifest for labpacks.
- Simplify record keeping by using aggregate waste units—labpack units for wastes taken off-site and class units for wastes kept on-site.
- Continue to regard laboratory hazard reduction methods as an unregulated activity and the products of these methods as nonhazardous unless proven otherwise.
- Provide for the design and operation of small-scale incinerators that are purchased pretested and approved for operation below 25 kg/h for ignitable, listed, and up to 5% acute wastes.

ceptions of mercury and some organic solvents, few wastes can be reclaimed economically. Nevertheless, the University of Minnesota and other schools have reclaimed silver from photographic wastes (*7*). Ohio State University has recycled paint thinner from which contaminants have precipitated and has redistilled ethanol (*18*). Turning chemical wastes over to commercial recyclers is normally infeasible; they are interested in volumes of waste that are far larger than academic institutions normally generate.

Chemical treatment. Chemical treatment has great potential because the necessary expertise and facilities already exist at most academic institutions. Neutralization is the easiest method, but numerous other options are available for the treatment of reactive materials, cyanides, and other toxic agents (*19, 20*). The University of Wisconsin's hazardous waste program, for example, will not accept waste acids and bases; they must be neutralized in the laboratory and disposed of through the sewer. Other chemicals also can be treated in the laboratories where the wastes are generated; researchers can carry out the necessary procedures.

Another approach is to bring wastes to a central facility for treatment by specialized personnel, thereby relieving researchers of the responsibility for treatment. This method takes advantage of economies of scale and avoids liability that could be incurred as a result of disposal by untrained persons. Each school decides on what approach to use according to its resources and priorities. But many schools, particularly smaller ones, cannot bear the expense of a treatment facility, properly trained personnel, or the hazardous waste permits that are required in many cases.

None of these management strategies should be considered a panacea applicable to all waste chemicals, although the landfilling of labpacks has been viewed as such. Instead, a sound management program combines these strategies, as appropriate, with the goal of minimizing the generation of wastes.

Current needs

Managers of waste chemicals at academic institutions will benefit most from increased awareness of the nature of the hazardous waste problem; this will motivate them to develop policies, services, and technologies to deal with the wastes generated. The most thorough discussion of these problems is found in the National Research Council's book, "Prudent Practices" (*20*). Its authors recommend certain changes in EPA regulations and describe a number of useful developments that deserve encouragement.

In April 1984, ACS petitioned DOT for a simplification of the shipping requirements for labpacks (*21*). Although other organizations have lobbied for regulatory changes most academic institutions consider themselves to be small-quantity generators and have not given much attention to hazardous waste disposal rules. Managers of academic institutions should note that the new definition of small-quantity generators in the law reauthorizing RCRA brings many more schools into the hazardous waste regulatory system.

The following is a short list of topics that merit consideration and discussion by academic hazardous waste managers, hazardous waste disposal companies, and regulatory agencies:

Hazard assessment procedures for chemicals not specifically regulated by EPA. By focusing on industrial wastes, EPA regulates only a small fraction of the millions of chemicals in existence. Although some general guidelines have been prepared, determining whether a chemical or chemically contaminated material can be safely disposed of in an ordinary trash container or sanitary sewer may be extremely difficult (*20*).

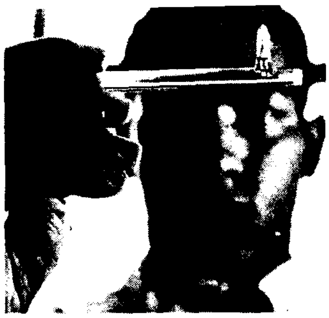
Small, or *de minimis* quantities or concentrations of hazardous wastes, considered exempt from regulation. The lack of agreement on what constitutes a *de minimis* amount leaves colleges and universities liable for record keeping, management, and disposal of all sizes of containers, even those of the frequently encountered gram and milliliter capacities. More schools will be concerned about regulatory requirements for small containers of waste chemicals, since the small-quantity generator limit has been lowered from 1000 kg/mo to 100 kg/mo by the law reauthorizing RCRA.

Standard tests for the identification of unknown contaminants. These tests would clarify a generator's responsibility and liability. They are needed because wastes with deteriorated, cryptic, or missing labels are common in academic institutions. Contractors charge anywhere from a few dollars to several hundred dollars per sample for analysis and disposal of wastes of unknown composition.

Acutely hazardous wastes. Because the accumulation of an acutely hazardous waste, such as a cyanide compound, is subject to much tighter regulations than those covered by the small-quantity provisions of RCRA, almost all academic institutions should be prepared to comply with the stringent generator rules. Alternative regulations are suggested for minimizing this regulatory burden; for instance, the shipment of 1 kg every 90 d (in the extreme case) is an inappropriate requirement for small schools.

One-time generation. The unclear regulatory status of infrequent generators of hazardous waste discourages schools that have adopted waste reduction procedures from cleaning existing chemical stockrooms. Because of the uncertain regulatory status, these infrequent generators often are required to spend an inordinate amount of time learning the regulatory requirements that apply to larger generators.

Simplification of record keeping. Current requirements for record keeping on waste generation, storage, transport, and disposal focus on each chemical entity separately and multiply disproportionately for the many different wastes that academic institutions produce (*22*). Academic institutions should be allowed to simplify this record keeping. For example, rather than specifying that a drum of commingled



solvents contains 1 L of one solvent and 10 L of another, it could be specified that the drum contains nonhalogenated flammable solvents.

Access to services. Because the volume of hazardous wastes from colleges and universities is small, companies in the hazardous waste business do not find it profitable to serve academic institutions. Therefore, when they are called upon to do so, these companies charge high prices. Also, the diversity of waste composition presents a major problem for contractors; some have refused to serve academic institutions because of this problem (*23*). Commercial facilities for the incineration of nonsolvent wastes, such as organic solids or contaminated laboratory apparatus, generally will not handle the relatively small quantities academic institutions have. Few companies offer appropriate services, such as chemical treatment and solvent recycling, for the quantities typically generated by academic institutions.

One way of reducing costs may be through cooperative efforts, following the examples of the University of Minnesota and some municipalities (*6*). We believe that cooperative ventures aimed at meeting the hazardous waste disposal needs of small-quantity generators are worthy of encouragement.

Small-scale incineration. As an alternative preferable to landfilling, some schools have considered the use of existing incinerators that normally burn pathological (usually infectious) wastes for destroying solvents and other waste chemicals. Most existing on-campus incinerators, however, are not designed to destroy chemical wastes as efficiently as EPA requires.

Moreover, a waste stream that constantly changes in chemical composition is difficult and expensive to test. Although a test burn may cost as little as \$10,000, EPA estimates the usual cost of a trial burn to be \$50,000–\$100,000 (*24*). Exacerbating this is the possibility of incurring large expenses in complying with current regulations and in improving equipment. The high costs, combined with the lack of availability of small-scale incinerators, have made on-campus incineration an impractical option for almost all institutions (*25*).

The alternative of using some waste solvents as a fuel supplement in boilers may become restricted by the RCRA amendments of 1984. In any event, the fuel supplement approach is suitable for only some of the wastes.

Several developments could lead to the availability of an off-the-shelf, small-scale (<25 kg/h) incinerator that could be granted an EPA permit for the destruction of certain chemicals. These include EPA's acceptance of a trial burn of surrogate principal organic hazardous compounds rather than a burn of specific wastes (*26*), a generic permit application, and reduced siting procedures and instrumentation requirements for small treatment facilities. Given that the quantities of waste involved are relatively small, it might be reasonable for EPA to relax the 99.99% destruction efficiency standards for small-scale incinerators.

Standard methods for destruction of potentially explosive materials. Degraded picric acid and compounds that can form peroxides are serious laboratory hazards that are usually found in larger amounts than the gram quantities recommended for laboratory treatment procedures. Off-campus help has come from local bomb squads, but they often ignore DOT transportation rules and EPA regulations for thermal treatment facilities. Moreover, contractors that handle shock-sensitive materials are almost impossible to find, and those few that render this service charge up to \$500/lb to dispose of these wastes. Standard procedures for siting, containment during detonation, and monitoring for residuals are needed.

Uncertain future

We have identified some, but by no means all, of the difficult issues of managing hazardous wastes at academic institutions. There are other newer problems, such as those with leaking underground storage tanks, that arise all too frequently.

It is unlikely that EPA or the waste disposal industry will soon address the hazardous waste problems of colleges and universities. The few large firms that dominate the hazardous waste management industry do not need the business of such a small economic sector. Because of the prohibitive cost of liability insurance, hazardous waste management is not a field suited to small businesses that might otherwise be interested in the academic market.

Many treatment technologies have been investigated, but the simplest, incineration, is bogged down by requirements for siting, testing, and permitting. As a result, some wastes will be stored until appropriate methods of disposal or destruction become available.

We believe that the answer for most academic generators is self-sufficiency in all aspects of hazardous materials management, from waste reduction and recycling to laboratory scale treatment. This approach may become the model for all hazardous waste generators.

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