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ABSTRACT

This guide provides an overview of waste generating processes and operations that occur in educational or research institutions and presents options for minimizing waste generation through source reduction and recycling. A broad spectrum of waste chemicals in laboratories, art studios, print shops, maintenance, and other operations can be generated from these institutions, and while the total waste quantities are small, the variety of wastes is considerable. Reducing the generation of these wastes at the source, or recycling the wastes on or off site, will benefit research and educational institutions by reducing disposal costs and lowering the liabilities associated with hazardous waste disposal. The worksheets and the list of waste minimization options were developed through assessments of three research and educational institutions in the Los Angeles, California, area: (1) a small, private liberal arts college; (2) a large university; and (3) a technical research institute. Appendices contain case studies of waste generation and waste minimization practices of the three institutions studied, and sources of useful technical and regulatory information. (MLF)

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GUIDES TO POLLUTION PREVENTION: RESEARCH AND EDUCATIONAL INSTITUTIONS

RISK REDUCTION ENGINEERING LABORATORY
AND
CENTER FOR ENVIRONMENTAL RESEARCH INFORMATION
OFFICE OF RESEARCH AND DEVELOPMENT
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NOTICE

This guide has been subjected to U.S. Environmental Protection Agency's peer and administrative review and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. This document is intended as advisory guidance only to research and educational institutions in developing approaches for pollution prevention. Compliance with environmental and occupational safety and health laws is the responsibility of each individual business and is not the focus of this document.

Work sheets are provided for conducting waste minimization assessments of educational and research institutions. Users are encouraged to duplicate portions of this publication as needed to implement a waste minimization program.

FOREWORD

This guide provides an overview of waste generating processes and operations which occur in educational or research institutions and presents options for minimizing waste generation through source reduction and recycling. A broad spectrum of waste chemicals in laboratories, art studios, print shops, maintenance, and other operations can be generated from these institutions, and while the total waste quantities are small, the variety of wastes is considerable.

Reducing the generation of these wastes at the source, or recycling the wastes on or off site, will benefit research and educational institutions by reducing disposal costs and lowering the liabilities associated with hazardous waste disposal.

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Lisa M. Brown of the U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, was the project officer responsible for the preparation and review of this document. Other contributors and reviewers include: Dennis Veith, Delco Systems; and Ross Grayson, University of California at Santa Barbara.

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SECTION 1
INTRODUCTION

Reduction of pollutant emissions associated with research and educational activities is an important objective consistent with national environmental policy. More significantly, however, the adoption of waste minimization by the research and educational community carries with it a tremendous potential for designing pollution out of future industrial processes right in the lab. Waste minimization awareness can also be instilled and propagated by educational institutions, so that today's students and tomorrow's professionals can apply pollution prevention in their endeavors. Hence, the importance of instituting pollution prevention within research and educational organizations cannot be overstated.

This guide was prepared to provide research and educational institutions with guidelines and options to minimize hazardous wastes. These options and procedures can also be used in efforts to minimize all wastes generated at a facility. The guide is intended primarily for use by research and development laboratories and graduate and undergraduate educational institutions that conduct research or teaching activities which employ hazardous materials. Others who may find this document useful include high schools, community colleges, and vocational institutions, as well as industrial laboratories, regulatory agencies, and consulting organizations.

The worksheets and the list of waste minimization options were developed through assessments of three research and educational institutions in the Los Angeles area. The effort was commissioned by the California Department of Health Services (Calif. DHS 1988). The institutions consisted of:

- A small, private liberal arts college;
- A large university; and
- A technical research institute.

Their operations, research and teaching activities, and waste generation and management practices were surveyed. Existing and potential waste minimization options were characterized.

In the following sections of this manual you will find:

- An overview of research and educational institutions and the hazardous chemicals they employ (Section Two);
- Waste minimization options for research and educational institutions (Section Three);
- Waste Minimization Assessment Guidelines and Worksheets (Section Four)
- Appendices, containing:
  - Case studies of waste generation and waste minimization practices of the three institutions studied; and
  - Where to get help: Sources of useful technical and regulatory information.

To provide the reader with general background information, the next subsection will present an overview of waste minimization goals and opportunity assessments.

Overview of Waste Minimization Goals and Opportunity Assessments

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for implementing RCRA, the U.S Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the institutions concerned. This guide is one of the approaches EPA is using to provide institution-specific information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a facility.

EPA has also developed a general waste minimization manual for use by industry. The *Waste Minimization Opportunity Assessment Manual* (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into organizational policies and structures, how to establish an institution-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization opportunity assessment are explained below.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is usually considered preferable to recycling from an environmental perspective.

A Waste Minimization Opportunity Assessment (WMOA), sometimes called a waste minimization audit, is a systematic procedure for identifying ways to reduce or eliminate waste. The steps involved in conducting a waste minimization assessment are outlined in Figure 1 and presented in more detail in the next paragraphs. Briefly, the assessment consists of a careful review of an institution's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

Research and educational institutions have different waste management problems than most industrial waste generators and different resources available to deal with them. In addition, the management structures of research and educational institutions often do not lend themselves to the more centralized decision making and direction typical of business management. While decentralization may facilitate academic independence, a decentralized approach to hazardous waste management poses nearly insurmountable obstacles to those responsible for tracking and assuring the proper disposal of hazardous wastes. Decentralization also diffuses management commitment -- an essential ingredient in successful waste minimization programs -- to many separate departments, further complicating the already complex problem of identifying and controlling hazardous material streams within an institution.

ASSESSMENT PROCESS

The four phases of a waste minimization assessment are planning and organization, assessment phase, feasibility analysis phase, and implementation. Each of these phases is discussed below.

Planning and Organization

Essential elements of planning and organization for a waste minimization program are:

- Getting management and administration commitment for the program;
- Setting waste minimization goals; and
- Organizing an assessment program task force.

The importance of getting top level management commitment to a waste minimization program cannot be overestimated.

Assessment Phase

The assessment phase involves a number of steps:

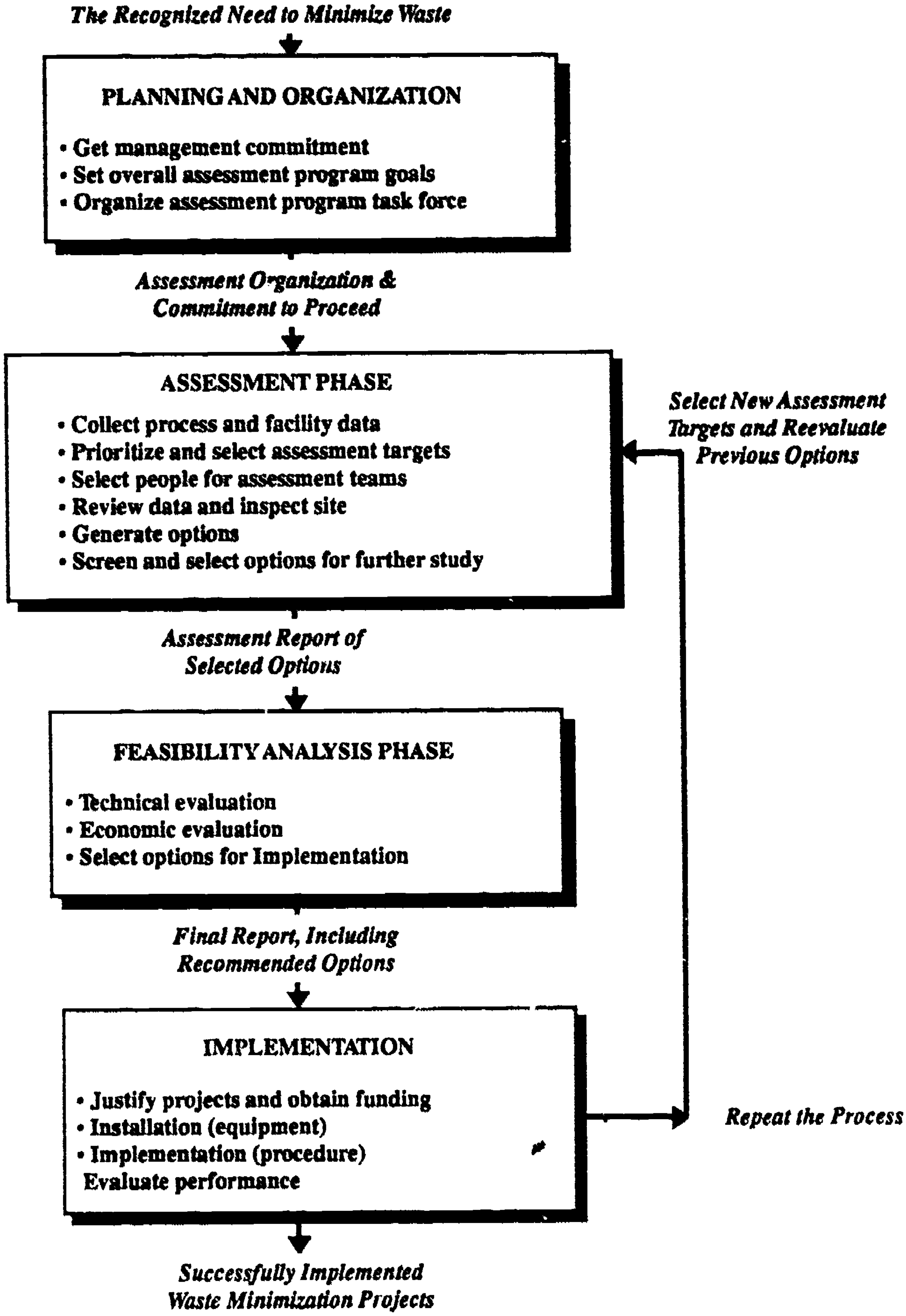
- Collect activity and facility data
- Select and prioritize assessment targets
- Select assessment team
- Review data and inspect laboratories and waste handling facilities
- Generate waste minimization options
- Screen and select options for further study

Collect data on sources and quantities of waste generation. The waste streams at an institution should be clearly identified and succinctly characterized. Since waste streams and volumes are highly variable, a review of long term records is the best source of information, if such records exist in a format and in sufficient detail that provides useful information. Information about waste streams may be available on purchase orders or requisitions; hazardous waste manifests; lab pack packing lists; from sampling programs and other possible sources.

A basic understanding of the activities that generate waste at an institution is essential to the WMOA process. Activity inventories should be prepared to identify the sources, quantity, types, and rates of waste generation. Also, preparing material balances for various activities can be useful in developing estimates of overall waste generation and emissions that may have been unaccounted for previously. Research and educational institutions may find this data collection phase to be difficult due to lack of comprehensive and detailed records and the irregular nature of research and teaching activities where chemicals used and quantities of waste generated change from one time period to the next. It may be useful to identify the larger and relatively predictable waste streams first and focus on them. The institution may find it highly beneficial to conduct a preliminary waste minimization opportunity assessment prior to commencing a research or teaching program which would generate wastes in order to identify opportunities for waste minimization specific to that program.

Prioritize and select assessment targets. Ideally, all waste streams in an institution should be evaluated for potential waste minimization opportunities. With limited resources, however, it may be necessary to concentrate waste minimization efforts in one or two specific areas. Such considerations as quantity of waste generated, probability of success, hazardous properties of the waste, regulations, safety of employees, economics, and other characteristics need to be evaluated in prioritizing target waste streams.

Figure 1. The Waste Minimization Assessment Procedure



Select assessment team. The team should include people with direct responsibility for and knowledge of the activities generating the waste stream.

Review data and inspect laboratories and waste handling areas. The assessment team first evaluates data on the research or teaching activities in advance of the inspection. The inspection should follow the target activities from the point where input materials are received, through the activities generating the wastes, to the points where wastes leave. Waste generating activities may include laboratory experiments and demonstrations, including residues from unsuccessful experiments; art studios and photography laboratories; maintenance operations; and storage areas for raw materials and wastes both in the laboratories and at other locations within the institution. The inspection may result in the formation of preliminary conclusions about waste minimization opportunities. Full confirmation of these conclusions may require additional data collection, analysis, or site visits.

Generate options. The objective of this step is to generate a comprehensive set of waste minimization options for further consideration. Since technical and economic concerns will be considered in the later feasibility step, no options are ruled out at this time. Information from the site inspection, as well as from chemical suppliers, technical and trade literature, equipment vendors, government agencies, consultants, researchers and technicians may serve as sources of ideas for waste minimization options.

Both source reduction and recycling options should be considered. Source reduction may be accomplished through:

- Good operating practices
- Reducing the scale of laboratory experiments
- Eliminating use of carcinogenic chemicals such as benzene and chloroform
- Increasing use of instrumentation
- Eliminating use of oil based paints in maintenance
- Improving inventory control utilizing computerized tracking and inventory systems.

Recycling opportunities may include:

- Establishing an internal recycling program where unused reagents are stored centrally and made available to all users
- To the extent possible, recycling wastes from one activity to another.

Screen and select options for further study. This screening process is intended to select the most promising options for full technical and economic feasibility study. Through either an informal review or a quantitative decision-making process, options that appear marginal, impractical or inferior are eliminated from consideration.

Feasibility Analysis

An option must be shown to be technically and economically feasible in order to merit serious consideration for adoption by an institution. A technical evaluation determines whether a proposed option will work in a specific application. Both activities and equipment or operating changes need to be assessed for their overall effects on waste quantity.

An economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. As in any project, the cost elements of a waste minimization project can be broken down into capital costs and operating costs. Cost savings and changes in revenue need also to be considered. For options that are technically feasible but are not initially shown to be cost effective, consideration of benefits to society (e.g., teaching of a waste minimization ethic to students) should be considered as well.

Implementation

An option that passes both technical and economic feasibility reviews should then be implemented at an institution. It is then up to the WMOA team, with management support, to continue the process of tracking wastes and identifying further opportunities for waste minimization throughout a facility by way of periodic reassessments. Either the ongoing reassessments or an initial investigation of waste minimization opportunities can be conducted using this manual.

SECTION 2
RESEARCH AND EDUCATIONAL INSTITUTION PROFILE

The U S. Environmental Protection Agency (EPA) has estimated that the total amount of hazardous waste generated by research/educational institutions is from 2,000 to 4,000 metric tons per year (USEPA 1987). This is less than one percent of the national total of hazardous waste generated annually. While the total waste generated is small, the variety of wastes is considerable. These wastes are generated at literally thousands of institutions located throughout the country. For example, in 1988 there was an estimated total of 3,406 higher level educational institutions in the United States, plus over 101,000 primary and secondary schools (Encyclopedia Britannica, 1989).

WASTE GENERATION

Hazardous waste generation at educational and research institutions contrasts with that of most industrial generators. Industrial generators typically have a few large volume waste streams. Educational and research institutions, however, use small amounts of a broad spectrum of chemicals. The waste generated consists of small quantities of a wide diversity of materials. This difference requires research and educational institutions to employ unique waste reduction strategies.

For example, the University of Illinois disposed of 7,300 containers holding more than 2,100 different chemicals and mixtures in 1984. The University of Massachusetts, Amherst disposes of approximately 2,000 different chemicals and mixtures each year. The size of containers containing wastes prior to shipment ranges from 55-gallon drums to a single ampoule (Sanders 1986).

Laboratory wastes are typically generated in quantities of less than one gallon per occurrence. Research-related waste streams include inorganic acids and bases, organic solvents, metals, unused chemicals, reaction products from experiments, and some photographic waste. Waste oil is also generated in many laboratories where vacuum pumps and other rotating equipment is utilized.

Research laboratories typically generate more waste than teaching laboratories. Chemistry departments tend to be the largest hazardous waste generators of the teaching laboratories. Other departments with laboratories are geology, physics, psychology, and engineering.

Art, printing, photography, and institution maintenance also generate hazardous waste. Art waste includes paints, thinners, other solvents, and heavy metals. Printing operations generate waste ink and solvents. Photographic processing generates waste silver and rinsing and developing solutions. Maintenance operations generate waste oils, vehicle maintenance waste, solvents, pesticides, water treatment chemicals, PCB oil from old transformers, possibly asbestos, and small quantities of other wastes.

Secondary and vocational schools also generate chemical waste. In secondary schools waste is generated in science laboratories, arts and shop classes, and in vocational programs (USEPA 1987). Table 1 shows typical waste generation in secondary schools.

WASTE MANAGEMENT

Disposal in lab packs is the most common disposal practice. Waste oils and solvents may be accumulated in 55 gallon drums. In lab packs, small bottles, vials, cans, and other containers of waste, segregated by compatibility of contents, are packaged in drums with absorbent cushioning sufficient to protect against breakage and to absorb liquids in the event of leakage. This procedure is required by the federal Department of Transportation (DOT) for lab packs. The drums may then shipped to a Class I landfill for disposal or to an incineration or recycling facility. The upcoming restriction on land disposal of many hazardous chemicals commonly disposed of in lab packs will provide institutions with strong incentives to implement waste reduction strategies.

Three waste audit studies were conducted for the California Department of Health Services in preparing this manual. They included a large state university, a small private college, and a research institute. These studies, described in the appendices, found that the two larger institutions had established waste management programs. The EPA also found that campuses with large research programs have extensive waste management programs (USEPA 1987).

The historical reason for this is that large institutions have needed formal programs addressing disposal of radioactive and special-hazard chemical wastes. When hazardous waste control laws and regulations were implemented in the early 1970's, the existing programs were expanded to deal with the collection of all regulated wastes. The need to keep disposal and liability costs down were key incentives for establishing waste management programs. Safety concerns have resulted in elimination of many carcinogenic compounds from institutional use.

The waste audit studies also found that educational institutions that are part of a statewide system may have more difficulty implementing and expanding hazardous waste management programs. This is attributable to the many levels of administrative bureaucracy that control policy and funding decisions regarding all aspects of institutional management. Strong local campus management commitment may overcome this bureaucratic impediment.

Regulatory agencies have not, until recently, enforced environmental and safety regulations at secondary schools. As a result, little or no effort on the part of the school district administrators was put into hazardous material management. The EPA found (USEPA 1987) that several school districts studied had no budget at all for dealing with hazardous materials. EPA researchers encountered some school administrators who had no interest in developing a waste management program. Awareness is beginning to increase as a result of the recent right-to-know laws.

Table 1. High School Course Hazardous Waste Generation

Courses Likely to Generate Hazardous Waste	Percentage of Schools Offering Courses 1983[a]	1982[b]	Types of Wastes That Are Potentially Hazardous
AGRICULTURAL ARTS:			
Agriculture	29.7	48.4	Pesticides, fertilizers
Horticulture/Landscaping	1.6	23.4	Pesticides, fertilizers
GRAPHIC ARTS:			
Art	74.0	89.6	Oil-based paints, solvents
Graphics	6.0	33.3	Inks, solvents, acids
Jewelry and Metalwork	6.9	9.8	Acids
Pottery and Ceramics	16.2	28.8	Metals in glazes, silica in clays
Painting/Drawing/Design	19.6	36.0	Oil-based paints, inks, solvents
Photo/Film Making	6.4	14.1	Silver, developing and fixing chemicals
INDUSTRIAL ARTS:	75.5	90.6	
Carpentry/Woodworking	46.1	70.3	Stains, solvents, wood preservatives
Leather/Textiles/Upholstery	2.1	6.9	Dyes
Plastics	4.1	4.8	Ketones
Photography	5.5		Silver, photochemicals, inks and solvents
Printing/Photo/Graphics			
Metalworking/Foundry	33.8	41.7	Metal dust
Welding	9.0	31.7	Metal waste
Auto Mechanics	18.3	47.5	Degreasing solvents, oil, grease
Power/Auto Mechanics	17.6	33.1	
SCIENCE COURSES:			
Natural Science	89.3	99.7	Various chemicals, acids, bases
Biology	79.9	97.8	
Chemistry	88.1	89.4	
VOCATIONAL COURSES:			
Trades and Industry	24.0	94.0	
Graphic Arts	3.1	3.2	Inks, solvents
Printing/Lithography	1.9	10.3	
Textile/Leather Products	1.3	10.3	Dyes
Body and Fender Mechanics	4.4	17.9	Batteries, paints, degreasing solvents, oil,
Automobile Mechanics	12.5	11.7	grease, acids, alkaline waste
Masonry	2.5	9.5	Paint, solvents, muriatic acid
Carpentry	6.4		Stains, solvents, paints, wood preservatives
Woodworking 1st year	4.0		
Woodworking-Advanced	3.9	4.3	
Machine Shop	7.0	17.7	Stripping and cleaning solutions, plating
Sheet Metal	1.8	0.1	bath residues, acids, bases, metal dust
Metalworking	1.2	0.7	
Welding and Cutting	5.7		
Cosmetology	5.1	18.5	Various chemicals

Table 1. High School Course Hazardous Waste Generation (Continued)

Courses Likely to Generate Hazardous Waste	Percentage of Schools Offering Courses 1983a	1982b	Types of Wastes That Are Potentially Hazardous
HEALTH COURSES:			
Allied Health		20.6	Various chemicals and pharmaceuticals
Laboratory/Chemical Technology		4.5	
Nursing		11.7	

[a]Based on survey of 7,850 out of 15,306 schools.
[b]Based on survey of 941 out of 15,667 schools.
Source: A Trend of High School Offerings and Enrollment: 1972-1973 and 1981-1982, Evaluation Tech. Inc. under contract 300-83-0114 with DOE.

SECTION 3
WASTE MINIMIZATION OPTIONS FOR RESEARCH AND EDUCATIONAL INSTITUTIONS

In the institutional audits conducted for the California Department of Health Services, numerous hazardous waste reduction strategies were identified. Technological advances have reduced the amounts of chemicals required for qualitative and quantitative analyses. For example, instrumental analysis uses one-tenth to one-hundredth the volume typically used in wet chemistry techniques. These waste reduction strategies have decreased chemical usage by as much as tenfold. Many of these could be implemented at high schools and vocational training schools.

In addition, standard waste minimization practices, such as replacing oil-based paints, reducing disposal of unused or out-of-date materials (paints, pesticides, chemicals, etc.), controlling inventories, and improving waste tracking systems are all applicable to the research and educational institution environment. The waste minimization options available can be classified into three general groups for further discussion. These waste reduction methods are improved material management practices, improved laboratory practices, and improved practices in other departments. A list of appropriate methods is shown in Table 2.

Better operating practices are procedural or institutional policies that result in a reduction of waste. They include:

- Waste stream segregation
- Personnel practices
  - Management initiatives
  - Employee training
  - Employee incentives
- Procedural measures
  - Documentation
  - Material handling and storage
  - Material tracking and inventory control
  - Scheduling
- Loss prevention practices
  - Spill prevention
  - Preventive maintenance
  - Emergency preparedness
- Accounting practices
  - Apportion waste management costs to departments that generate the waste

Better operating practices apply to all waste streams. In addition, specific better operating practices that apply to certain waste streams are identified in the appropriate sections that follow.

Improved Material Management Practices

Two federally funded research laboratories, Lawrence Livermore National Laboratory (LLNL) in Livermore, California and Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee have extensive waste minimization programs. At LLNL, a study completed by Bechtel (Bechtel National, Inc. 1986) will be used to establish waste minimization programs for the four largest hazardous waste generators: plating shops, experimental circuit board manufacturing, nuclear chemistry, and general plant. At ORNL, an institution-wide program has been implemented which commits ORNL management to "the reduction of hazardous waste generation and minimization of generated waste to reduce impacts on human health and the environment." Economically practical waste minimization techniques, including waste abatement, recycling, good housekeeping, and in-plant treatment are being implemented (Barkenbus 1987).

During 1983-84, ORNL generated 200,000 pounds of hazardous waste each year. To reduce this amount the Hazardous Waste Minimization Program includes the following components (Barkenbus 1987):

- Identify all waste streams, review and make recommendations for procedural modifications, provide incentive mechanisms for new ideas/procedures, and information exchange
- Establish effective planning and procurement practices
- Set goals to meet quantitative reduction levels
- Establish a baseline with which to compare waste minimization progress
- Prioritize possible waste treatment options according to cost and environmental problems
- Develop waste reduction/elimination plans for each waste stream
- Assess economic, technical, and regulatory feasibility of plans and
- Implement those plans that meet cost/benefit goals.

Table 2. Waste Minimization Methods for Research and Educational Institutions

Category	Waste Minimization Methods
Improved Material Management Practices	Establish a centralized purchasing program. Order reagent chemicals in exact amounts. Encourage chemical suppliers to become responsible partners (e.g., accept outdated supplies). Establish an inventory control program that can trace. chemical from cradle to grave. Rotate chemical stock. Develop a running inventory of unused chemicals for use by other departments. Centralize waste management. Appoint a safety/waste management officer for each department. Educate staff on the benefits of waste minimization. Establish waste minimization goals. Perform routine self-audits.
Improved Laboratory Practices	Scale down the volumes of chemicals used in laboratory experiments. Increase use of instrumentation. Reduce or eliminate the use of highly toxic chemicals in laboratory experiments. Preweigh chemicals for undergraduate use. Reuse/recycle spent solvents. Recover metal from catalyst. Treat or destroy hazardous waste products as the last step in experiments. Keep individual hazardous waste streams segregated, segregate hazardous waste from nonhazardous waste, segregate recyclable waste from non-recyclable waste. Assure that the identity of all chemicals and wastes is clearly marked on all containers. Investigate mercury recovery and recycling with an outside vendor.
Improved Practices in Other Departments	Replace oil-based paints with water-based paints in art instruction and maintenance operations. Modify paint-spraying techniques. Reduce generation of pesticide waste. Collect waste oil and solvents for recycling. Use biodegradable aqueous or detergent cleaners. Investigate silver recovery or recycling with an outside vendor for photoprocessing wastes. Provide training in hazardous waste management practices for students in art and photography courses and facilities management/maintenance personnel.

While many institutions may not have an adequate level of funding to perform all of the steps included in the above program, there are a number of low-cost options which can be employed to reduce chemical usage and disposal costs. These options are discussed below:

- A centralized purchasing program should be established. This program should monitor requests for chemicals, and implement policies. These policies would include staggered deliveries, sharing of chemicals between common users, arranging with instructors and investigators to purchase part of their request if the quantities seem excessive, and arrange for partial shipment with the remainder shipped on an as-needed basis (USEPA 1987). The program should include plans for leftover chemicals.
- Order reagent chemicals in exact amounts to be used. Do not order extra chemical quantities to take advantage of unit cost savings. The net savings will be lost due to eventual disposal costs if the chemical is not used (American Chemical Society 1985).
- Encouraging chemical suppliers to become responsible partners in a waste minimization program by ordering chemicals from suppliers who will provide quick delivery of small orders, will accept return of unopened stock, and are willing to offer off-site waste management outlets or cooperatives for laboratory wastes.
- Establish an inventory control program which can trace chemical usage from cradle to grave. This will promote sharing of chemicals between common users, provide data on who is using extremely hazardous chemicals, identify who the high volume users are, locate where caches of unused reagents are, and delineate where waste reduction options need to be implemented. Reagent chemicals having remaining shelf-life can be monitored for approaching expiration. The inventory can be computerized or kept on a card filing system.
- Rotate chemical stocks using chemicals before their shelf life expires (first-in-first-out stock usage).
- Develop a running inventory of unused reagent chemicals for use by other laboratories or faculty. The inventory control program should extend to all laboratories, including that of individual professors.
- Appoint or hire a safety/waste management officer for each department, or for the entire school if it is a small institution. Centralizing waste management into one position will facilitate a coordinated and efficient implementation of regulations, institution policy and waste reduction goals. The officer should develop a waste reduction training program for faculty, students, and staff.
- Educate professors, students and staff on the benefits of waste reduction. This should include instruction on specific techniques for reducing waste generation.
- Establish annual goals for institution-wide and departmental waste reduction. First determine past yearly totals of waste generation, then assess economic and technical feasibility for establishing and achieving specific reduction goals.
- Provide routine self-audits for laboratories of professors, students, and staff to minimize reagent accumulation and maximize recycling.

Education on waste minimization opportunities can enhance efforts to reduce the volume of waste generated. This can occur through departmental meetings, memos, and seminars. Information communicated should include why reduction is important and available opportunities for reduction. The major generating departments should have a training program for all faculty and staff who may generate or handle hazardous materials. Special training should be held for procurement staff to make them aware of the exit costs of unused chemicals.

Implementing an institution-wide program allows for a coordinated approach to addressing each area or department generating waste. The program should be prioritized by addressing campus-wide generation first, then chemistry, biology, other science departments, art, photography, and maintenance functions. An overall hazardous waste management decision tree diagram is presented in Figure 2.

Improved Laboratory Practices

Laboratories are responsible for the largest variety of wastes, even if the individual volumes are not large. Chemistry generally generates the most hazardous waste, followed by biology and other departments (materials science, chemical engineering, physics, geology, etc.) and by the other activities noted above. Faculty, researchers, and students in departments which generate hazardous wastes often do not know requirements for proper disposal of wastes they handle and may not even be aware of the hazards posed by some of the chemicals in regular use. Old practices die hard. Wastes from chemistry experiments may still be poured down the sink and end up in the sewer. Forgotten chemicals and used or unused reagents may be left in unmarked test tubes, beakers, vials, or bottles, losing

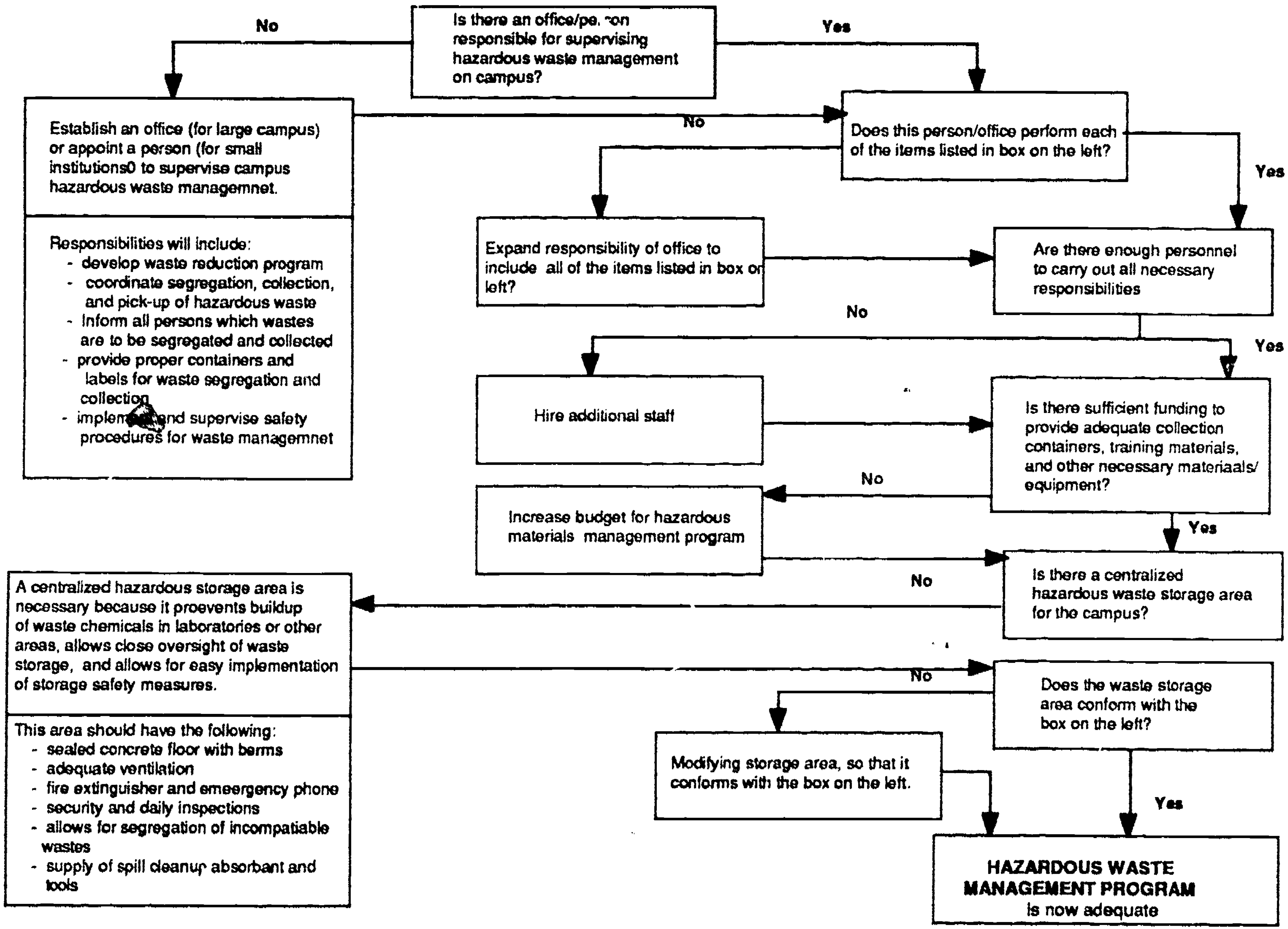


Figure 2. Hazardous waste Management Decision Tree Diagram

their identity and becoming "unknowns" which require expensive re-identification prior to disposal.

Practices that can reduce laboratory waste generation include the following:

Scale down the volumes of chemicals used in laboratory experiments. Using smaller volumes of chemicals in teaching laboratories has reduced waste generation. Five years ago at the university, undergraduate laboratory experiments were performed using 50 to 500 ml of reactants. Last year volumes were reduced to 10 to 100 ml. This year the experiments will use 1 to 10 ml. At the college all experiments are performed with one fourth the volume stated in the laboratory manuals.

Professor Dana at Bowdoin College, Brunswick, Maine, has developed a microscale organic laboratory course. Students perform laboratory experiments using one hundredth to one thousandth the volume of starting material typically used. Using such small volumes has the following advantages: reduction in chemical usage and waste generation, decreased hazard of fire and explosion, and reduced concentration of harmful organic vapors in laboratory air (Rawls 1984). Another facility that has developed a complete microscale laboratory course for its Chemical Technology Program is the St. Paul Technical Institute (Bridges et al. 1989).

Increase use of instrumentation. Instrumentation in laboratories has increased in recent years. Instrumental analysis only requires minute quantities for quantitative determinations as opposed to more traditional wet chemistry techniques. Chemical usage has been reduced ten to one-hundred-fold as a result. In chemistry, Nuclear Magnetic Resonance (NMR) analysis requires a 1 ml sample for quantitative analysis. Entire chemical reactions can be performed in an NMR tube which holds under 5 ml of reactants/products. Other common instruments used are chromatography (gas, high pressure liquid, thin layer, other types), mass spectrophotometry, atomic absorption, photoionization detectors, ion probes, X-ray diffraction analyzers, IR and UV spectrophotometers, magnetic balances, and others.

- Substitute less hazardous chemicals in experiments. For example: substitute sodium hypochlorite for sodium dichromate; use alcohol for benzene; substitute cyclohexane for carbon tetrachloride in the standard qualitative test for halide ions; stearic acid can replace acetamide in phase change and freezing point depression experiments; and use 1,1,1-trichloroethane instead of carbon tetrachloride and/or chloroform. A number of laboratories are using detergents, potassium hydroxide, or sonic baths as substitutes for the chromic acid solutions used to clean glassware (Bridges et al. 1989).
- Pre-weigh chemicals for undergraduate usage. This will reduce spills and other wastes generated by students performing their own weighing. It will also increase laboratory productivity by reducing lab time per student.
- When cleaning with solvents reuse the spent solvent for the initial cleaning and use fresh solvent only for the final rinsing. This reuse will decrease the amount of reagent solvent used (USEPA 1987).
- Segregate solvents in a closed top drum and recycle.
- Distill and reuse solvents for classroom experiments or as thinners and degreasers by the maintenance department. Low cost solvent stills are available in a variety of sizes, including high quality fractional distillation units. Check with fire and worker safety regulations regarding use of on-site solvent distillation.
- Platinum, palladium, and rhodium contained in catalysts can be recovered using chemical procedures specific to the particular metals. Segregation of these wastes for off-site recycling may be preferable.
- Investigate if unused reagent chemicals and their containers can be returned to the manufacturer. Sealed bottles of stable chemicals may be resalable by the supplier.
- Destroy wastes as the final step in experiments. This will reduce the need for off-site disposal. If done in undergraduate laboratories it will develop in students an awareness of proper waste management and waste reduction. Numerous chemical wastes can be destroyed as a final step in experiments. See Prudent Practices for Disposal of Chemicals from Laboratories, National Research Council, 1983, for information.
- Provide a designated facility for waste storage, segregation and treatment. This area should be ventilated contain a safety shower and eye wash, have sealed bermed floors and an emergency telephone.
- Keep individual waste streams segregated.
  - Keep hazardous waste segregated from nonhazardous waste. All waste contaminated with a hazardous substance becomes hazardous.
  - Keep recyclable waste segregated from

non-recyclable waste.
- Minimize dilution of hazardous waste.

- Ensure that the identity of all chemicals and wastes is clearly marked on all containers. When researchers leave an institution, they often leave laboratory chemicals behind. These include unused reagent chemicals, unlabeled containers, and an assortment of mixtures and solutions. Unlabeled containers present a particularly troublesome waste management problem since unidentified wastes cannot legally be shipped for disposal and analysis is very costly.

Improved Practices in Other Departments

As noted above, departments and activities at colleges and universities besides those with scientific laboratories also generate hazardous wastes. These include art and photography departments, printing shops, and facilities and vehicle maintenance operations. Research institutions often have campuses where grounds maintenance, building maintenance, and vehicle servicing may generate hazardous wastes as well.

While not producing the variety of wastes generated in laboratories, these departments and activities can contribute substantially to the volumes of hazardous wastes requiring disposal. Waste streams from art departments include paints, thinners, other solvents, and heavy metals (in paint pigments). Printing operations generate waste inks and solvents. Photographic processing generates waste silver, developer, fixer, and rinsing solutions. Maintenance operations generate waste oils, vehicle maintenance waste, solvents, pesticides, water treatment chemicals, PCB oil from old transformers, possibly asbestos, and small quantities of other wastes.

Opportunities to minimize wastes in these activities include:

- Replace oil-based paints with water-based paints in art instruction and maintenance operations. Non-toxic (solvent, lead, and chrome free) paints should be used where-ever possible.

- Modify spray-painting techniques to reduce paint waste. Set the correct air pressure for the spray gun and use the following stroking technique: 1) overlap the spray pattern by 50%, 2) maintain a distance of 6 to 8 inches from the workpiece, 3) hold the gun perpendicular to the surface, and 4) trigger the gun at the beginning and end of each stroke. (USEPA 1987).

- Reduce generation of pesticide waste by reducing pesticide application, using non-chemical pest control methods, and preparing and using only the required minimum quantity of pesticide for the job. Investigate the use of irrigation injection of pesticides through the sprinkler system (with back flow protection), or the use of dry pesticides that are spread on the grounds and watered into the ground. This practice will eliminate the need for pesticide spraying operations and the resulting contaminated washwater.

- Collect waste oil and solvents for recycling. Segregate recyclable oils and solvents from non-recyclable wastes. Spent degreasing solvents can be recycled on site using small batch stills. Contractual agreements can be entered into with companies that supply fresh solvents and remove and recover the usable fraction of spent solvents.

- Use biodegradable aqueous or detergent cleaners in place of more hazardous and toxic solvents.

- Investigate silver recovery or recycling with an outside vendor for photoprocessing wastes.

- Investigate mercury recovery with an outside vendor for liquid mercury obtained from broken thermometers, barometers, switches, and mercury found in sink traps.

- Provide training in hazardous waste management practices for students in departments/courses that generate waste and facilities management/maintenance personnel.

SECTION 4
GUIDELINES FOR USING THE WASTE MINIMIZATION ASSESSMENT WORKSHEETS

Waste minimization assessments conducted at three different research or educational institutions were used to develop the waste minimization questionnaire and worksheets that are provided in the following section.

A comprehensive waste minimization assessment includes a planning and organizational step, an assessment step that includes gathering background data and information, a feasibility study on specific waste minimization options, and an implementation phase.

Conducting Your Own Assessment

The worksheets provided in this section are intended to assist research and educational institutions in systematically evaluating waste generating processes and in identifying waste minimization opportunities. These worksheets include only the assessment phase of the procedure described in EPA's *Waste Minimization Opportunity Assessment Manual.* For a full description of waste minimization assessment procedures, refer to the EPA Manual.

Table 3 lists the worksheets that are provided in this section.

Table 3. List of Waste Minimization Opportunity Assessment Worksheets

Number	Title	Description
1.	Waste Generation: Questionnaire	General questionnaire regarding waste generation patterns and practices.
2.	Waste Generation: Internal Manifest	Forn. for documenting wastes generated by each department.
3.	Waste Management: Laboratories	Questionnaire on general waste management practices for each laboratory.
4.	Waste Minimization: Science Departments	Waste minimization options regarding good operating practices, material handling, and laboratory practices.
5.	Option Generation: Science Departments	Waste minimization options regarding good operating practices, material handling, and laboratory practices.
6.	Waste Minimization: Other Departments	Waste minimization options for Art, Theater Arts, Scenery Shop, Printing, and Maintenance Shop.
7.	Option Generation: Other Departments	Waste minimization options for Art, Theater Arts, Scenery Shop, Printing, and Maintenance Shop.

Firm ______	**Waste Minimization Assessment**	Prepared By ______
Site ______		Checked By ______
Date ______	Proj. No. ______	Sheet __ of __ Page __ of __

WORKSHEET
1

WASTE GENERATION: Questionnaire

Are facility-wide material balances routinely performed? ☐ yes ☐ no
Are they performed for each material of concern (e.g. solvent) separately? ☐ yes ☐ no
Are records kept of individual wastes with their sources of origin and eventual disposal? ☐ yes ☐ no
(This can aid in pinpointing large waste streams and focus reuse efforts.)

Having this type of data is important for the following reasons:

- the data define the scope of waste generation for the entire campus and for each department;

- realistic waste reduction goals can be established

- specific generators can be targeted for waste reduction; and

- costs for proper waste management can be determined.

If answer is No: It is recommended that methods for quantifying the waste generated for the entire campus and for each department be implemented. If adequate waste generation data are not available, establish an internal manifest system to be completed by each waste generator. An example of an internal manifest can be found on Worksheet 2. These forms should be kept on file and if possible, stored on a computer data base. Quarterly and yearly totals for hazardous waste generation can easily be determined using these manifests.

If answer is Yes: Establish campus-wide and departmental waste reduction goals. Setting specific goals provides an incentive to meet established goals. A committee should establish goals. Such committee should be made up of personnel from the campus environmental/safety office, administration, and professors/instructors from each waste generating department. Reduction goals should range from a 3% to 10% per year. The committee should meet quarterly to assess progress in achieving goals.

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet __ of __ Page __ of __

WORKSHEET
2

WASTE GENERATION:
Internal Manifest

Complete all information requested below. Do not leave any space or column empty (except Other Comments column)

Department ______

Person Completing Manifest ______ Phone No. ______

Date Generated	Chemical	Quantity	Gas, Liq,, Solid	Hazard	Other Comments

Contact the campus Hazardous Waste Coordinator at ______
when manifest is completed and/or wastes need to be picked up.

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet __ of __ Page __ of

WORKSHEET
3

WASTE MANAGEMENT: Laboratories

This section is to be completed by the chemistry, biology, geology, physiology, physics, and any other departments that use chemicals in laboratories. Each question below is to be completed for each department.

Department person in charge of chemical storage/stock rooms: ______
Chairman of the department: ______
Total number of laboratories in department: ______
Number of research laboratories: ______
Number of undergraduate teaching laboratories: ______
Number of chemical storage (stock) rooms: ______
Number of professors in the department: ______
Subdivisions within the department (i.e., for chemistry department: general chemistry, organic chemistry, analytical chemistry, etc.) ______

Rank the subdivisions from the highest to the lowest for quantity of waste generated. ______

How are chemicals purchased within the department? ______

Is there an oversight mechanism capable of monitoring all purchases of chemicals? ______

Describe the current method of maintaining an active inventory of chemicals in stock: ______

Who in the department maintains Material Safety Data Sheet (MSDS) files? ______

How are wastes currently collected for disposal within the department? ______

Note: If you have trouble answering any of the above questions, investigate to find the answers. The answers will assist in implementing waste reduction opportunities.

Firm ________	**Waste Minimization Assessment**	Prepared By ________
Site ________		Checked By ________
Date ________	Proj. No. ________	Sheet __ of __ Page __ of __

WORKSHEET
4A

WASTE MANAGEMENT: Science Departments

The following checklist should be completed by each professor/instructor who supervises student laboratory exercises, supervises a research laboratory, or any staff person involved with handling chemicals including chemical stockroom supervisor, solutions preparation, technical supervision.

Department ________________

Name of Person Completing this Checklist ________________ Title ________

A. GOOD OPERATING PRACTICES

Are all affected personnel provided with detailed operating manuals or instruction sets?	❑ yes	❑ no
Are regularly scheduled training programs related to waste minimization?	❑ yes	❑ no
Are there employee/student incentive programs offered to all personnel?	❑ yes	❑ no
Does the facility have an established waste minimization program in place?	❑ yes	❑ no
If yes, is a specific person assigned to oversee the success of the program?	❑ yes	❑ no

Discuss the goals of the program and results: ________________

Has a waste minimization assessment been performed at the facility in the past? If yes, discuss: ________

B. MATERIALS HANDLING

Has a centralized purchasing program been established?	❑ yes	❑ no
Does the current program adequately prevent the generation of waste due to over-purchasing?	❑ yes	❑ no
Since a significant portion of laboratory waste is actually surplus reagent chemicals, is it possible to purchase smaller quantities of reagent chemicals?	❑ yes	❑ no
Is it possible to increase the amount of sharing of chemicals between research laboratories? This would reduce the amount of surplus chemicals that require disposal.	❑ yes	❑ no
Is obsolete raw material returned to the supplier?	❑ yes	❑ no
Is inventory used in first-in, first-out order?	❑ yes	❑ no
Is the inventory system computerized?	❑ yes	❑ no
Does the current inventory control system adequately prevent waste generation?	❑ yes	❑ no

What information does the system track? ________________

Firm ______	Waste Minimization Assessment	Prepared By ______
Site ______		Checked By ______
Date ______	Proj. No. ______	Sheet __ of __ Page __ of __

WORKSHEET
4B

WASTE MANAGEMENT: Science Departments

Is there a formal personnel and student training program on raw material handling, spill prevention, proper storage techniques, and waste handling procedures? ☐ yes ☐ no ☐ yes ☐ no

Does the program include information on the safe handling of the types of drums, containers and packages received? ☐ yes ☐ no

How often is training given and by whom? ______

______

______

C. LABORATORY PRACTICES

Is it possible to reduce the volumes of reactants used in certain laboratory experiments without affecting the desired results? ☐ yes ☐ no

Instrumental methods use significantly smaller quantities of chemicals than wet chemistry methods. Is it possible to increase the use of instrumental analyses for selected experiments? ☐ yes ☐ no

Is it possible to substitute less hazardous chemicals in certain laboratory experiments such as: using sodium hypochloride for sodium dichromate, alcohols instead of benzene, cyclohexane for carbon tetrachloride, stearic acid for acetoamide, and any other potential substitutes? ☐ yes ☐ no

Is it possible to substitute specialty detergents for chromic/sulfuric acid for cleaning glassware? ☐ yes ☐ no

For certain undergraduate laboratory exercises, is it possible to pre-weigh chemical reactants for students? This would eliminate chemical waste due to spillage during weighing and transfer operations, by students. ☐ yes ☐ no

If solvents are used for cleaning, is counter current cleaning possible? (Using spent solvent for initial cleaning and fresh solvent only for the final cleaning.) This decreases the amount of reagent solvent used. ☐ yes ☐ no

Is a solvent sink used? If not, could one be used? ☐ yes ☐ no

Can solvent waste be redistilled and reused for classroom experiments or as thinners or degreasers by the maintenance department? ☐ yes ☐ no

If onsite solvent distillation is done, does it comply with fire and worker safety regulations? ☐ yes ☐ no

Are many different solvents used for cleaning? ☐ yes ☐ no

If too many small-volume solvent waste streams are generated to justify on-site distillation, can the solvent used for cleaning be standardized? ☐ yes ☐ no

Are all chemicals containers properly labeled? ☐ yes ☐ no

Are all wastes properly segregated? ☐ yes ☐ no

Has off-site reuse of wastes through Waste Exchange services been considered? ☐ yes ☐ no

Or reuse through commercial brokerage firms? ☐ yes ☐ no

If yes, describe results: ______

______

______

Can waste chemicals be destroyed, neutralized or treated to reduce hazards as the final step of selected laboratory classwork and research experiments? ☐ yes ☐ no

Inst. ______	**Waste Minimization Assessment**	Prepared By ______
Site ______	Proc. Unit/Oper. ______	Checked By ______
Date ______	Proj. No. ______	Sheet __ of __ Page __ of __

WORKSHEET
5A

OPTION GENERATION: Science Departments

Meeting format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Good Operating Practices		
Establish waste minimization policy		
Set goals for source reduction		
Set goals for recycling		
Conduct annual assessments		
Provide operating manuals/instructions		
Employee/student training		
Increased supervision		
Provide employee/student incentives		
B. Materials Handling		
Centralize purchasing		
Purchase smaller quantities		
Share surplus chemicals		
Return material to supplier		
Minimize inventory		
Computerize inventory		
Formal training		

Inst. ______	**Waste Minimization Assessment**	Prepared By ______
Site ______	Proc. Unit/Oper. ______	Checked By ______
Date ______	Proj. No. ______	Sheet __ of __ Page __ of __

WORKSHEET
5B

OPTION GENERATION: Science Departments

Meeting format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
C. Laboratory Practices		
Scale down experiments		
Increase instrument use		
Eliminate toxic chemical use		
Pre-weigh chemicals		
Standardize solvents & recycle		
Properly label containers		
Segregate wastes		
Recycle through waste exchange		
As final step, treat waste		

Firm ________ Site ________ Date ________	**Waste Minimization Assessment** Proj. No. ________	Prepared By ________ Checked By ________ Sheet __ of __ Page __ of

WORKSHEET
6A

WASTE MANAGEMENT: Other Departments

A. ART, THEATER ARTS, SCENERY SHOP, AND PRINTING

Is it possible to significantly reduce or eliminate use of oil-based paints?	❑ yes	❑ no
When spray painting, is it possible to use the following techniques to reduce the amount of paint used?	❑ yes	❑ no
- employ high transfer efficiency guns?	❑ yes	❑ no
- overlap the spraying pattern by 50%?	❑ yes	❑ no
- maintain a distance of 6 to 8 inches from the work piece?	❑ yes	❑ no
- hold the gun perpendicular to the surface?	❑ yes	❑ no
- trigger the gun at the beginning and end of each stroke?	❑ yes	❑ no
Use fully enclosed gun cleaning stations?	❑ yes	❑ no
Reuse clean-up solvent as thinner in next compatible batch of paint?	❑ yes	❑ no
Hazardous chemicals are used in art department subdivisions including silk screening, metal work, and sculpture. Is it possible to reduce or make substitutions for specific hazardous chemicals in any of these areas?	❑ yes	❑ no

If yes, discuss: ____

____

____

Certain photoprocessing cleaning chemicals are hazardous (e.g. chromic acid). Is it possible to substitute less hazardous cleaning compounds?	❑ yes	❑ no
In photographic processing is there currently a silver recovery unit in place to recover silver salts in the waste water?	❑ yes	❑ no
If there is no silver recovery unit, is it possible to install one?	❑ yes	❑ no
Is off-site recovery feasible?	❑ yes	❑ no
In pottery making or other related work, is it possible to eliminate use of lead glazes?	❑ yes	❑ no

B. MAINTENANCE SHOP

Is it possible to eliminate use of oil-based paints and replace with water-based paints?	❑ yes	❑ no
Is it possible to standardize oils used for many kinds of machinery?	❑ yes	❑ no
Can water-based cutting fluids be used in place of oil-based fluids?	❑ yes	❑ no
Does the facility have a proper coolant management program in place?	❑ yes	❑ no
Can hazardous solvent degreasers be replaced by alkaline degreasers or less hazardous solvent degreasers?	❑ yes	❑ no
If a vapor degreasing unit is used,is it always covered when not in use to reduce loss of solvent to the atmosphere?	❑ yes	❑ no
When using a vapor degreasing unit, are the parts rotated before removal to allow condensed solvent to return to the degreasing unit?	❑ yes	❑ no
Is it possible to restrict the number of parts that must be degreased to only those parts that badly need degreasing rather than routinely degreasing all parts?	❑ yes	❑ no

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet __ of __ Page __ of

WORKSHEET
6B

WASTE MANAGEMENT: Other Departments

B. MAINTENANCE SHOP (CONT.)

To conserve use of reagent solvents, can dirty solvent be used for initial cleaning, and fresh solvent used for final cleaning?	☐ yes	☐ no
Is a solvent sink being used? If not, could one be used?	☐ yes	☐ no
Is a bench-top still appropriate? If one is being used, does it comply with fire and worker	☐ yes	☐ no
safety regulations?	☐ yes	☐ no
When spray painting, is it possible to use the following techniques to reduce the amount of paint used?		
- overlap the spraying pattern by 50%	☐ yes	☐ no
- maintain a distance of 6 to 8 inches from the work piece		
- hold the gun perpendicular to the surface		
- trigger the gun at the beginning and end of each stroke?	☐ yes	☐ no
For pesticide spraying equipment, can the generation of pesticide contaminated rinse water be reduced or eliminated? This can be done by saving and using the rinse water for makeup of the next pesticide application solution.	☐ yes	☐ no
To reduce or eliminate the need for spraying pesticides can either of the following be implemented:		
- irrigation injection where the pesticide formulation is injected directly into the sprinkler/irrigation system at a controlled rate and with adequate backflow prevention devices	☐ yes	☐ no
- spread pesticides in the dry powder form and then water them into the ground?	☐ yes	☐ no
For spent fluorescent lamps and mercury recovered from lab sink traps has an outside vendor been contacted to investigate the feasibility of recovering mercury?	☐ yes	☐ no

Discuss any other methods used to minimize waste: ______

______

______

______

______

Inst.	Waste Minimization Assessment	Prepared By
Site	Proc. Unit/Oper.	Checked By
Date	Proj. No.	Sheet ___ of ___ Page ___ of ___

WORKSHEET
7

OPTION GENERATION: Other Departments

Meeting format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Art, Theater Arts, Scenery Shop, and Printing		
Eliminate oil-based paint use		
Proper spray paint techniques		
Enclosed spray gun cleaning		
Reuse clean-up solvent		
Use less hazardous cleaners		
Recover photographic silver		
Eliminate use of lead-based glaze		
B. Maintenance Shop		
Eliminate oil-based paint use		
Proper spray paint techniques		
Standardize machine oil		
Use water-based cutting fluids		
Proper coolant management program		
Replace solvent degreasers		
Keep degreaser covered		
Operate degreaser properly		
Recycle pesticide rinse water		
Use dry pesticide or irrigation injection		
Recover mercury		

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APPENDIX A
WASTE AUDIT OF A LARGE UNIVERSITY

A large university was audited to determine the extent of hazardous waste generation and investigate reduction opportunities. The university has a large graduate program and teaching hospital. There are over two thousand teaching and graduate laboratories on campus.

Hazardous Waste Management Overview

A formal waste management program was in existence for five years. The program is carried out by the campus safety office. They are responsible for collection of hazardous waste, spill response, chemical safety, and other compliance activities.

The largest waste stream is organic solvents. The second largest is corrosives. The corrosive category includes organic and inorganic acids and bases. Waste oil is also generated in maintenance shops and laboratories. Approximately 50% of the total campus hazardous waste stream is unused bottles of reagent chemicals. The other 50% is mixtures, contaminated solutions and spent solvents. When professors leave the university there are usually large quantities of surplus reagents and waste chemicals left in their laboratory. University administrators estimate that by the year 2000 sixty-five percent (65%) of the professors will retire which will increase the number of these laboratory chemical cleanouts. Figure A-1 shows the bulk versus lab pack disposal for the university. Figure A-2 shows waste streams generated at the university. (Table A-1 explains the abbreviations found on Figures A-2 and A-3.)

Approximately 50% of the hazardous waste on campus is collected. When waste is generated a form is completed and sent to the safety office. Arrangements are then made for pickup and disposal. Figure A-3 shows a copy of this form. In some departments wastes are temporarily stored in the chemical stockroom. In others the safety office picks up wastes directly from the generator. All waste ends up at a central waste storage area. In this area wastes are segregated into compatibility groups and are "lab packed" by an outside contractor. Bulk solvents received in five gallon safety cans are poured into 55 gallon drums and sent off campus for recycle, fuels blending or incineration.

Table A-1. ABBREVIATIONS FOUND ON BAR DIAGRAMS

Ex = Explosives

ORM-A = Department of Transportation hazardous materials classification "Other Regulated Material-A". This category includes materials which have "an anesthetic, irritating, noxious, toxic or other similar property and which can cause extreme annoyance or discomfort to passengers and crew in the event of leakage during transportation". Typical chemicals in this category are chlorinated solvents.

ORM-B = Department of Transportation hazardous materials classification "Other Regulated Material-B". These are chemicals capable of causing significant damage to transport vehicle from leakage during transportation.

ORM-E = Department of Transportation hazardous materials classification "Other Regulated Material-E". This category includes materials that are not included in any other hazard class, but it is subject to appropriate transportation regulations. Materials in this class include hazardous materials and wastes.

OP = Organic Peroxide waste.

WR = Water Reactive waste.

Waste Sources

The largest waste generator is chemistry. Other generators of waste are biology, physics, geology, art, engineering, printing operations and maintenance. Waste generated from the teaching hospital was not included in the scope of this study.

CHEMISTRY DEPARTMENT

The undergraduate program has six subdivisions: general, organic, inorganic, analytical, physical and biochemistry. General chemistry generates waste silver. This silver is saved for recycle. Acids and bases are neutralized and poured down the drain. All other general chemistry waste is nonhazardous. Organic chemistry waste includes halogenated and nonhalogenated solvents, and inorganic salts. Heavy metal waste is generated in inorganic chemistry. Analytical chemistry generates very little waste because of

Figure A-1
Large University Chemical Waste Disposal-Labpack vs. Bulk

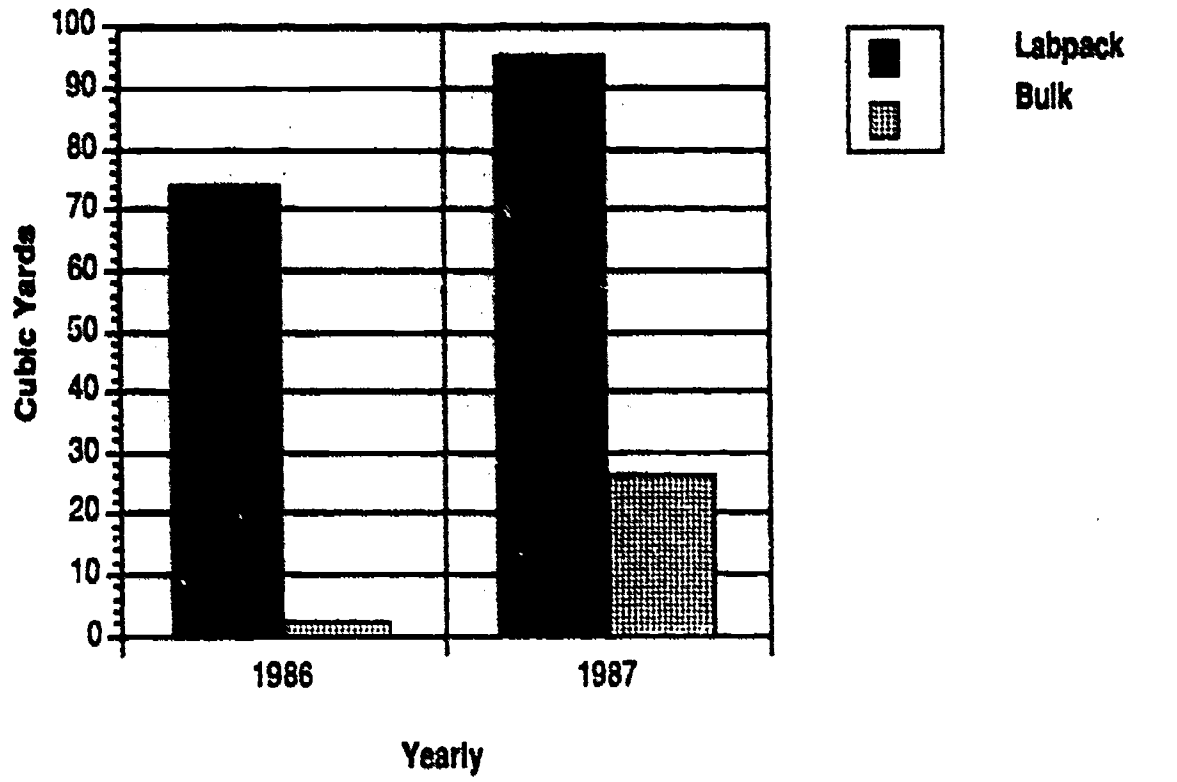

Figure A-2-1
Hazardous Waste Disposal for the Large University

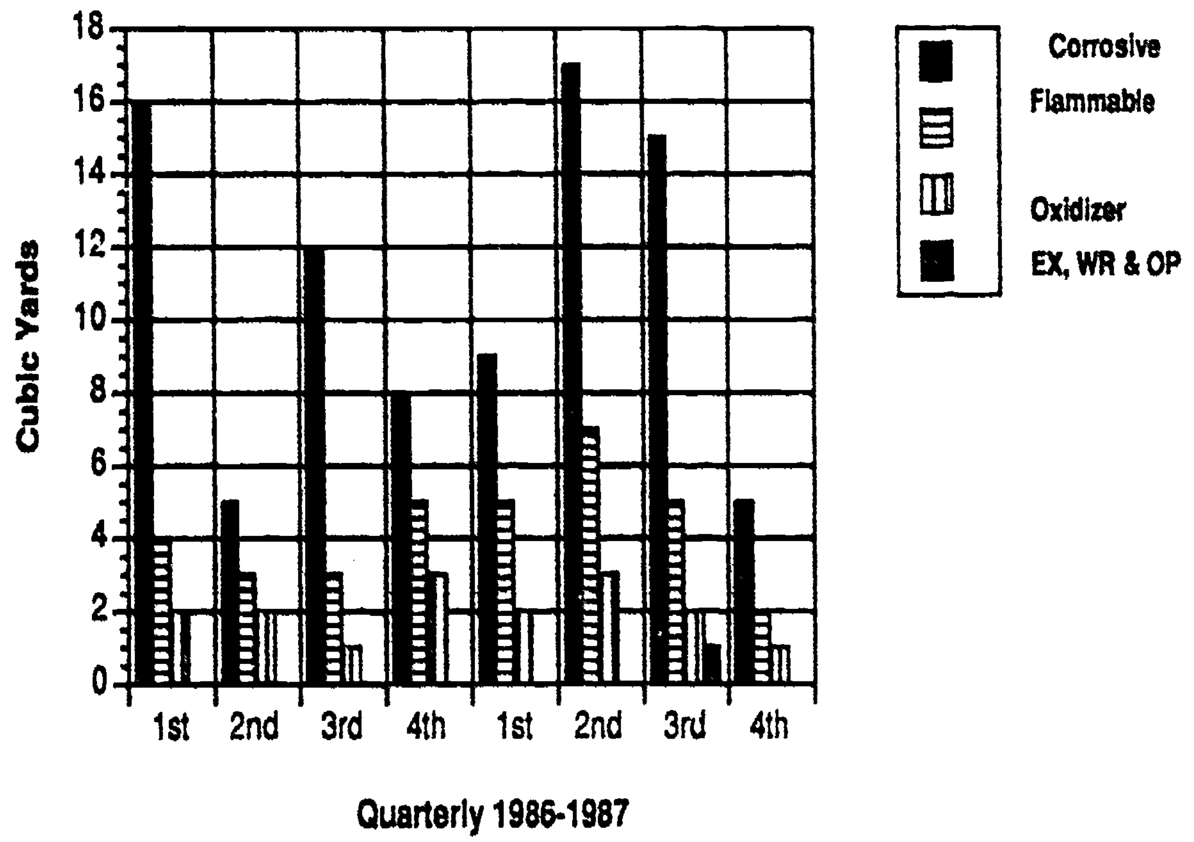

Figure A-2-2
Hazardous Waste Disposal for the Large University

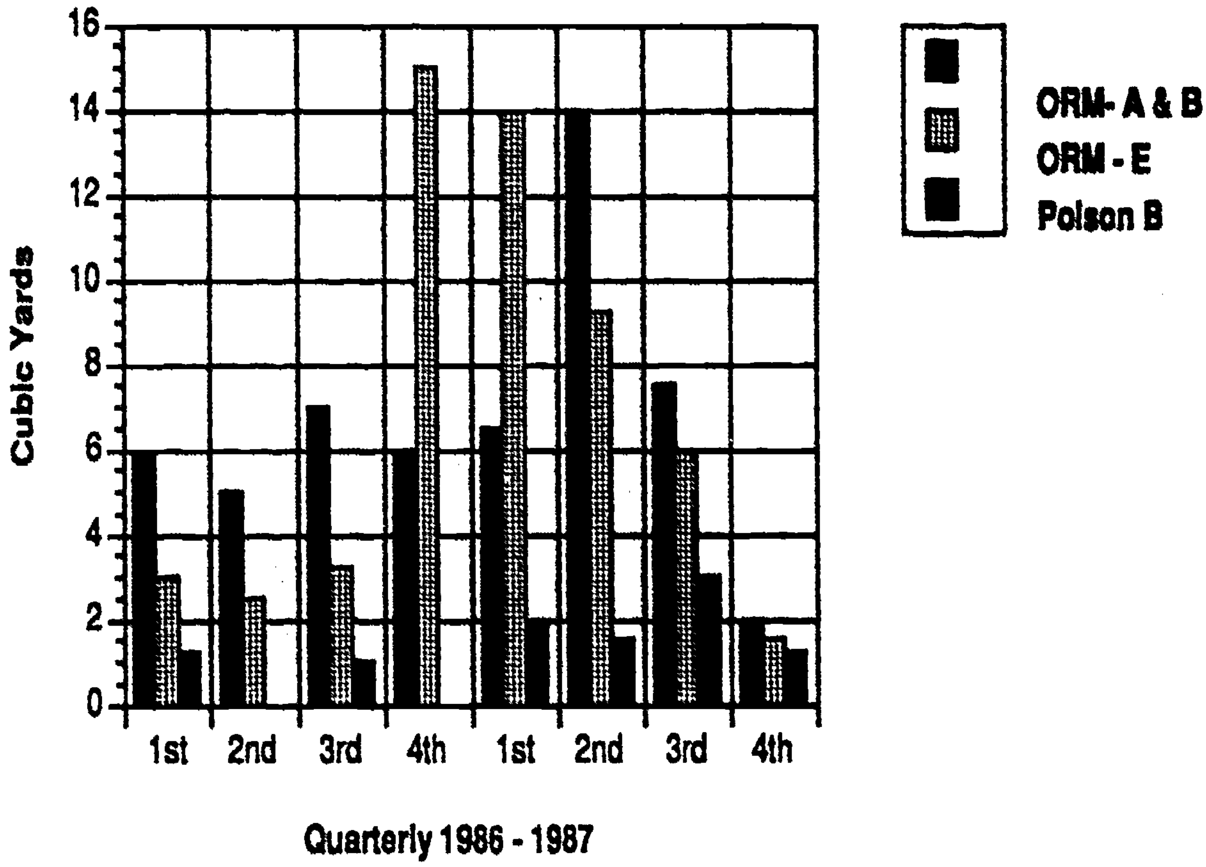

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Figure A-3. Hazardous Chemicals Disposal List

Date ____________________

Department ____

Person to contact regarding this list:

______________________________ Name

______________________________ Telephone Number

HAZARD CLASSIFICATION - CHECK ALL THAT APPLY

NAME OF CHEMICAL	GAS	LIQUID	SOLID	Flammable Combustible	CORROSIVE ACID	CORROSIVE BASE	OXIDIZER	ORG. PEROXIDE	EXPLOSIVE	WATER REACT	CARCINOGEN	PHARMACEUTICAL	POISON	:Quantity

the micro scale volumes used in instrumental analysis. Physical and biochemistry generate very little waste. A breakdown of waste chemicals generated in sophomore organic chemistry and undergraduate biochemistry can be found in Tables A-2 and A-3. Increased environmental regulation has changed undergraduate chemistry. Use of lead and mercury has been eliminated. Physical chemistry has eliminated the use of benzene. There has been a significant increase in collection and segregation of waste chemicals. "Micro-scale" laboratory exercises are selectively being instituted throughout the department.

Professors stated the following advantages and disadvantages to full implementation of "micro scale" laboratory work:

Advantages of micro scale:

- Students learn to work more carefully because of the small sizes. It helps students improve their laboratory technique.
- Significant decreases occur in chemical usage and waste generation.

Disadvantages of micro scale:

- Glassware is expensive. Micro glassware kits range in cost from $60 to $200 per kit, depending on the quality and size of glassware desired.
- Need to redesign experiments.
- Certain reactions overheat and run out of control when using small quantities.
- Micro scale experiments require pure grade chemicals which are expensive.
- Students do not get the experience of handling and assembling large glassware.
- Certain reactions require at least 50 ml to work (i.e., Grignard reaction).

The department has reduced the scale of laboratory experiments from 50-100 ml to 1-10 ml for most experiments.

Use of instrumentation in undergraduate laboratories has increased. This has reduced chemical usage 10 to 100 fold. Instruments used are gas chromatography, infrared spectrophotometry, and nuclear magnetic resonance (NMR). NMR is becoming the major method of identifying organic compounds. Wet chemistry is becoming less common.

Organic and inorganic graduate chemistry subdivisions generate the most waste. The largest waste stream is organic solvents. Quantities of chemicals used in all graduate subdivisions has decreased as a result of instrumentation. Surplus reagent chemicals from the research laboratories are added to the intracampus chemical exchange program. Research funding cutbacks have increased the efficiency of chemical usage. Three thousand different chemicals are used in the department.

A computerized chemical tracking system is used within the chemistry department. This system tracks chemicals from the time it arrives on campus to the time it is used up or until it leaves campus as a waste. A diagram depicting chemical flow in the department and where computer input occurs is shown on Figure A-4.

BIOLOGY DEPARTMENT

The biology department has a large graduate program in addition to undergraduate studies. Undergraduate biology uses organic solvents, acids, stains, and numerous nonhazardous

chemicals. Many toxic chemicals have been phased out. The volume of reactants used has been reduced to the minimum required to perform experiments. The need to cut costs, and increased use of instrumentation, are promoting reduction.

The graduate division is divided into two areas: molecular and cell biology. Chemicals used and waste generated in cell biology are: organic and inorganic acids and alkalies, organic solvents, carcinogenic compounds (benzidine, diazide, and nitrogenous compounds used in assays), and small quantities of other hazardous and nonhazardous compounds.

Molecular biology uses less chemicals than cell biology. Chemicals used and wastes generated are phenol, methanol, formaldehyde, ethers, acrylonitrides, organic solvents, heavy metals, inorganic acid washes, and inorganic salts. Research is geared to DNA and protein analysis/synthesis.

Since biological research is said to be underfunded, professors are trying to cut costs. This drive toward cost effectiveness has reduced the volume of chemicals used and increased the sharing of chemicals between laboratories.

Use of instrumentation has made analytical work "micro scale". Chromatographic analysis and gel electrophoresis are two methods commonly used. There has been a two to ten fold decrease in chemical usage as a result of instrument usage.

The biology department sporadically generates 50-200 gallons of formalin. This waste comes from use of preserved specimens.

GEOLOGY, PHYSICS, PSYCHOLOGY AND ENGINEERING DEPARTMENTS

Geology, physics, psychology and engineering each

Table A-2

WASTE GENERATED FROM SOPHOMORE ORGANIC CHEMISTRY

Experiment 1: Extraction, Crystallization and Distillation

Organic waste: Dichloromethane with a small amount (<1g/l) of Biphenyl
Aqueous waste: Ethanol and water, neutralized sodium salts
Solid waste: Biphenyl in bag, benzoic acid in bag

Experiment 2: Diels Alder

Organic waste: ethyl acetate, hexanes, dicyclopentadiene
Solid waste: cis-Norbornene 5, 6 endo-dicarboxylic anhydride cis-Norbornene 5, 6-endo-dicarboxylic acid

Experiment 5; Grignard Reaction

Organic waste: Ethyl ether with a trace of benzoic acid
Aqueous waste: Magnesium salts, neutralized sodium salts
Solid waste: Benzoic acid

Experiment 6: Benzoin Condensation

Aqueous waste: Thiamine, ethanol, sodium hydroxide, trace benzaldehyde and benzoin
Organic waste: Dichloromethane with a trace of thiamine, benzoin and benzaldehyde
Solid waste: Benzoin in bag

Experiment 8: Semicarbazide

Aqueous waste: Furfural semicarbazone, cyclohexanone semicarbonazone, and methanol
Solid waste: Furfural semicarbazone and cyclohexanone semicarbozone in bag

Table A-3

WASTE GENERATED FROM UNDERGRADUATE BIOCHEMISTRY EXPERIMENTS

Experiment 1: Nitrophenols

Aqueous waste: 0-nitrophenol, p-nitrophenol, m-nitrophenol and 2,5-dinitrophenol dissolved in ethanol and water

Experiment 2: Carbohydrate

Aqueous waste: Sodium periodate dissolved in water

Experiment 3: Invertase

Aqueous waste: Oxidation products of 3,5-dinitrosalicylate

Experiment 4: Lactate dehydrogenase

None

Experiment 5: B-Galactosidase

Aqueous waste: O-nitrophenol and Folin reagent (phenol and sodium tungstate) dissolved in water

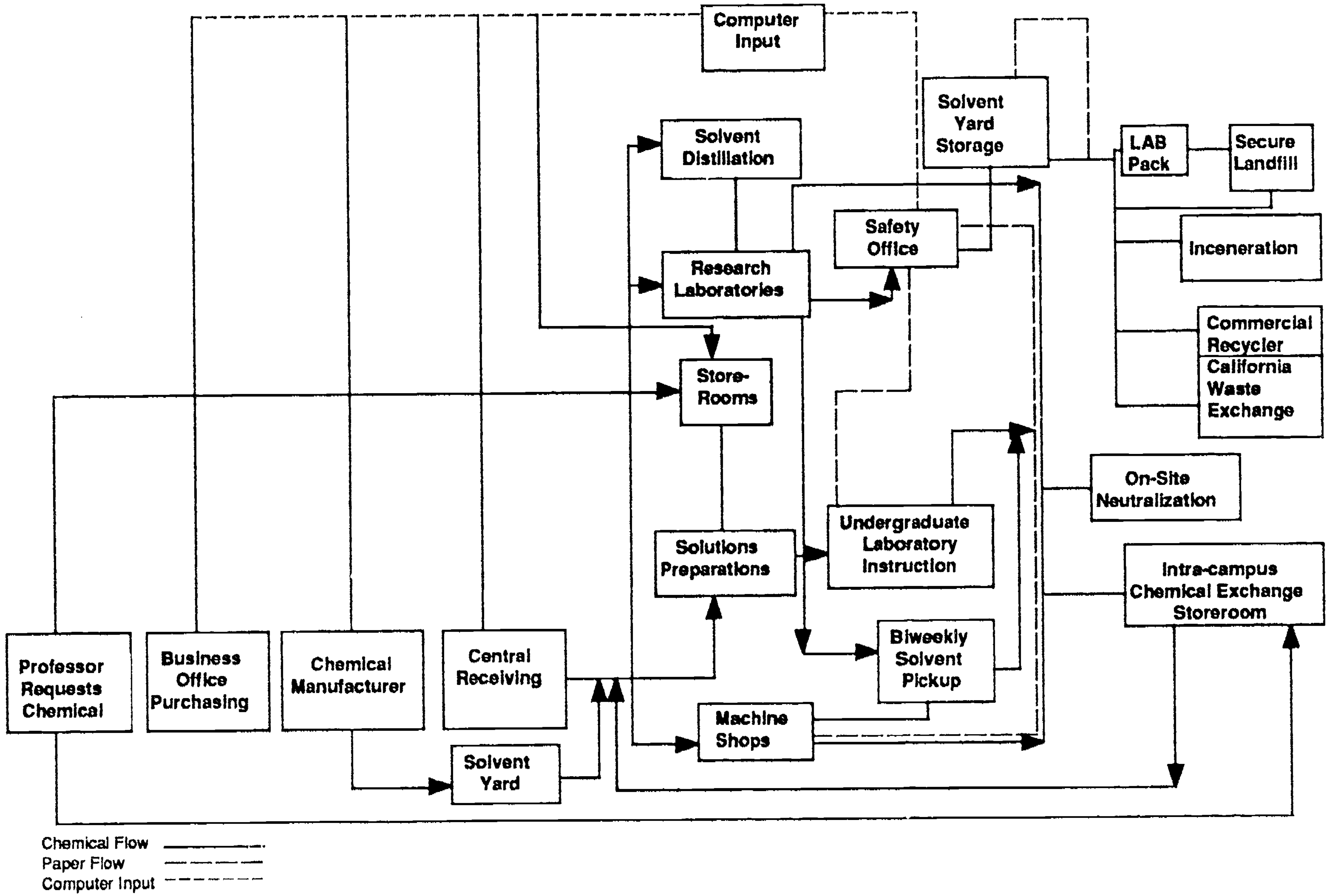

Figure A-4 Large University Chemistry Department Chemical Flow Diagram use less chemicals than chemistry and biology. Small amounts of organic solvents, acids, bases, metals, and other chemicals are used. Small quantities of waste are generated from use of these chemicals. Instrumental analysis used in these disciplines has decreased the amounts of chemicals used and the resulting waste generated.

ART DEPARTMENT

The art department uses a wide range of chemicals. Specialties that use chemicals are printing, textiles, ceramics, painting, silk screening, sculpture and photography. Chemicals used and wastes generated from these processes are: inorganic acids, zinc, acetic acid, diesel, kerosene, turpentine, alcohols, oils, paints, and small amounts of other chemicals. There have been few, if any, substitutions of less hazardous chemicals used as a result of increased safety and environmental regulations. Only the awareness of the hazards of chemicals used has increased.

THEATER DEPARTMENT

The scenery shop has eliminated use of oil-based paints and thinners. It presently uses only water based paints.

MAINTENANCE DEPARTMENT

Maintenance functions are divided into the following specialties: electrical, painting, plumbing, hardware, sign shop, building maintenance, sheet metal, plant operations, building and grounds, custodial and fleet services. The paint shop generates waste paint, paint sludge and spent thinner. The other areas generate waste solvents and oils. Buildings and grounds avoids generation of pesticide rinse water by saving this rinse water and using it in the next spraying operation. Replacement of old polychlorinated biphenyl (PCB) transformers has created a PCB waste stream that is incinerated.

Recommendations

Waste reduction can be increased by implementing the following recommendations for laboratory practices and for hazardous waste management practices.

LABORATORY PRACTICES

- Increase dissemination of information regarding proper waste management and waste reduction to generators.
- Purchase and distribute additional 5 gallon safety cans to promote segregated collection of chlorinated and nonchlorinated solvents.
- Encourage laboratory personnel to purchase smaller volumes of chemicals. This will reduce generation of surplus reagent chemicals.
- Implement a bar coding system for chemicals used on campus to facilitate tracking of these chemicals. Advantages are: increase the sharing of chemicals between common users, provide up-to-date records on inventory and ages of chemicals, and identify which labs use extremely toxic chemicals.
- In physical chemistry laboratories use magnetic balances (Gouy Balances) to reduce the volume of heavy metals needed for certain experiments.
- In undergraduate laboratories, use pre-weighed chemicals for students. This will eliminate waste generation by student spilling/ mishandling chemicals. If cost-effective, pre-weighed packages could be purchased directly from the manufacturer.
- Encourage use of the intracampus chemical exchange/recycle program that is in existence.
- For biology establish a hazardous material/ waste handling room. At present, there are no safe areas for storage and handling of hazardous materials and wastes. Providing such a facility would promote proper management of hazardous waste and aid in waste reduction.
- Substitute special detergents for chromic acid for washing glassware.
- In all laboratory work increase the use of micro-glassware to reduce the volume of chemicals required.
- Purchase desktop solvent recovery units to increase re-use of solvents on campus.
- Increase in-lab destruction/treatment of waste chemicals. Many toxic and corrosive waste chemicals can be converted to nonhazardous chemicals via chemical treatment (see "Prudent Practices for Disposal of Chemicals From Laboratories", National Research Council, 1983; Chapter 6). Waste destruction should be included as the final procedure in experiments.

HAZARDOUS WASTE MANAGEMENT PRACTICES

- For each department appoint a hazardous waste management coordinator. This person will oversee safety, chemical handling, waste collection, proper container use, and promotion of waste reduction.
- Establish campus and departmental goals for waste reduction. Establishing specific goals will provide an incentive for achieving these goals. They can be established as either a

percent reduction or total volume reduction. Prior to establishing goals, detailed analyses of current generation rates must be performed. A campus waste reduction committee should be established. The committee should include representative departments' hazardous waste coordinators, and chairpersons, campus safety office, and a high level campus administrator. The committee function will be to establish reduction goals and oversee progress.

- For pesticide application investigate the use of irrigation injection to replace spraying operations. Use of irrigation injection will reduce the amount of pesticide and rinse waters generated. Special plumbing modifications to sprinkler systems will allow direct input of pesticides to the sprinkler system. Another alternative to spraying is applying pesticides in dry powder form and watering them into the soil.
- Provide additional staff in the safety office to assist in proper management and coordination of hazardous waste on campus.

APPENDIX B
WASTE AUDIT OF A RESEARCH INSTITUTE

A research institute was audited as part of the study. Current research areas at the institute are in chemistry, biology, geology, physics, engineering, environmental science and computer science.

Hazardous Waste Management Overview

An established waste management program was in place. It is carried out by the campus health and safety office. The program includes collection of waste chemicals, spill response, and technical assistance to generators. There is a central waste chemical storage area. This area stores drums of bulk waste, chemicals to be lab packed, and chemicals intended for recycle/exchange within the institute. Figure B-1 shows the bulk versus lab pack disposal for the institute.

Waste Sources

Data and analysis of waste streams can be found in Appendix B. There were no records available at the institute on waste generation from particular laboratories. The only records were Uniform Hazardous Waste Manifests. Asbestos and waste oil are not included in this study. Chemistry and biology departments generate the largest quantity and diversity of waste. Figure B-2 shows waste streams generated at the institute. (Table B-1 explains the abbreviations used on Figure B-2).

CHEMISTRY DEPARTMENT

Organic and inorganic subdivisions generate the largest quantity and diversity of waste. The other subdivisions generate small volumes. Both increased use of instrumentation and performing experiments under a vacuum have reduced chemical usage and waste generation.

There are 900 different chemicals in the department stockroom. Acetone is used at the rate of four 55 gallon drums every two months, methanol at six 55 gallon drums per year, and hexane at four 55 gallon drums per year.

Table B-1. ABBREVIATIONS FOUND ON BAR DIAGRAMS

Ex = Explosives

ORM-A = Department of Transportation hazardous materials classification "Other Regulated Material-A". This category includes materials which have "an anesthetic, irritating, noxious, toxic or other similar property and which can cause extreme annoyance or discomfort to passengers and crew in the event of leakage during transportation". Typical chemicals in this category are chlorinated solvents.

ORM-B = Department of Transportation hazardous materials classification "Other Regulated Material-B". These are chemicals capable of causing significant damage to transport vehicle from leakage during transportation.

ORM-E = Department of Transportation hazardous materials classification "Other Regulated Material-E". This category includes materials that are not included in any other hazard class, but it is subject to appropriate transportation regulations. Materials in this class include hazardous materials and wastes.

OP = Organic Peroxide waste

WR = Water Reactive waste.

The biology department uses a wide range of solvents, acids, bases, heavy metals and stains. The department is divided between neurobiology and cellular/molecular biology. Cellular/molecular biology generates the most hazardous waste. There are two chemical stockrooms, one for each subdivision. One stockroom surveyed had over 300 different chemicals in stock. A partial listing of these chemicals can be found in Table B-2. The stockrooms also store waste chemicals prior to transfer to the campus waste storage area. The highest volume chemical used is ethanol

Figure B-1
Research Institute Chemical Waste Disposal - Labpack vs. Bulk

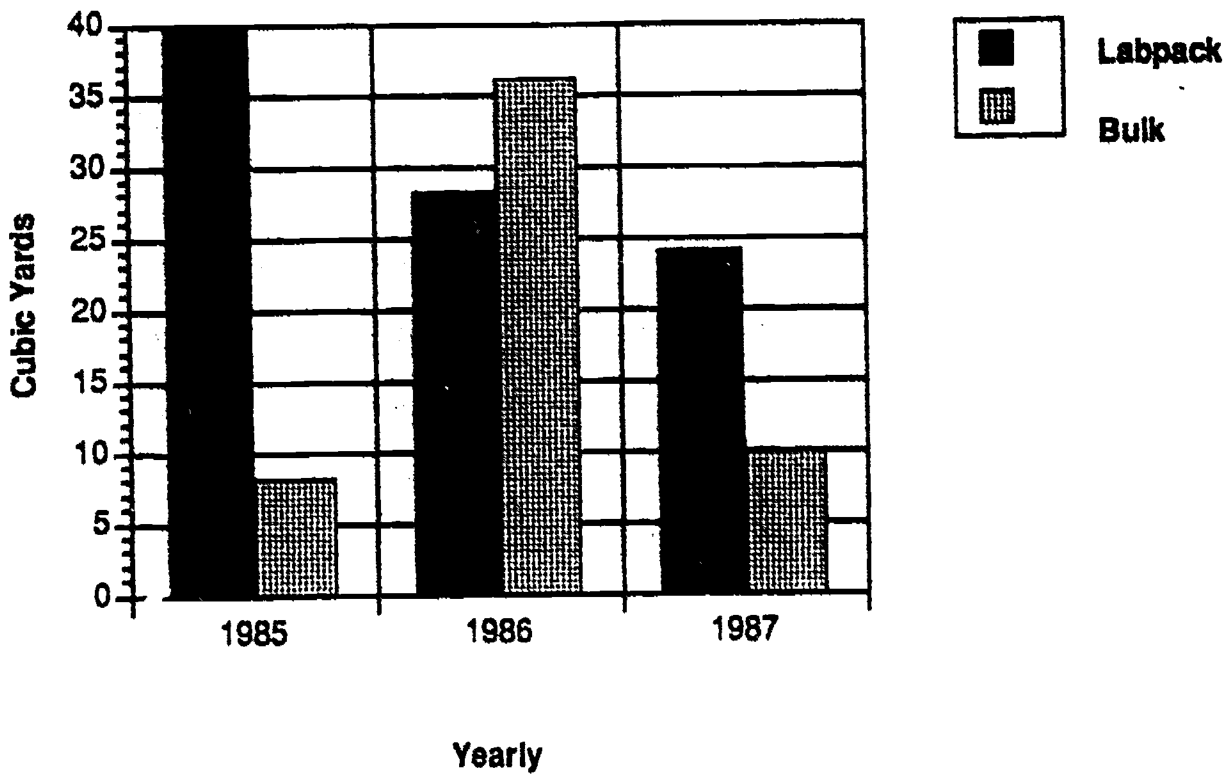

Figure B-2-1
Hazardous Waste Disposal for th erResearch Institute

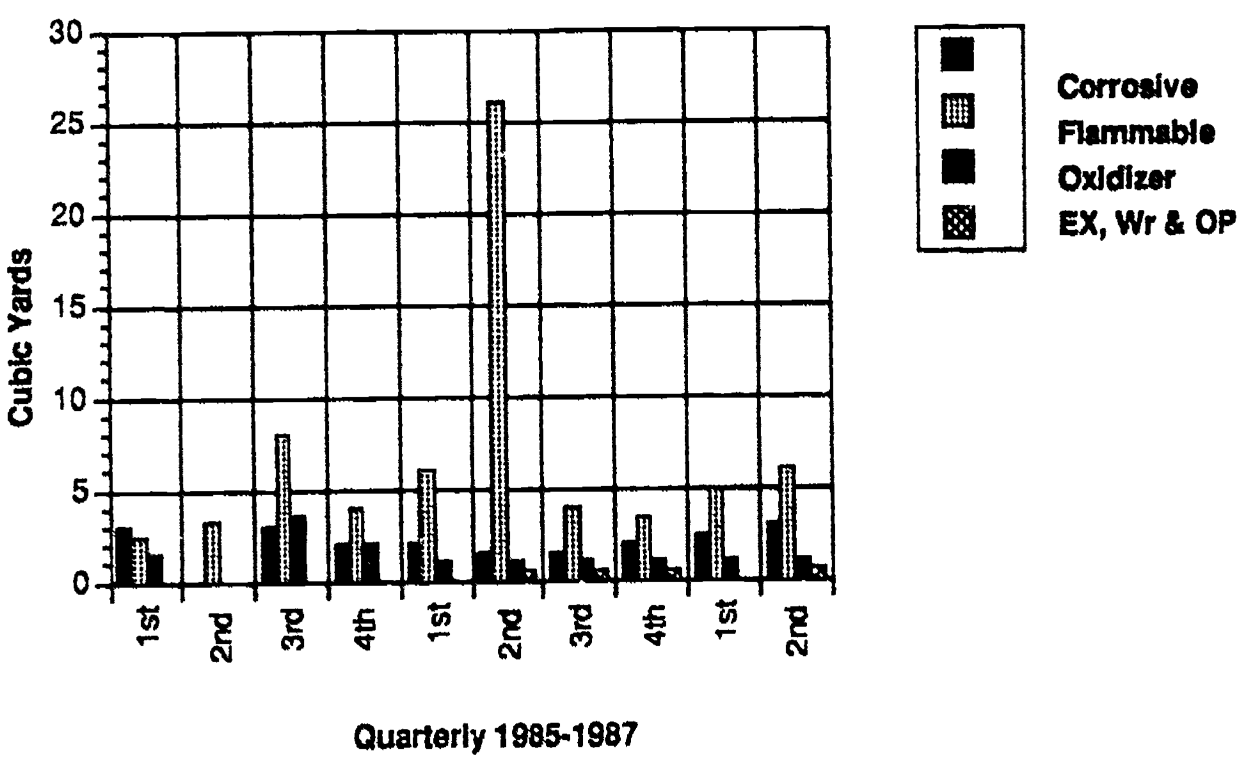

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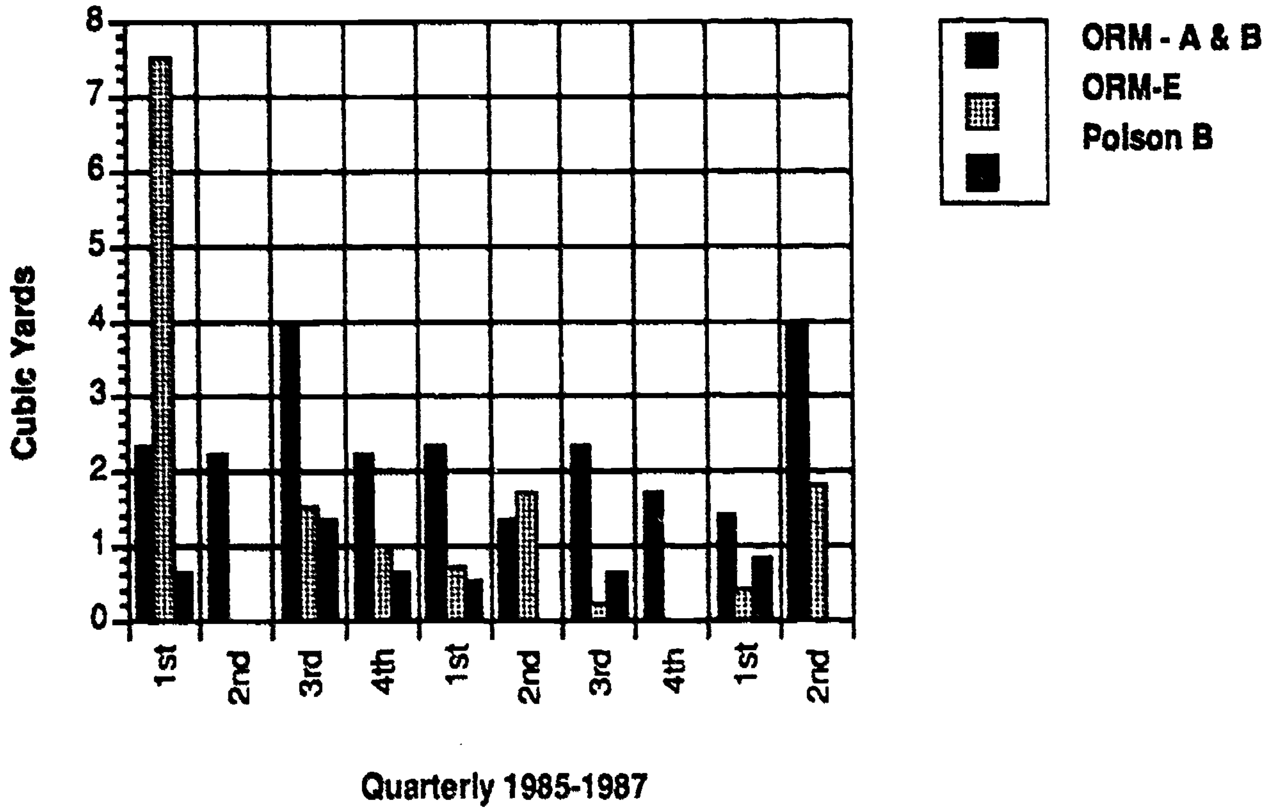
Figure B-2-2
Hazardous Waste Disposal for the Reserach Institute



at 1500 gal/yr. Formaldehyde is used at 150 gal/year. Chlorinated solvents are used in small quantity.

The scarcity and expense in obtaining usable material to study (i.e., DNA, proteins) reduces waste generation. The increased use of chromotography and other micro-analytical techniques has also reduced waste generation.

Awareness of safety and environmental issues has grown in the last two years. Not as many chemicals are disposed of down drains and there is increased concern for handling chemicals safely.

Researchers do share chemicals. Similar research focus and the proximity of laboratories to one another promote sharing.

GEOLOGY AND PHYSICS

Geology and physics generate small amounts of waste solvents and assorted inorganic compounds. Acids and bases are neutralized and poured down the drain. In geology analytical techniques are micro scale. A one gram sample is large for most analyses. In physics the waste streams are 15 gallons of solvent per month (mostly alcohols), metals (mainly arsenic), and assorted inorganic salts and cyanides. In both disciplines increased instrumentation has reduced chemical usage.

ENGINEERING AND ENVIRONMENTAL SCIENCE

Engineering has the following subdivisions: environmental, chemical, materials, fluid, mechanical, electrical and others. Different chemicals are used in each subdivision. Instrumentation is used in most laboratories which has reduced chemical usage.

PLANT OPERATIONS AND MAINTENANCE

Plant operations and maintenance generate waste solvents, paint and oil. Oil-based paints are being phased out and replaced with water-based paints. The only oil-based painting to continue will be for metal objects. Two 55-gal drums of waste thinner are generated per year from oil-based painting.

The grounds department applies fertilizers and pesticides to the lawns, trees and shrubs. The department is phasing out restricted pesticides and substituting non-toxic ones. Use of irrigation injection and water-soluble gravel pesticides that are spread on the grounds and watered into soil are being investigated. This will eliminate spraying operations.

Many academic departments have specialty machine shops that generate waste solvents and oils.

Trends in Waste Management Practices

A driving force for reducing chemical usage is economics. In biology the drive to reduce overhead costs has increased sharing of chemicals between researchers, increased use of micro-analytical techniques, and reduced the quantity of reagent chemicals purchased. In other departments, limited research funding is increasing the efficient use of chemicals.

Whenever professors retire or leave, there is a large number of chemicals left behind in their laboratories. Most of the chemicals are disposed of in lab packs. Some are retained for internal exchange and recycle.

Recommendations for Waste Reduction

There are many opportunities for waste reduction beyond the efforts currently being implemented. These additional opportunities are:

- Establish an internal waste manifesting system to create a data base on generation of hazardous waste. This information can be put onto a computer data base.
- After waste generation data is collected, determine the quantities of waste generated for the entire campus and for each department. Establish yearly waste reduction goals for the campus and for each department. Appoint one person in each department to carry out the waste reduction policy. A campus waste reduction committee should be established to set goals and monitor progress.
- To eliminate the need for chromic acid washing of glassware, either increase the use of disposable plastic glassware, or clean glassware with specialty detergents.
- Increase the amount of in-lab destruction of waste chemicals. Many toxic and corrosive waste chemicals can be converted to nonhazardous chemicals via chemical treatment (see "Prudent Practices for Disposal of Chemicals From Laboratories, National Research Council, 1983; Chapter 6). Waste destruction should be the final procedure for experiments.
- Purchase small solvent distillers for recovery and recycle of spent solvents. Recycled solvents can be used for cleaning or other processes where ultra pure solvent is not required.
- Purchase laboratory chemicals, paints, and other maintenance chemicals in small sizes only. This will reduce generation of surplus materials requiring disposal.
- Establish a tracking system for chemicals from purchase to disposal. This will reduce duplicate purchases, and minimize the waste generated from old, partially used containers that age on laboratory shelves. A bar coding system would enhance inventory control. Each chemical would have a different code which allows efficient tracking. This system will also assist in promoting sharing of surplus chemicals.
- Hire additional staff to assist in waste collection, data management (i.e., internal manifests), and dissemination of waste reduction information.
- Encourage use of the intra-campus chemical exchange/recycle program.
- Provide routine self-audits for professors' laboratories. Focus on unused reagent accumulation and recyclable wastes.

Appendix C
WASTE AUDIT OF A SMALL COLLEGE

A private liberal arts college was audited as part of the study. The student population is less than 2000. Undergraduate degrees are offered in physical sciences, social sciences and humanities. A few departments such as biology offer a Masters Degree.

Waste Management Overview

No waste management program was in effect at the college. One chemistry professor had organized a waste collection program for waste chemicals. These chemicals were disposed of in lab packs in 1986 in the second off-site shipment of waste chemicals. The first shipment was in 1983. The college administration is considering hiring a part-time Safety/Waste Management Officer and implementing a formal safety/waste management program.

Since there is no formal program, concerned professors take a "piecemeal" approach to waste management. There is no budget for chemical safety and waste disposal. Each time a safety or waste disposal expenditure is necessary, it must come out of a department's budget or be obtained from general college funds, which is difficult and slow.

The above description correlates with findings of a recent EPA study (EPA 1987; see references following text sections). The EPA found that large universities with extensive research programs have established waste management programs. Small colleges and secondary schools have small programs or none at all.

Waste Sources

Waste generation was found in chemistry, general biology, marine biology, psychology, art, maintenance, and the school newspaper. Figure C-1 shows waste streams generated at the college.

CHEMISTRY DEPARTMENT

The department is strictly undergraduate with an emphasis on research. Diverse organic and inorganic chemicals are used in laboratory exercises and research. Most waste (60-75%) comes from general chemistry. The following wastes are generated in general chemistry: iodine, xylene, naptha, p-dichlorobenzene, mercury, chromium, lead and carbon tetrachloride. Research does not generate significant waste. Benzene is used in one project, but is recycled. Use of instrumentation has reduced the volume of chemicals used.

BIOLOGY DEPARTMENT

There is a small graduate program in addition to undergraduate study. Chemicals used in the department are organic solvents, heavy metals, acids, bases, stains, enzymes, and other organic compounds. Chemical waste generation includes formaldehyde, mercury salts, solvents and old chemicals. Acids and bases go down the drain. A small amount of osmium tetroxide is also generated.

Marine biology generates small amounts of acids, bases, alcohols, and chlorinated solvents. Formalin is generated in larger quantities. The college has not been able to dispose of old formalin. Over 250 gallons of formalin has accumulated thus far.

ART DEPARTMENT

The art department generates acids, waste paint and solvents from silk screen and printing processes. The department is switching from oil-based paints to water-based paints. This will eliminate use of thinners. Ventilation is not adequate in many studios. As a result many volatile compounds are being phased out.

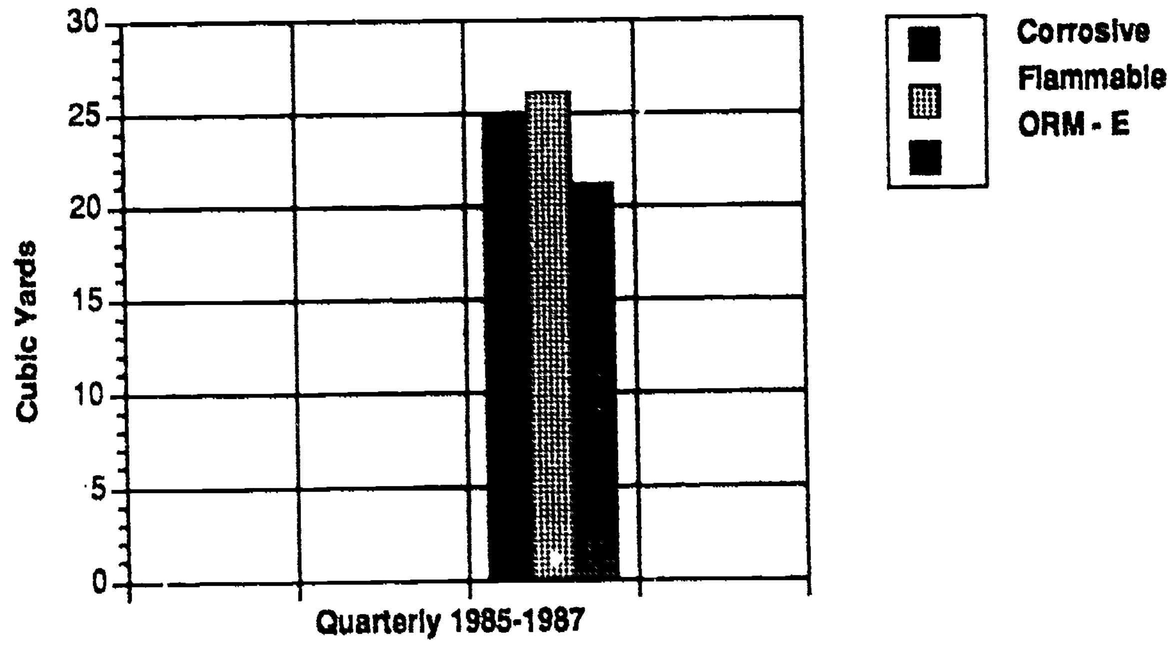
WASTE GENERATION FROM OTHER SOURCES

Psychology generates waste solvent. The school newspaper uses photo processing chemicals (organic acids, bases, chromic acid cleaning solution) and waste chemicals are generated. The maintenance department generates waste oil. The paint shop uses water-based paints only. The grounds crew applies pesticides to lawns and trees. To avoid generation of waste pesticide they completely use up each application load.

Trends in Waste Management Practices

As a result of increased environmental regulations many changes have occurred. The chemistry department has phased out carcinogenic compounds such as benzene and chloroform, has purchased flammable storage cabinets, and has installed a better ventilation system. There has been a reduction in the volume of chemicals used in

Figure C-1
Hazardous Waste Disposal for the Small College



laboratory course work. Typically one quarter the quantity of chemicals called for in laboratory manuals are used in teaching laboratory experiments.

In biology changes are less noticeable than in chemistry. Many professors do not support waste collection programs and new safety protocol. Chemical disposal down drains still occurs.

A significant increase in the amount of analytical instrumentation used in research has decreased the amount of chemicals used. Teaching laboratories still use wet chemistry methods.

Recommendations for Waste Reduction

The following recommendations can improve waste management and promote waste reduction:

- Establish a new administrative position entitled "Hazardous Material/Waste Management Officer". Duties would include chemical safety, waste collection, disposal, in ventory control, establishing an intracampus chemical exchange program, respond to spills, and development of a waste reduction program. This position may require only 20 hours per week, so other functions could be performed (teach, security functions, etc.).
- Establish a separate budget for chemical safety and waste management and charge it back to the departments that generate hazardous waste. This will provide an economic incentive to reduce waste.
- Eliminate use of toxic compounds in laboratory experiments by substituting a less toxic/ hazardous compound, and/or using a different experiment entirely.
- Establish a central location for waste chemical storage. This area should be well ventilated, secure, contain a fire extinguisher, eye wash, shower, allow for segregated storage of incompatible chemicals, and be surrounded by berms to contain spills. The area can be used to store surplus reagent chemicals which are to be recycled within the college.
- Substitute less hazardous chemicals for cleaning the photo processor machines in the school newspaper office. Present use of chromic acid cleaning solutions creates unnecessary safety and disposal problems.

- Have printing done off site. If the school newspaper obtains educational value from the printing activity, printing instruction can be contracted to a nearby technical school.
- Coordinate with other small colleges to have laboratory instruction done at one location. This would allow consolidation of laboratory waste generation.
- Eliminate drain disposal of all toxic and hazardous wastes.
- Increase the amount of in-lab destruction of waste chemicals. Many waste chemicals can be converted to nonhazardous chemicals via chemical treatment (see "Prudent Practices for Disposal of Chemicals From Laboratories", National Research Council, 1983). Waste destruction should be the final procedure for experiments.
- Increase the use of instrumentation in undergraduate laboratory course work.
- For pesticide application, investigate the use of irrigation injection of pesticides to replace spraying operations. Use of irrigation injection will reduce the amount of pesticide and rinse waters generated. Special plumbing modifications to the sprinkler systems will allow direct input of pesticides to the sprinkler system. Another alternative is applying pesticides in the dry powder form and watering them into the soil.

APPENDIX D
WHERE TO GET HELP
FURTHER INFORMATION ON POLLUTION PREVENTION

Additional information on source reduction, reuse and recycling approaches to pollution prevention is available in EPA reports listed in this section, and through state programs (listed below) that offer technical and/or financial assistance in the areas of pollution prevention and treatment.

In addition, waste exchanges have been established in some areas of the U.S. to put waste generators in contact with potential users of the waste. Four waste exchanges are listed below. Finally, EPA's regional offices are listed.

EPA REPORTS ON WASTE MINIMIZATION

U.S. Environmental Protection Agency. "Waste Minimization Audit Report: Case Studies of Corrosive and Heavy Metal Waste Minimization Audit at a Specialty Steel Manufacturing Complex." Executive Summary.*

U.S. Environmental Protection Agency. "Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste for Parts Cleaning and from Electronic Capacitor Manufacturing Operation." Executive Summar .*

U.S. Environmental Protection Agency. "Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Wastes from Electroplating Operations." Executive Summary.*

U.S. Environmental Protection Agency. Report to Congress: Waste Minimization, Vols. I and II. EPA/530-SW-86-033 and -034 (Washington, D.C.: U.S. EPA, 1986).**

U.S. Environmental Protection Agency. Waste Minimization - Issues and Options, Vols. I-III EPA/530-SW-86-041 through -043. (Washington, D.C.: U.S. EPA, 1986).**

* Executive Summary available from EPA, WMDDRD, RREL, 26 West Martin Luther King Drive, Cincinnati, OH, 45268; full report available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

** Available from the National Technical Information Service as a five-volume set, NTIS No. PB-87-114-328.

WASTE REDUCTION TECHNICAL/ FINANCIAL ASSISTANCE PROGRAMS

The EPA's Office of Solid Waste and Emergency Response has set up a telephone call-in service to answer questions regarding RCRA and Superfund (CERCLA):

(800) 242-9346 (outside the District of Columbia)

(202) 382-3000 (in the District of Columbia)

The following states have programs that offer technical and/or financial assistance in the areas of waste minimization and treatment.

Alabama
Hazardous Material Management and Resources Recovery Program
University of Alabama
P.O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Alaska
Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue, Suite 101
Anchorage, AK 99501
(907) 276-2864

Arkansas
Arkansas Industrial Development Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California
Alternative Technology Section
Toxic Substances Control Division
California State Department of Health Service
714/744 P Street
Sacramento, CA 94234-7320
(916) 324-1807

Connecticut
Connecticut Hazardous Waste Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Connecticut Department of Economic Development
210 Washington Street
Hartford, CT 06106
(203) 566-7196

Georgia

Hazardous Waste Technical Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Division
Georgia Department of Natural Resources
Floyd Towers East, Suite 1154
205 Butler Street
Atlanta, GA 30334
(404) 656-2833

Illinois

Hazardous Waste Research and Information Center
Illinois Department of Energy of Energy and Natural Resources
1808 Woodfield Drive
Savoy, IL 61874
(217) 333-8940

Illinois Waste Elimination Research Center
Pritzker Department of Environmental Engineering
Alumni Building, Room 102
Illinois Institute of Technology
3200 South Federal Street
Chicago, IL 60616
(313) 567-3535

Indiana

Environmental Management and Education Program
Young Graduate House, Room 120
Purdue University
West Lafayette, IN 47907
(317) 494-5036

Indiana Department of Environmental Management
Office of Technical Assistance
P.O. Box 6015
105 South Meridian Street
Indianapolis, IN 46206-6015
(317) 232-8172

Iowa

Center for Industrial Research and Service
205 Engineering Annex
Iowa State University
Ames, IA 50011
(515) 294-3420

Iowa Department of Natural Resources
Air Quality and Solid Waste Protection Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319-0034
(515) 281-8690

Kansas

Bureau of Waste Management
Department of Health and Environment
Forbes Field, Building 730
Topeka, KS 66620
(913) 269-1607

Kentucky

Division of Waste Management
Natural Resources and Environmental Protection Cabinet
18 Reilly Road
Frankfort, KY 40601
(502) 564-6716

Louisiana

Department of Environmental Quality
Office of Solid and Hazardous Waste
P.O. Box 44307
Baton Rouge, LA 70804
(504) 342-1354

Maryland

Maryland Hazardous Waste Facilities Siting Board
60 West Street, Suite 200 A
Annapolis, MD 21401
(301) 974-3432

Maryland Environmental Service
2020 Industrial Drive
Annapolis, MD 21401
(301) 269-3291
(800) 492-9188 (in Maryland)

Massachusetts

Office of Safe Waste Management
Department of Environmental Management
100 Cambridge Street, Room 1094
Boston, MA 02202
(617) 727-3260

Source Reduction Program
Massachusetts Department of Environmental Quality Engineering
1 Winter Street
Boston, MA 02108
(617) 292-5982

Michigan
Resource Recovery Section
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-0540

Minnesota
Minnesota Pollution Control Agency
Solid and Hazardous Waste Division
520 Lafayette Road
St. Paul, MN 55155
(612) 296-6300

Minnesota Technical Assistance Program
W-140 Boynton Health Service
University of Minnesota
Minneapolis, MN 55455
(612) 625-9677
(800) 247-0015 (in Minnesota)

Minnesota Waste Management Board
123 Thorson Center
7323 Fifty-Eighth Avenue North
Crystal, MN 55428
(612) 536-0816

Missouri
State Environmental Improvement and Energy Resources Agency
P.O. Box 744
Jefferson City, MO 65102
(314) 751-4919

New Jersey
New Jersey Hazardous Waste Facilities Siting Commission
Room 614
28 West State Street
Trenton, NJ 08608
(609) 292-1459
(609) 292-1026

Hazardous Waste Advisement Program
Bureau of Regulation and Classification
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625

Risk Reduction Unit
Office of Science and Research
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625

New York
New York State Environmental Facilities Corporation
50 Wolf Road
Albany, NY 12205
(518) 457-3273

North Carolina
Pollution Prevention Pays Program
Department of Natural Resources and Community Development
P.O. Box 27687
512 North Salisbury Street
Raleigh, NC 27611
(919) 733-7015

Governor's Waste Management Board
325 North Salisbury Street
Raleigh, NC 27611
(919) 733-9020

Technical Assistance Unit
Solid and Hazardous Waste Management Branch
North Carolina Department of Human Resources
P.O. Box 2091
306 North Wilmington Street
Raleigh, NC 27602
(919) 733-2178

Ohio
Division of Solid and Hazardous Waste Management
Ohio Environmental Protection Agency
P.O. Box 1049
1800 WaterMark Drive
Columbus, OH 43266-1049
(614) 481-7200

Ohio Technology Transfer Organization
Suite 200
65 East State Street
Columbus, OH 43266-0330
(614) 466-4286

Oklahoma
Industrial Waste Elimination Program
Oklahoma State Department of Health
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-7353

Oregon
Oregon Hazardous Waste Reduction Program
Department of Environmental Quality
811 Southwest Sixth Avenue
Portland, OR 97204
(503) 229-5913

Pennsylvania
Pennsylvania Technical Assistance Program
501 F. Orvis Keller Building
University Park, PA 16802
(814) 865-0427

Center of Hazardous Material Research
320 William Pitt Way
Pittsburgh, PA 15238
(412) 826-5320

Bureau of Waste Management
Pennsylvania Department of
Environmental Resources
P.O. Box 2063
Fulton Building
3rd and Locust Streets
Harrisburg, PA 17120
(717) 787-6239

Rhode Island
Ocean State Cleanup and Recycling Program
Rhode Island Department of Environmental Management
9 Hayes Street
Providence, RI 02908-5003
(401) 277-3434
(800) 253-2674 (in Rhode Island)

Center for Environmental Studies
Brown University
P.O. Box 1943
135 Angell Street
Providence, RI 02912
(401) 863-3449

Tennessee
Center for Industrial Services
102 Alumni Hall
University of Tennessee
Knoxville, TN 37996
(615) 974-2456

Virginia
Office of Policy and Planning
Virginia Department of Waste Management
11th Floor, Monroe Building
101 North 14th Street
Richmond, VA 23219
(804) 225-2667

Washington
Hazardous Waste Section
Mail Stop PV-11
Washington Department of Ecology
Olympia, WA 98504-8711
(206) 459-6322

Wisconsin
Bureau of Solid Waste Management
Wisconsin Department of Natural Resources
P.O. Box 7921
101 South Webster Street
Madison, WI 53707
(608)267-3763

Wyoming
Solid Waste Management Program
Wyoming Department of Environmental Quality
Herchler Building, 4th Floor, West Wing
122 West 25th Street
Cheyenne, WY 82002
(307) 777-7752

WASTE EXCHANGES

Northeast Industrial Exchange
90 Presidential Plaza, Syracuse, NY 13202
(315) 422-6572

Southern Waste Information Exchange
P.O. Box 6487, Tallahassee, FL 32313
(904) 644-5516

California Waste Exchange
Department of Health Services
Toxic Substances Control Division
Alternative Technology & Policy Development Section
714 P Street
Sacramento, CA 95814
(916) 324-1807

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