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GUIDES TO POLLUTION PREVENTION: SELECTED HOSPITAL WASTE STREAMS

RISK REDUCTION ENGINEERING LABORATORY
CENTER FOR ENVIRONMENTAL RESEARCH INFORMATION
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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 hospitals in developing approaches for pollution prevention. Compliance with environmental and occupational safety and health laws is the responsibility of each individual medical institution and is not the focus of this document.

Worksheets are provided for conducting waste minimization assessments of hospital facilities. Users are encouraged to duplicate portions of this publication as needed to implement a waste minimization program.

FOREWORD

This guide provides an overview of hospital waste generating processes and presents options for minimizing waste generation through source reduction and recycling. Reducing the generation of these materials at the source, or recycling the wastes on or off site, will benefit hospitals by reducing disposal costs and lowering the liabilities associated with hazardous waste disposal.

The hazardous wastes generated by general medical and surgical hospitals are small in volume relative to those of industrial facilities; however, the wastes are of a wide variety. Some of the hazardous materials used by hospitals that become part of their waste streams include chemotherapy and antineoplastic chemicals; solvents; formaldehyde; photographic chemicals; radionuclides; mercury; waste anesthetic gases; and other toxic, corrosive and miscellaneous chemicals. Additional wastes such as infectious waste, incinerator exhaust, laundry-related waste, utility wastes, and trash are not addressed in this guide.

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CONTENTS

SECTION 1
INTRODUCTION

This guide was prepared to provide general medical and surgical hospitals with guidelines and options to minimize hazardous waste in selected waste streams. However, the waste minimization assessment approach described here can be used in efforts to minimize all wastes generated at a facility. The guide is intended primarily for use by hospitals, particularly administrators and environmental compliance personnel. Others who may find this document useful are regulatory agency representatives, hospital service organizations, and consulting firms.

The worksheets and the waste minimization options were developed through assessments of three San Francisco Bay Area hospitals commissioned by the California Department of Health Services (Calif. DHS 1988). The hospitals' operations and waste generation and management practices were surveyed and their existing and potential hazardous waste minimization options characterized for the following selected waste streams:

- solvents
- chemotherapy wastes
- photographic chemicals
- formaldehyde wastes
- radioactive wastes
- mercury
- other toxics and corrosives

The scope of the assessments did not include infectious waste, incinerator exhaust, laundry-related waste, utility wastes, and trash. Information about waste anesthetic gases has been added for this EPA guide.

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.

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

In the following sections of this manual you will find:

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

Overview of Waste Minimization Assessment

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.

To determine whether a WMOA would be useful in your circumstances, you should first read this section describing the aims and essentials of the WMOA process. For more detailed information on conducting a WMOA, consult the Waste Minimization Opportunity Assessment Manual.

ASSESSMENT PROCESS

The four phases of a waste minimization assessment, described briefly below, are:

- Planning and organization
- Assessment phase
- Feasibility analysis phase
- Implementation

Planning and Organization

Essential elements of planning and organization for a waste minimization program are: getting management commitment for the program; setting waste minimization goals; and organizing an assessment program task force. The importance of getting management support for waste minimization cannot be overstated.

Assessment Phase

The assessment phase involves a number of steps:

- Collect process and facility data
- Prioritize and select assessment targets
- Select assessment team
- Review data and inspect site
- Generate options
- Screen and select options for feasibility study

Collect process and facility data. The waste streams at the facility should be identified and characterized. Information about waste streams may be available on hazardous waste manifests, lab pack packing lists, National Pollutant Discharge Elimination System (NPDES) reports, routine sampling programs and other sources.

Developing a basic understanding of the activities that generate waste at a hospital facility is essential to the WMOA process. Flow diagrams should be prepared to identify the quantity, types and rates of waste generating activities. Also, preparing material balances for various processes can be useful in tracking various process components and identifying losses that may have been unaccounted for previously. This may be especially useful when attempting to differentiate between infectious and hazardous wastes.

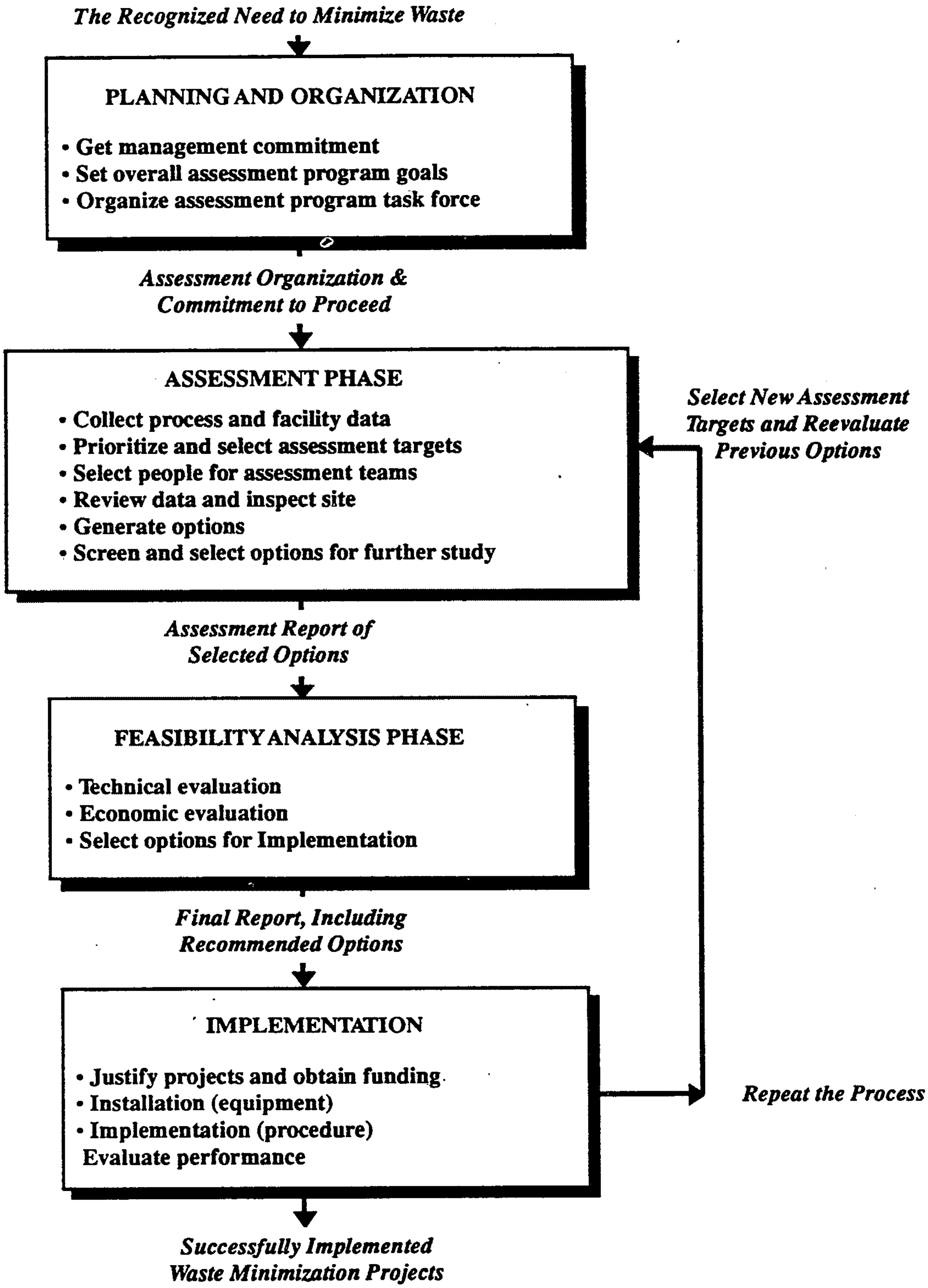
Prioritize and select assessment targets. Ideally, all waste streams in a facility should be evaluated for potential waste minimization opportunities. However, with limited resources, a hospital administrator may need to concentrate waste minimization efforts in a specific area. Such considerations as quantity of waste, hazardous properties of the waste, regulations, safety of employees, economics, and other characteristics need to be evaluated in selecting a target stream.

Select assessment team. The team should include people with direct responsibility for and knowledge of the waste streams or activities that generate the wastes. Use of consultants should be considered when no internal expertise is available.

Review data and inspect site. The assessment team evaluates activity data in advance of the site inspection. The inspection should follow the target activities from the point where raw materials enter the facility to the points where wastes leave. The team should identify the suspected and known sources of waste. For hazardous waste this may include laboratories, pharmacies, pathology, radiology, surgery, dialysis, embalming, nursing units, nuclear medicine, mercury from broken or obsolete equipment, "red bag" (infectious) wastes; maintenance operations; and storage areas for raw materials and wastes. The inspection may result in the formation of preliminary conclusions about waste minimization opportunities. Full confirmation of these conclusions may require additional data collection or analysis.

Generate options. The objective of this step is to generate a comprehensive set of waste minimization options for

Figure 1. The Waste Minimization Assessment Procedure



further consideration. Since technical and economic concerns will be considered in the later feasibility step, no options should be ruled out at this stage. Information from the site inspection, as well as medical associations, government agencies, technical and medical reports, equipment vendors, consultants, and facility engineers and technicians may serve as sources of ideas for waste minimization options.

Both source reduction and recycling options should be considered. Source reduction approaches include:

- Good operating practices
- Eliminating or reducing use of carcinogenic chemicals such as benzene and chloroform
- Increased use of analytical instrumentation - this can decrease the use of chemicals
- Improved inventory control utilizing computerized tracking and inventory systems, also use of central purchasing
- Elimination of use of oil based paints in maintenance

Recycling includes:

- Use and reuse of waste
- Reclamation

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. A technical evaluation determines whether a proposed option will work in a specific application. Both operational and equipment changes need to be assessed for their overall effects on waste quantity. Also, any new products or raw materials need to be tested for efficacy.

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. Savings and changes in revenue need also to be considered.

Implementation

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

SECTION 2
HOSPITAL WASTE PROFILE

Hospital hazardous waste is unique in several ways. There is a large variety of wastes but the volumes are small relative to industrial facilities. Hospitals employ toxic chemicals and hazardous materials for numerous diagnostic and treatment purposes. The hazardous materials include:

- Chemotherapy and antineoplastic chemicals
- Formaldehyde
- Photographic chemicals
- Radionuclides
- Solvents
- Mercury
- Waste anesthetic gases
- Other toxic, corrosive, and miscellaneous chemicals

Based on audits of three hospitals conducted for this study, chemotherapy wastes, including concentrated antineoplastic chemicals mixed with other inert materials, represented the highest volume of hazardous waste at each hospital. This was followed by spent photographic chemicals and formaldehyde solutions used for disinfecting equipment. Other significant and potentially significant sources of hazardous wastes noted were solvents, radioactive wastes, mercury, waste anesthetic gases and other toxics and corrosives. The scope of the assessments did not include infectious waste, incinerator exhaust, laundry-related waste, utility waste and trash.

Waste Description

CHEMOTHERAPY AND ANTINEOPLASTIC CHEMICALS

Procurement of antineoplastic, or cytotoxic, agents that are used to produce chemotherapy solutions is generally conducted through a central clinic or pharmacy. Quantities kept on hand at the hospitals audited were generally sufficient to last less than two weeks. Chemicals are mixed or compounded within a hood, which recirculates air through a filter. Chemotherapy wastes account for the largest volume of hazardous wastes produced by surveyed hospitals. Only a small percentage of these wastes contain concentrated amounts of chemotherapy compounds. Much of the waste volume is associated with lightly contaminated items such as personal protective clothing and gauze pads. Sharp items such as needles ("sharps") are also discarded, but may be separated and handled as infectious waste.

Waste materials are placed into plastic bags or plastic containers that are either replaced daily, or when they are full. An average of 2 to 8 cubic feet of chemotherapy wastes per week were generated by the hospitals surveyed. These wastes are either transported off-site to a Class I landfill or incinerated as infectious waste. However, it should be noted that the latter may not be an acceptable alternative under some state hazardous waste regulations. Landfilling of hazardous wastes is discouraged or prohibited in many areas of the country and should not generally be considered a viable disposal option for hospital hazardous wastes.

FORMALDEHYDE

Formaldehyde is used in pathology, autopsy, dialysis, embalming, and nursing units. Occupational exposure to airbone concentrations of formaldehyde is regulated by OSHA. New regulations limit the permissible exposure to 1.0 ppm as an 8-hour time weighted average (TWA), with an action level of 0.5 ppm (ECRI, Jan, 1988).

Formaldehyde also represents a significant source of hazardous waste at many hospitals. For use in dialysis, formaldehyde is generally purchased as a 37 percent formaldehyde-in-water solution (formalin). It is subsequently diluted with filtered, deionized water to achieve a final formaldehyde concentration of 2-4 percent. The formalin is either pumped or poured into dialysis machines to disinfect the membranes and the effluent is discharged to the sewer. In other departments, formaldehyde is generally used to preserve specimens with small quantities of waste generated and discharged to the sewer. Discharging a hazardous material to the sewer may be illegal and is generally an undesirable management practice, even if sanitation authorities allow such disposal.

PHOTOGRAPHIC CHEMICALS

Full-service hospitals generally have a radiology department. The photographic developing solutions used in X-ray departments consist of two parts, a fixer and a developer. The fixer normally contains 5-10 percent hydroquinone, 1-5 percent potassium hydroxide, and less than 1 percent silver. The developer contains approximately 45 percent glutaraldehyde. Acetic acid is a component of stop baths and fixer solutions. These two chemical solutions usually are obtained in 30- or 55-gallon drums. The contents are routed from these drums directly to the developing machine.

Silver-containing effluent from the fixer solution is passed through a steel wool filter or otherwise treated to recover this precious metal. The remaining aqueous waste, containing approximately 1.4 percent glutaraldehyde, 0.3 percent hydroquinone, and 0.2 percent potassium hydroxide, is typically discharged to the sewer. Some hospitals utilize X-ray services that also provide silver recovery as part of the package.

RADIONUCLIDES

Radioactive wastes are generated in nuclear medicine and clinical testing laboratory departments. At the hospitals surveyed, radioactive materials in nuclear medicine were retained on site until they decayed to nonhazardous levels. In clinical testing laboratories, solvents are also used for radioactive tagging. Wastes at the audited hospitals are generated at a rate of about 800 cubic centimeters per week. The radioactive wastes are transported off site for land disposal.

SOLVENTS

Solvent wastes are typically generated in various departments throughout a hospital. These include pathology, histology, engineering, embalming, and laboratories. Volumes of solvent wastes generated at the hospitals surveyed were small. Specific solvents used in medical settings include halogenated compounds such as methylene chloride, chloroform, freons, trichloroethylene, and 1,1,1-trichloromethane. Other solvents include non-halogenated compounds such as xylene, acetone, ethanol, isopropanol, methanol, toluene, ethyl acetate, and acetonitrile. Xylene, methanol, and acetone were the most frequently used solvents at the audited hospitals.

Xylene and ethanol are used in histology and cytology laboratories of hospital anatomic pathology departments. In tissue processing, ethanol dehydrates and xylene clears tissue prior to paraffin infiltration and embedding. Then xylene is used to remove paraffin and ethanol to hydrate sections before staining. Ethanol and xylene are again used to dehydrate and clear sections before the cover slip is applied to the microscope slide preparation (L. McGlothlin, histology supervisor at UC Davis, cited in Roark 1989).

While acetone and methanol waste are usually evaporated or discharged to the sewer, the xylene wastes are normally handled as hazardous materials. Some of these wastes are absorbed in specimens which are then treated instead as infectious wastes. Solvent wastes are typically stored in 30- or 55-gallon drums and are either recycled or transported off site for incineration. In the past, small quantities of solvent wastes were routinely disposed of via lab packs to land fills. This alternative is becoming increasingly less desirable due to higher disposal costs, long-term liability, and limitations introduced by new, more stringent regulations.

MERCURY

The primary sources of mercury waste at most hospitals include broken or obsolete equipment. Mercury wastes are decreasing in quantity due to the substitution of solid state electronic sensing instruments (thermometers, blood pressure gauges, etc.) for those containing mercury.

Mercury from broken equipment is recovered and reused (if uncontaminated). Mercury losses due to spillage may not be frequently recovered; no mercury spill kits were present in any of the three surveyed hospitals.

ANESTHETIC GASES

Nitrous oxide and the halogenated agents halothane (Fluothane), enflurane (Ethrane), isoflurane (Forane), and other substances are used as inhalation anesthetics. Exposure of health care personnel to these substances may result in acute toxic effects and, possibly, reproductive disorders and carcinogenesis (ECRI Feb. 1988).

Nitrous oxide is supplied as a gas in cartridges or cylinders that are attached directly to the anesthetic administering equipment. Used containers are returned to the supplier. The halogenated anesthetic agents are supplied in liquid form, in glass bottles. Once empty, the bottles are handled as hazardous waste.

Purchase

Waste anesthetic gases are generally removed from the operating room, or the site of application, in one of two ways. At some of the larger hospitals, a scavenging unit is attached to the anesthesia unit to remove the waste gases. The scavenging unit may have a charcoal filter which would adsorb halogenated anesthetic gases but not nitrous oxide. Spent charcoal filters are sent off site as hazardous waste. If there is no scavenging unit, or if the scavenging unit does not have a filter, then vacuum lines are used to collect waste anesthetic gases and vent them to the outside.

TOXICS, CORROSIVES, AND MISCELLANEOUS CHEMICALS

Poisons, oxidizers, and caustics are used throughout most hospitals, generally in small quantities. Waste oils and solvents from maintenance may also be considered hazardous wastes as may some boiler water conditioning chemicals. Although many of these types of wastes are considered hazardous materials, only ethylene oxide was used at the surveyed hospitals in large quantities. All of the audited hospitals currently discharge this gas to the atmosphere but may soon be required to treat it. Many facilities in California are already required to "scrub" these emissions.

Listed below are some major toxic, corrosive, and miscellaneous chemical wastes and their sources of origin:

Ethylene Oxide	Used in sterilizers. Classified by EPA as a probable human carcinogen; also a smog forming agent, and explosive/flammability hazard.
Disinfecting Cleaning Solutions	Phenol based, used for scrubbing floors and other applications.
Utility Wastes	Boiler feed water treatment residuals (resin regeneration brine, spent resin) Boiler blowdown Boiler cleaning (layup) wastes Cooling tower blowdown Cooling tower sludges/ sediments
Maintenance Wastes	Waste lube oils, vacuum pump oils Cleaning solvents Paint stripping wastes Leftover paints and painting accessories Spent fluorescent lamps

Ethylene Oxide

Ethylene oxide (EtO), used to sterilize medical devices, is used in central supply areas, respiratory therapy, and at times, in operating rooms. This colorless and odorless gas can cause a number of acute toxic reactions and is a probable human carcinogen (ECRI Jan. 1989).

Ethylene oxide is purchased in cartridges or cylinders that can be attached directly to specially designed sterilizers. Equipment that has been sterilized in a EtO sterilizer is transferred to an EtO aeration chamber. Both EtO sterilizers and aerators are connected to ventilation systems which duct the exhaust to the outside. Used ethylene oxide cylinders are returned to the supplier. Some hospitals are going to bulk storage of ethylene oxide, using large tanks.

Waste Management Issues

A large variety of hazardous materials is used in hospitals; however, overall waste quantities generated are relatively low. Tracking of hazardous wastes in hospitals is often complicated by a lack of available records on waste generation. This results from hazardous wastes being mixed with infectious wastes and from disposal of potentially hazardous wastes into the sewer.

The Medical Waste Tracking Act is a demonstration program (participants are New York, New Jersey, Connecticut, Rhode Island, Louisiana, and the District of Columbia) that will require generators of more than 50 pounds of waste monthly to use a four-copy manifest tracking system. Included in "medical waste", for the purposes of the Act, will be cultures and stocks of infectious agents and associated biologicals; pathological waste; human blood and blood products; used sharps; contaminated animal carcasses; surgery or autopsy waste; laboratory wastes; dialysis wastes; discarded medical equipment; and isolation wastes.

MWTA is expected to lead eventually to a broader tracking program that will affect all states. It may also provide impetus to hospitals to incinerate many types of waste on site. With this possibility in view, EPA expects to establish medical waste incineration regulations under the Clean Air Act (Roy 1989).

INFECTIOUS WASTES

Although recently awareness has increased regarding the need for proper disposal of medical waste, there has been a misconception at some hospitals regarding the need to apply proper hazardous waste disposal practices for wastes containing both infectious and hazardous components. By current law, any waste mixture of non-hazardous and hazardous or infectious and hazardous wastes must be handled as a hazardous waste. Many items that are routinely handled as infectious waste (gauze pads, gowns, etc. that are contaminated with hazardous waste) should be handled as hazardous waste. The lack of manifesting requirements for infectious wastes makes accurate determinations of hazardous components in these waste streams even more difficult. The generation and disposal of infectious wastes were excluded from the scope of the assessments.

SEWER USE AND PRETREATMENT

The diluted nature and/or low volume of certain hazardous liquid wastes has resulted in some hospitals obtaining permission from the local sanitary district to discharge these solutions to the sewer. For instance, formaldehyde solutions from dialysis and pathology departments are routinely discharged to the sewer. Wastes from these departments contain between 4 and 10 percent formaldehyde, respectively. Permission by the sanitary districts to discharge these wastes to the sewer is normally granted only for non-bioaccumulative wastes.

SECTION 3
WASTE MINIMIZATION OPTIONS

Description of Techniques

This section discusses recommended waste minimization methods for general medical and surgical hospitals. These methods were identified through waste minimization assessments of hospitals and through reference to technical literature. Hospitals' primary waste streams are listed in Table 1 along with recommended control methods. Infectious wastes, incinerator exhaust, laundry-related waste, utility wastes and trash are not addressed. The control methods can be classified generally as source reduction methods which can be achieved through material substitution, process or equipment modification, or better operating practices; or as recycling. Treatment of hazardous waste is not the focus of this guide.

The waste minimization options are presented for specific waste streams, following a discussion of better operating practices that can be used in overall hospital waste management.

Better Operating Practices

Better operating practices are procedures and institutional policies that result in a reduction of waste. Improved management oversight, tracking, and inventory control can effectively reduce waste generation. Computerized data base tracking systems provide a very effective and efficient method of tracking and inventory control.

Key overall operating strategies include:

- Keep individual waste streams segregated.
  - Keep hazardous waste segregated from nonhazardous waste. All waste contaminated with a hazardous substance becomes hazardous.
  - Keep hazardous chemical wastes segregated from infectious wastes.
  - Keep recyclable waste segregated from non-recyclable waste.
  - Minimize dilution of hazardous waste.
- Assure that the identity of all chemical and wastes is clearly marked on all containers.

Improved management and control practices include:

- Centralize purchasing and dispensing of drugs and other hazardous chemicals.
- Monitor drug and chemical flows within the facility from receipt as raw materials to disposal as hazardous wastes. This may be partially or fully automated by the use of computer systems and computer-readable barcoded labels for incoming chemicals, similar to those used in supermarkets.
- Apportion waste management costs to the departments that generate the wastes.
- Improve inventory control by:
  - Requiring users of chemicals with limited shelf life to use up old stock before ordering or using new stock.
  - Ordering hazardous chemicals only when needed and in minimal quantities to avoid outdated inventory.
- Provide employee training in hazardous materials management and waste minimization. The major generating departments should have a training program for all staff who may generate or handle hazardous materials. Training should include:
  - Chemical hazards.
  - Spill prevention.
  - Preventive maintenance.
  - Emergency preparedness and response, including spill clean-up.
- Implement an institution-wide waste reduction program.

Table 1. Waste Minimization Methods for General Medical and Surgical Hospitals

Waste Category	Waste Minimization Method
Chemotherapy and Antineoplastics	Reduce volumes used. Optimize drug container sizes in purchasing. Return outdated drugs to manufacturer. Centralize chemotherapy compounding location. Minimize waste from compounding hood cleaning. Provide spill cleanup kits. Segregate wastes.
Formaldehyde	Minimize strength of formaldehyde solutions. Minimize wastes from cleaning of dialysis machines and RO units. Use reverse osmosis water treatment to reduce dialysis cleaning demands. Capture waste formaldehyde. Investigate reuse in pathology, autopsy laboratories.
Photographic Chemicals	Return off-spec developer to manufacturer. Cover developer and fixer tanks to reduce evaporation, oxidation. Recover silver efficiently. Recycle waste film and paper. Use squeegees to reduce bath losses. Use countercurrent washing.
Radionuclides	Use less hazardous isotopes whenever possible. Segregate and properly label radioactive wastes, and store short-lived radioactive wastes in isolation on site until decay permits disposal in trash.
Solvents	Substitute less hazardous cleaning agents, methods for solvents cleaners. Reduce analyte volume requirements. Use pre-mixed kits for tests involving solvent fixation. Use calibrated solvent dispensers for routine tests. Segregate solvent wastes. Recover/reuse solvents through distillation.
Mercury	Substitute electronic sensing devices for mercury-containing devices. Provide mercury spill cleanup kits and train personnel. Recycle uncontaminated mercury wastes using proper safety controls.
Waste Anesthetic Gases	Employ low leakage work practices. Purchase low-leakage equipment. Maintain equipment properly to avoid leaks.
Toxics, Corrosives and Miscellaneous Chemicals	Inspection and proper equipment maintenance for ethylene oxide sterilizers. Substitute less toxic compounds, cleaning agents. Reduce volumes used in experiments. Return containers for reuse, use recyclable drums. Neutralize acid waste with basic waste. Use mechanical handling aids for drums to reduce spills. Use automated systems for laundry chemicals. Use physical instead of chemical cleaning methods.

- Establish an internal recycling program. Package stills are available that are capable of recycling histology and other solvents to reagent grade purity.

Other approaches that will improve hazardous waste management in hospitals include:

- Requiring that all new materials (cleaning compounds, process chemicals, etc.) that may result in hazardous waste generation be tested in small quantities before being purchased in bulk to assure that large quantities of unused materials that do not perform as expected do not need disposal.

- Encouraging drug and chemical suppliers to become responsible partners in a waste minimization program by ordering 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 hazardous wastes.

These 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.

CHEMOTHERAPY AND ANTINEOPLASTIC WASTES

The toxicity of antineoplastic agents is inherent, because of their efficacy against cancer. The hazards associated with the handling of a given antineoplastic drug are usually of secondary concern compared with its pharmaceutical effectiveness. Because individual responses to drugs in this category vary widely, many different antineoplastics have been marketed.

The greatest volume of antineoplastic wastes is generated from drug dispensing devices, contaminated protective clothing, and associated paraphernalia. At surveyed hospitals, there is significant potential for reducing waste volumes through administrative controls. These include waste segregation, minimizing clean-up waste volume, and employee training. Other methods include:

- Segregate chemotherapy wastes from other wastes. Adherence to this procedure is facilitated through training and by providing separate containers with distinctive labels in chemotherapy drug handling areas.

- Disposable garments may be disposed of with nonhazardous refuse if no chemotherapy agents were spilled during handling. However, gloves should be assumed to be contaminated.

- Minimize the cleaning frequency and volume of gauze material used for the compounding hood.

OSHA has a publication 8-1.1 (January 29, 1986) regarding health and safety when handling antineoplastic drugs. In it, OSHA recommends that hoods be wiped down daily with 70 percent alcohol and be decontaminated weekly with a high-pH (basic) solution. The actual cleaning frequency required depends on drug handling volume and the amount of spillage which occurs in the hood. Proper handling practices should be emphasized to minimize hood cleaning requirements.

- Purchase drug volumes according to need.

Over-purchasing results in the generation of out-of-date materials that must be disposed of. Reducing the generation of residual material may be accomplished by computing daily compounding requirements of each drug and ordering appropriately sized containers. In addition, obtain pre-scored ampule containers. This will minimize spillage associated with breaking open unscored ampule necks.

- Employ proper spill containment and clean-up procedures.

Spill containment and clean-up kits should be readily available in the compounding area(s). These kits, usually available from the drug suppliers, should contain both small and large absorbent devices.

- Proper training.

Effective administrative and engineering control require ongoing employee training and supervision. Surveyed hospitals reported that chemotherapy drug handling training is primarily limited to health and safety. However, employees also need to be trained in methods to minimize generation of chemotherapy wastes.

- Return outdated drugs to the manufacturer.

- Centralize the location of chemotherapy compounding areas.

FORMALDEHYDE WASTES

For use in dialysis, formaldehyde is generally purchased as a 37% formaldehyde-in-water solution (formalin). It is subsequently diluted with filtered, deionized water to achieve a final formaldehyde concentration of 3-4%. The formalin is either pumped or poured into dialysis machines, and the effluent is discharged to the sewer. Ways to minimize this waste include installation of reverse osmosis water supply equipment, using minimium effective cleaning procedures, recycling and reusing waste solutions, and proper waste management.

Install Reverse Osmosis (RO) Water Supply Equipment.

Since the cleaning of dialysis equipment is the major reason for formaldehyde waste, any measures that help to reduce the need for cleaning will help reduce waste generation. Hospitals reported that use of RO units allows a reduction in the cleaning frequency requirements of dialysis machines. While RO water treatment units also are typically flushed with formalin, they can be cleaned instead with hydrogen peroxide, which is less persistent in the environment.

Determine Minimum Effective Cleaning Procedures.

At the surveyed hospitals, a significant variation was observed in the cleaning frequency of the hemodialysis machines and of the reverse osmosis (RO) water supply equipment. Since waste generation rates are directly related to cleaning frequency and formalin strength, the potential exists for minimizing these wastes by optimizing both variables. There is an apparent need to develop consistent standards for formalin solutions, based upon microbial culture studies. These studies should compare microbial residues with variations in formalin strength, cleaning frequency, and water supply systems.

Reuse/Recycle Waste Solutions.

The diluted formalin waste stream contains approximately 4 percent formaldehyde, 1 percent methanol, and 95 percent water. Surplus or absolute dialysis units could possibly be used to concentrate the formaldehyde for reuse. Dialysis has been used to recover organic material in rayon manufacturing (Sawyer and McCarty 1967). Off-spec dialysis membranes could possibly be used to extract and concentrate the formaldehyde wastes for eventual reuse, recycle, or incineration.

Recovery of waste formalin through distillation is also theoretically feasible. However, none of the surveyed hospitals is recycling formaldehyde wastes through distillation. The tendency for formaldehyde to polymerize and form azeotropes with water and methanol may affect recovery efficiencies. Moreover, a high purity extract is required for reuse in dialysis to ensure that there are no pathogenic contaminants in the aqueous fraction. For these reasons, distillation would need to be monitored carefully.

In autopsy and pathology laboratories, depending upon the type of specimen, direct reuse of formaldehyde solutions may be feasible. These solutions retain their desired properties for periods far longer than the usual holding times for specimens. In addition, the desired preservative properties may be effective at lower concentrations than the 10 percent formaldehyde solutions typically used. Reuse of hospital formaldehyde wastes through an open-market waste exchange does not appear feasible. This is because of the potential presence of pathogens in the waste stream.

Proper Waste Management.

All waste management methods should stress control of airborne emissions since formaldehyde is a suspected carcinogen of the upper respiratory system (ACGIH 1987). The OSHA permissible exposure level (PEL) for formaldehyde was recently reduced from 10 ppm to 1 ppm.

PHOTOGRAPHIC CHEMICAL WASTE

The major waste stream associated with image processing at hospital radiology departments is wastewater that contains photographic chemicals and silver removed from film. Other wastes include spoiled chemicals and scrap film. Ways to reduce these wastes include:

Store Materials Properly.

Many photoprocessing chemicals are sensitive to temperature and light. Photosensitive film and paper storage areas should be designed for economical and efficient use. Chemical containers list the recommended storage conditions. Meeting the recommended conditions will increase their shelf life.

Recycle Spoiled Photographic Film and Paper.

It is a current practice in the photoprocessing and printing industry to send used and/or spoiled film to professional recyclers for recovery of silver (USEPA 1986). However, this option might not be practical to small scale operations or available to facilities located far away from recyclers.

Test Expired Material for Usefulness.

Materials having expired shelf-life should not automatically be thrown out. Instead, this material should be tested for effectiveness. The materials may be usable, rather than becoming a waste. A recycling outlet should be found for left over raw material that is no longer wanted.

Extend Processing Bath Life.

Wastes from photographic processing can be reduced by extending the life of fixing baths. Techniques include

(1) adding ammonium thiosulfate, which doubles the allowable concentration of silver buildup in the bath; (2) using an acid stop bath prior to the fixing bath; and (3) adding acetic acid to the fixing bath as needed to keep the pH low.

Accurately adding and monitoring chemical replenishment of process baths will cut down chemical wastage. Stored process bath chemicals should be protected from oxidation by reducing exposure to air. Some smaller photo developers store chemicals in closed plastic containers. Glass marbles are added to bring the liquid level to the brim each time liquid is used. In this way, the amount of chemical subject to degradation by exposure to air is reduced, thereby extending the chemical's useful life and the life of the bath.

Use Squeegees.

Squeegees can be used in non-automated processing systems to wipe excess liquid from the film and paper. This can reduce chemical carryover from one process bath to the next by 50 percent (Campbell and Glenn 1982). Minimizing chemical contamination of process bath increases recyclability, enhances the lifetime of the process baths, and reduces the amount of replenisher chemicals required. Most firms, however, use automated processors. Also, using squeegees may damage the film image if it has not fully hardened, so a squeegee should be used after the film image has hardened.

Use Countercurrent Washing.

In photographic processors, countercurrent washing can replace the commonly used parallel tank system. This can reduce the amount of wastewater generated. In a parallel system, fresh water enters each wash tank and effluent leaves each wash tank. In countercurrent rinsing, the water from previous rinsings is used in the initial film-washing stage. Fresh water enters the process only at the final stage, at which point much of the contamination has already been rinsed off the film. However, a countercurrent system requires more space and equipment.

Recover Silver and Recycle Spent Chemicals.

Basically, photoprocessing chemicals consist of developer, fixer, and rinse water. Keeping the individual process baths as uncontaminated as possible is a prerequisite to the successful recycling of these chemicals. Silver is a component in most photographic films and paper and is present in the wastewaters produced. Various economical methods of recovering silver are available (e.g. metallic replacement, chemical precipitation, electrolytic recovery), and a number of companies market equipment that will suit the needs of even the smallest generator.

The most common method of silver recovery employed by hospitals is metallic replacement. The spent fixing bath is pumped into a cartridge containing steel wool. An oxidation-reduction reaction occurs and the iron in the wool replaces the silver in solution. The silver settles to the bottom of the cartridge as a sludge.

Another, more efficient, method of silver recovery is electrolytic deposition. In an electrolytic recovery unit, a low voltage direct current is created between a carbon anode and stainless steel cathode. Metallic silver plates onto the cathode. Once the silver is removed, the fixing bath may be able to be reused in the photographic development process by mixing the desilvered solution with fresh solution. Recovered silver is worth about 80% of its commodity price.

Some of the companies that buy used film or cartridges containing recovered silver can be located under "Gold and Silver Refiners and Dealers" in a business telephone directory. These firms may pick up directly or may purchase through dealers. To recycle used film, it may be worthwhile to sort the film into "largely black" versus "largely clear" segments, since the rate of payment for mostly black film may be twice that for mostly clear.

Technologies for reuse of developer and fixer are available and include ozone oxidation, electrolysis, and ion exchange.

RADIONUCLIDES

Radioactive wastes cannot be treated or neutralized. Therefore, source reduction and substitution are the primary waste minimization strategies for such materials. Knowledge of the physical and biological properties of the various nuclides is required to enable assessment of environmental hazards associated with waste products.

Table 2 lists properties of common nuclides used in hospital research and treatment. The type of radiation emitted, energy, physical and effective half lives, and decay products are the factors which must be considered when choosing among various nuclides. The objective is to choose a nuclide which has a short half-life, low energy, a stable, non-toxic decay product, and emits minimal amounts of extraneous radiation. Extraneous radiation refers to the production of a type of radiation which is not required in the test or procedure. For example, if a beta emitter is required for a certain test, a nuclide which produces minimal gamma radiation should be chosen. This is because gamma radiation is hazardous to the patient and is more difficult to contain during handling.

Radium-226 is probably the most hazardous radionuclide used in hospitals. Its physical and effective half lives are extremely long and its decay products are unstable. Radium-226 needles used in cancer treatment are being phased out at many hospitals in favor of iridium-192 or cesium-137 needles.

Table 2. Properties of Radionuclides Used In Hospitals

Nuclide[1]	Type of Radiation[2]	Energies[3] (MeV)	Physical Half-Life[4]	Effective Half-Life[5]	R/hr per Ci at 1 meter[6]	Daughters[7]
Carbon-14	beta-, no gamma	0.156 max	5,730 yrs.	12 days	N.A.8	Nitrogen-14 (stable)
Phosphorus	beta-, no gamma	1.7 max	14 days	14 days	N.A.	Sulfur-32 (stable)
Chromium-51	gamma	0.32	28 days	27 days	0.018	Vanadium-51 (stable)
Gallium-67	gamma	0.093 (40%)	78 hrs.			Zinc-67 (stable)
Technetium-99	gamma	0.14	6 hrs.	5 hrs.	0.059	Technetium-99 (radioactive) Ruthenium-9(stable)
Indium-111	gamma	0.173	2.8 days			Cadmium-111 (stable)
Iodine-125	gamma	0.035	60 days	42 days	0.07	Tellurium-125 (stable)
Tritium	beta-, no gamma	0.0186 max	12.3 yrs.	12 days	N.A.	Helium-3 (stable)
Iodine-131	beta-	0.606 max	8 days	8 days	0.21	Xenon-131 (stable)
	gamma	0.365				
Cesium-137	beta-	1.176 max (7%) 0.514 max	30 years	70 days	0.32	Barium-137 (stable)
	gamma	0.662				
Barium-137m	gamma	0.662	2.5 min			Barium-137 (stable)
Iridium-192	beta-	0.666 max	74 days			Platinum-192(stable)
	gamma	0.317, 0.468				
Radium-226	alpha	4.78	1,600 yrs.	44 yrs.	0.825	Radon-22 (radioactive) (See Note 7)
	gamma	0.186				
Cobalt-609	beta-	0.318 max	5.27 yrs.	10 days	1.33	Nickel-60 (stable)
	gamma					

[1] Nuclide: Most common radioactive nuclides (radionuclides) present at hospitals. Tritium, iodine-125, and carbon-14 are most commonly used at research hospitals. The "m" in barium-137m and technetium-99m represents a metastable state of that nuclide (see note 7).

[2] Type of Radiation: beta-: negative beta particle called beta minus; alpha: alpha particle; gamma: gamma ray. "no gamma" means that nuclide emits no gamma rays, which is unusual; most alpha and beta decays are accompanied by gamma radiation. Only the major radiations are listed here.

[3] Energies: Most significant energies are given here (MeV = million electron-volts). For beta-decay, a continuous spectrum of beta energies are released up to some maximum value which is specific to a given radionuclide. The average beta- energy is a better indication of the hazard - average beta energy is generally 30-40% of the maximum energy.

[4] Physical Half-Life: The time required for half of the original number of atoms to decay: abbrev. T_ or Tp.

[5] Effective Half-Life: A combination of the physical T_ (Tp) and biological T_ (Tb), where $\frac{1}{Teff} = \frac{1}{Tp} + \frac{1}{Tb}$

T^b is the time required for half of the atoms to be removed from the body (through excretion)

[6] R/hr per Ci at one meter: Specific activity, given for gamma-emitting radionuclides - indicates the Roentgen/hr measurement expected from a one-Curie point source at a distance of one meter.

[7] Daughters: When an atom decays by beta or alpha emission it becomes an atom of another element; the original atom is called the parent and the product is called the daughter. Most of the radionuclides used in hospitals have daughters that are stable (i.e., they are not radioactive). However, some have daughters that are also radioactive, which in turn can produce subsequent radioactive daughters. For example, as radium-226 decays, it produces seven "generations" of distinct, radioactive decay products, and only in the eighth generation is a stable decay product, lead-206, produced. These seven daughters all emit alphas and betas and have a range of half-lives.

[8] N.A.: not applicable

[9] Used in teletherapy units only - not routine waste.

Note: Blanks indicate no information available.

Source: Calif. DHS, 1988.

E. Party and E.L. Gershey of The Rockefeller University, who reviewed the field of low-level radioactive waste (LLRW) for the Annual Review of Public Health, recommend several ways that the amounts of LLRW that are generated by biomedical institutions and that require disposal, can be reduced substantially (1989). The primary method of waste reduction requires allocation of space (100 to 200 square meters) on site where short-lived radioactive materials may be isolated and stored until decay to acceptably low levels as verified by survey meter. They then can be disposed of as non-radioactive liquids and trash.

Low level radioactive wastes need to be segregated and properly labeled as to isotope, form, volume, laboratory origin, activity, and chemical composition. Central processing is recommended.

SOLVENTS

The primary sources of hospital solvent wastes are the laboratory, pathology, histology, and maintenance (engineering) departments. Waste quantities vary significantly depending on the size and specific functions of the hospital. Solvents are used for degreasing and parts cleaning in engineering, for fixation and preservation of specimens in histology and pathology, and for extractions in laboratories.

For the purposes of waste management, solvents can be classified as either halogenated or non-halogenated. Halogenated solvents are generally more toxic and persistent. Specific halogenated compounds used in hospitals include methylene chloride, chloroform, tetrachloroethylene, chlorobenzene, trichloroethylene, 1,1,1-trichloromethane, and Freon. Non-halogenated compounds include xylene, acetone, toluene, methanol, ethyl ether, methyl ethyl ketone, and pyridine.

Routine procedures for managing solvent waste at many hospitals currently include discharge to the sewer and lab-pack disposal in landfills. While these procedures have been considered acceptable in the past, they are no longer advisable options and in some situations may be illegal. Land disposal is becoming increasingly costly and the number of substances banned from landfilling continues to grow. Although disposal of some solvent wastes to the sewer in small concentrations may be acceptable by some municipal standards, state and federal laws may prohibit such discharges. Questions of legality aside, both land disposal and sewer discharge are environmentally unsound alternatives.

Material Substitution

Source reduction options for solvents consist of substituting non-halogenated compounds for halogenated compounds, substituting simple alcohols and ketones for petroleum hydrocarbons (i.e., toluene or xylene), and using aqueous reagents (such as biodegradable Alconox) wherever possible. In addition, sonic or steam cleaning can often be substituted for alcohol-based disinfectants.

Histology solvents must dehydrate tissues, so aqueous-based solvents are not suitable in histology. In the past, benzene was the solvent of choice. However, due to concerns about the hazards of benzene, it has largely been replaced by xylene. There are a number of xylene substitutes currently on the market, one or more of which may be a viable substitute.

Improved Laboratory Techniques

Solvent use in laboratories has decreased in recent years due to technological advances. For example, monoclonal antibodies, radioisotope-labeled immunoassays, and ultrasensitive analytical devices have reduced or eliminated the need for solvent extractions and fixation.

Calibrated solvent dispensers or unitized test kits should be used. The sizes of cultures or specimens should be minimized in the pathology, histology, and laboratory departments.

Recycle Solvents

An important first step in determining the feasibility of on-site distillation and recovery of waste solvents consists of separating waste streams according to specific chemical components. This may allow the use of simple batch distillation equipment which is less expensive than fractional distillation equipment. Individual solvent recycling units suitable for hospital use have been developed. One manufacturer has a fractional distillation system equipped with a microprocessor to automatically distill, fractionate, and purify a solvent. It can be used, for example, to separate xylene from ethanol in histology wastes (Roark 1989).

In the event that on-site distillation is not feasible, off-site distillation or waste exchange should be considered. Solvent wastes that have been kept segregated (halogenated vs. non-halogenated) may be more easily recycled off site. Solvent wastes with sufficiently low chlorine content can be used as a fuel supplement in cement kilns and some industrial boilers.

MERCURY

Electronic Sensing Devices

Perhaps the best, if not the least costly, approach to mercury waste minimization is to eliminate mercury-containing instruments entirely. Substituting solid state electronic sensing devices for mercury-based thermometers and blood pressure instruments is occurring at many hospitals. This source elimination technique appears to be the primary reduction alternative for mercury wastes. The higher initial costs of electronic devices are typically justified because they eliminate costly clean-ups and associated hazards from glass breakage and mercury spills.

Proper Spill Clean-Up

Elemental mercury exhibits high toxicity via inhalation, skin absorption and ingestion. Spill clean-up procedures and handling operations must be carefully designed and monitored to protect employees and public health. Specially designed mercury vacuums and spill absorbent kits should be used for spill clean-ups.

Recycle/Reuse

Waste mercury can easily be recycled depending on the type or degree of contamination. Residual mercury in reservoirs of broken devices can be coarsely filtered and reused. While mercury recovered from spills or otherwise contaminated can be distilled to remove impurities, mercury distillation requires a hazardous waste treatment permit and possibly an air emissions permit. The equipment costs and elaborate permitting requirements make on-site distillation infeasible at most hospital facilities.

ECRI (ECRI March 1989) lists four mercury refineries in the U.S:

Adrow Chemical Co.
3 Lines Ave.
Wanaque, NJ 07465
(201) 839-2372

Bethlehem Apparatus Co., Inc.
890 Front St.
Hellertown, PA 18055
(201) 838-7034

D.F. Goldsmith Chemical and Metals Corp.
909 Pitner Ave.
Evanston, IL 60202
(312) 869-7800

Mercury Distributors, Inc.
13814 Almeda Rd
Houston, TX 77053
(713) 433-2418

In addition, your regional U.S. Environmental Protection Agency office or your state environmental department may have information about commercial mercury-recovery firms in your area.

One mercury recycler provides hospitals with an airtight steel container that can hold up to 76 pounds of mercury. The container is used at the hospital for collecting and then can be used to ship the mercury to the recycler without additional packaging (ECRI March 1989).

WASTE ANESTHETIC GASES

Non-hazardous substitutes are not available for anesthetic gases. The waste minimization options that are feasible are measures designed to reduce leaks and, as a result, reduce exposure of health care personnel to releases of these gases in the workplace. Many of these measures are in fact "better operating practices." The reduction of inadvertent releases of gases in the workplace will, in the long run, reduce the amount of gases purchased and the overall amount released as waste.

ECRI (Feb. 1988) recommends the following approach for controlling waste anesthetic gases:

- Use of low-leakage anesthetic equipment. Generally equipment less than 10 years old complies with low-leakage standards.
- Proper routine maintenance, by qualified personnel, of anesthesia equipment, scavenging equipment, and the ventilation system.
- Daily leak testing before use of equipment.
- Quarterly monitoring of waste anesthetic levels in operating rooms, recovery rooms, dental suites, and adjacent rooms that may receive waste gases.

In addition, ECRI recommends several anesthetist work practices designed to minimize leakage and resulting worker exposure. These include, before inducing anesthesia: confirming proper connections and leak tightness of equipment, and avoiding spillage of liquid anesthetics while filling vaporizers. During anesthesia administration, anesthetists can reduce leakage by properly fitting the mask on the patient's face before turning on anesthetic flow, and by turning off the gas supply before disconnecting the breathing circuit during short interruptions.

In larger operating rooms, the anesthesia supply system may include permanent piping in the walls of the room. This piping is tested rigorously for leaks at the time of installation. However, routine post-installation testing procedures are generally designed to assure proper flow and pressure of the anesthetic gases without specifically testing for leaks. As a result, leaks in wall plumbing may go undetected for years. To avoid losses of anesthetic gases and exposure of hospital personnel, tests for leakage in this part of the supply system should be performed periodically (Bastian 1989).

TOXICS, CORROSIVES, AND MISCELLANEOUS CHEMICALS

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 hospital environment. Vehicle and building and grounds maintenance operations generate waste oils, vehicle maintenance waste, solvents, pesticides, water treatment chemicals, and possibly PCB oil from old transformers, asbestos, and other wastes.

Opportunities to minimize wastes in these activities include:

- Collect waste oil and solvents for recycling.
- Segregate recyclable oils and solvents from non-recyclable wastes.
- Replace oil-based paints with water-based paints in maintenance operations.
- Reduce generation of pesticide waste by reducing pesticide application, using non-chemical pest control methods, and preparing and using only the required quantities.

Ethylene Oxide

There are currently no acceptable non-hazardous substitutes for ethylene oxide's (EtO) use as a sterilant for a number of medical devices. Several companies are reportedly working on alternatives to ethylene oxide (EtO); however, details on these substitutes are not yet available (ECRI Sept. 1988).

Currently all waste EtO is vented to the outside atmosphere. The California Air Resources Board has designated ethylene oxide as a toxic air contaminant; this development may lead to emissions regulations for EtO.

Better operating practices can be employed to reduce the chances of spillage and accidental release of EtO in hospitals. These include frequent inspection and proper maintenance of EtO sterilizer equipment including checking the seal integrity of sterilizer doors, and proper training of personnel in the use of EtO sterilization equipment and handling of EtO cylinders and cartridges.

Use of Recyclable Drums

Many chemicals used in hospital engineering/ maintenance and in the laboratories are supplied in drums. Unless the empty drums are triple rinsed before disposal, they may have to be handled as hazardous waste. Many industrial facilities now take delivery of chemicals in 400 gallon recyclable tote drums. When empty, the tote drum is returned to the supplier for cleaning and refilling. This will ensure that the container and any chemical residue left inside it do not have to be disposed of by the hospital.

Proper Material Handling

Use of mechanical handling aids for drums and adherence to general spill reduction techniques will decrease spill potential. Pre-mixed solutions of these compounds also decrease spill potential by reducing handling requirements. In the laundry facility, an automated system that pumps bleach directly from drums into the machines decreases spillage.

Material Substitution

Oxidizers are found in hospital laundries and laboratories. Process modification may minimize oxidizer waste. For liquid oxidizers, such as hydrogen peroxide, the most dilute form that will still be effective should be used. As an example of an opportunity for process modification, consider the procedure of using benzoyl peroxide to reduce color in tissue or blood samples. Benzoyl peroxide is a strong oxidizing agent that may explode spontaneously when dry. Substituting a 30 percent hydrogen peroxide solution for the benzoyl peroxide is more economical. This solution is a weaker, yet effective oxidizing agent and is not subject to spontaneous combustion.

In hospitals, poisons such as glutaraldehyde and phenol may be used in sterile processing, laboratories, and nursing units. The main waste minimization technique in dealing with poisons is substitution with a less environmentally hazardous compound or process, where possible. Examples of this are steam or sonic sterilization instead of chemical sterilization.

SECTION 4
GUIDELINES FOR USING THE WASTE MINIMIZATION ASSESSMENT

Waste minimization assessments were conducted at three hospitals. The assessments were used to develop the waste minimization questionnaire and worksheets that are provided in this section.

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

The worksheets provided in this section are intended to assist hospital managers in systematically evaluating waste generating processes and in identifying waste minimization opportunities. These worksheets include only the assessment phase of the procedure described in the 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 Assessment Worksheets

Number	Title	Description
1.	Waste Generation Questionnaire	Questions on hospital waste tracking
2.	Waste Quantities	Form for documenting wastes by type and department
3.	Material Procurement and Usage	Questionnaire
4	Material Procurement and Usage	Waste minimization options
5.	Waste Management Practices	Questionnaire
6.	Waste Management Practices	Waste minimization options
7A	Selected Waste Streams	Questionnaire on chemotherapy and antineoplastics; flammable and chlorinated solvents
7B.	Selected Waste Streams	Questionnaire on formaldehyde, photographic materials, radioactive materials
7C.	Selected Waste Streams	Questionnaire on mercury; anesthetic gases; and toxics, corrosives, and miscellaneous compounds Questionnaire on general practices
8A.	Options/Selected Waste Streams	Options for chemotherapy and antineoplastics; flammable and chlorinated solvents; and formaldehyde
8B.	Options/Selected Waste Streams	Options for photographic chemicals, materials, mercury, and waste anesthetic gases
8C.	Options/Selected Waste Streams	Options for toxics, corrosives and miscellaneous chemicals; general options

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

WORKSHEET
1

WASTE GENERATION: Questionnaire

A. GENERAL INFORMATION

Indicate which of the following departments are included in the facility:

Chemotherapy	______	Facilities maintenance	______
Analytical laboratory	______	Radiology	______
Clinical laboratory	______	Sterile processing	______
Hemodialysis	______	Pharmacy	______
Pathology	______	Nuclear medicine	______
Histology	______	Autopsy	______
Anesthesiology	______		

B. WASTE GENERATION DATA

Methods for quantifying the waste generated for the entire hospital facility should be developed and implemented.

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.)

If answer is no: If adequate waste data are not available, establish a method for assessing waste quantities such as the table shown in 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.

This type of data is important for the following reasons:

- the data define the scope of waste generation for the entire facility 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 yes: Establish facility wide and departmental waste reduction goals. Setting specific goals provides an incentive to meet established goals. A central committee should establish goals. The committee should be made up of personnel from the hospital environmental/safety office, administration, and managers/technicians from each waste generating department. Reduction goals should range from 3% to 10% per year. The committee should meet quarterly to assess progress in achieving goals.

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

WORKSHEET **2**

WASTE MINIMIZATION:
Waste Quantities

Compound/Waste Stream	Area/Department	(Optional) Estimated Quantity/ Volume On Hand	(Optional) Est. Quantity/Vol. Purchased (per month)	(Required) Estimated [1] Quantity/Volume Requiring Disposal (per month)
Antineoplastics	Pharmacy			
	Clinic			
Flammable Solvents	Laboratory			
	Pathology			
	Histology			
	Facilities Maintenance			
	Sterile Processing			
	Other			
Chlorinated Solvents	Laboratory			
Photographic Solutions	Radiology			
Formaldehyde	Pathology			
	Dialysis			
Caustics	Laboratory			
Mercury				
Radioisotopes	Clinical Testing			
Others: (list)				

1 Do not include quantities which are consumed or which evaporate during use, but do include dilution volumes and contaminated equipment.

Hosp. ____	Waste Minimization Assessment	Prepared By ____
Site ____		Checked By ____
Date ____	Proj. No. ____	Sheet __ of __ Page __ of __

WORKSHEET
3

WASTE MINIMIZATION:
Material Procurement and Usage

Use separate forms for departments if procurement is not done centrally.

Is procurement of chemicals done through a central department or person? ☐ yes ☐ no
If no, explain how procurement is handled: ____________________

When products arrive, are they processed through a central receiving department or person? ☐ yes ☐ no
If no, explain: ____________________

Is the inventory system computerized? ☐ yes ☐ no
The current supply stock is capable of meeting _____ months of usage. Complete inventories of chemicals stocks are conducted _____ times per year.
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? This would reduce generation of this chemical waste.
Is it possible to increase the amount of sharing of chemicals between 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
Does the current inventory control system adequately prevent waste generation? ☐ yes ☐ no
What information does the system track? ____________________

Is there a formal personnel training program on hazardous material handling, spill prevention, proper storage techniques, and waste handling procedures? ☐ 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? ____________________

Does the facility have a written spill prevention and mitigation plan? ☐ yes ☐ no

Hosp. ____	Waste Minimization Assessment	Prepared By ____
Site ____	Proc. Unit/Oper. ____	Checked By ____
Date ____	Proj. No. ____	Sheet __ of __ Page __ of __

WORKSHEET
4

OPTION GENERATION:
Material Procurement & Usage

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. General Information		
Centralize chemical and other procurement		
Computerize inventory		
Avoid over-purchase of supplies		
Purchase smaller quantities of chemicals		
Share chemicals among departments/laboratories		
Label all chemical and waste containers		
Return material to supplier		
Use supplies in first-in, first-out order		
Train personnel in material handling/		
spill prevention		
Write spill prevention/mitigation plan		

Hosp. ____________	**Waste Minimization Assessment**	Prepared By ____________
Site ____________		Checked By ____________
Date ____________	Proj. No. ____________	Sheet ___ of ___ Page ___ of ___

WORKSHEET
5

WASTE MINIMIZATION: Waste Management Practices

The following checklist should be completed by the facility's hazardous materials coordinator or engineer, or by departmental laboratory managers if practices vary among departments.

Department: ____________________

Name of person completing 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 offered to all personnel?	☐ yes	☐ no
Are there employee incentive programs related to waste minimization?	☐ 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. WASTE MANAGEMENT PRACTICES

Is there a master list of hazardous waste generated?	☐ yes	☐ no
Are containers and bags w/ hazardous waste residues segregated from nonhazardous wastes?	☐ yes	☐ no
To reduce the generation of empty containers, has the facility attempted to use bulk dispensers (e.g. returnable drums) and reuseable transfer containers?	☐ yes	☐ no
Are hazardous wastes stored in a centralized area?	☐ yes	☐ no
Is there a single individual in charge of hazardous waste tracking and management throughout the facility?	☐ yes	☐ no
Have waste streams which are discharged to the sewer or municipal landfill been evaluated for toxicity, flammability, corrosivity, and reactivity, to determine whether the waste stream is hazardous?	☐ yes	☐ no
Are infectious wastes which contain hazardous wastes segregated from nonhazardous infectious wastes?	☐ yes	☐ no

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

WORKSHEET
6

OPTION GENERATION:
Waste Management Practices

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		
Train personnel		
Provide operating manuals		
Employee incentives for waste minimization		
Establish waste minimization program & policy		
Set goals for source reduction		
Set goals for assessments		
Conduct annual assessments		
B. Waste Management		
Establish person responsible to		
track/manage wastes		
List hazardous wastes generated		
Segregate wastes		
Use bulk dispensers		
Store hazardous wastes centrally		
Evaluate hazard of discharged/landfilled wastes		
Segregate infectious from hazardous wastes		

Hosp. ____	Waste Minimization Assessment	Prepared By ____
Site ____		Checked By ____
Date ____	Proj. No. ____	Sheet __ of __ Page __ of __

WORKSHEET
7A

WASTE MINIMIZATION: Selected Waste Streams

A. CHEMOTHERAPY AND ANTINEOPLASTIC WASTES

Are chemotherapy wastes segregated from other wastes? ☐ yes ☐ no
(Disposable garments, if not contaminated, may be disposed of with non-hazardous refuse but gloves are assumed to be contaminated.)

Is the biological safety hood cleaned no more frequently than once per day, with thorough decontamination occurring once per week as specified in OSHA Publication 8-1.1 (Antineoplastic Drug Handling)? ☐ yes ☐ no

Are drugs purchased in container sizes that permit formulation of daily dosages with the least quantity of excess product leftover? ☐ yes ☐ no

B. FLAMMABLE AND CHLORINATED SOLVENTS

Has substitution with less environmentally hazardous materials or methods been evaluated? ☐ yes ☐ no

If yes, did the evaluation include:

- use of sonic or steam cleaning ☐ yes ☐ no
- use of aqueous reagents ☐ yes ☐ no
- use of simple alcohols and ketones instead of petroleum hydrocarbons ☐ yes ☐ no
- use of non-chlorinated instead of chlorinated solvents ☐ yes ☐ no
- other (explain)

Have routine processes such as fixation and extraction been evaluated to determine if quantities of reagents used in these processes could be minimized? ☐ yes ☐ no

If yes, did this evaluation include (check as appropriate):

- reducing volumes of reagents ☐ yes ☐ no
- using calibrated dispensers ☐ yes ☐ no
- using unitized test kits ☐ yes ☐ no
- other (explain):

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

Have requirements been established for purity of fresh solvents? ☐ yes ☐ no

Are waste solvents separated into containers specific to single compounds so that simple distillation is more feasible? ☐ yes ☐ no

If the above answer is yes, are any individual waste solvents generated in quantities large enough to warrant distillation of those solvents separately, using a simple batch distillation column? ☐ yes ☐ no
(Cost ranges from approximately $3,000 for a 5-gallon unit to $14,000 for a 55-gallon unit.)

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 equipment cleaning be standardized? ☐ yes ☐ no

Hosp. ____	Waste Minimization Assessment	Prepared By ____
Site ____		Checked By ____
Date ____	Proj. No. ____	Sheet __ of __ Page __ of __

WORKSHEET
7B

WASTE MINIMIZATION: Selected Waste Streams

B. FLAMMABLE AND CHLORINATED SOLVENTS (CONT.)

If solvent wastes cannot be segregated, are combined quantities of waste solvents large enough to warrant distillation using a fractionating distillation column? ☐ yes ☐ no

If on-site recycling is not currently feasible, has off-site recycling or the use of a waste exchange been evaluated? ☐ yes ☐ no

C. FORMALDEHYDE

Were culture studies performed to determine minimum strength of formalin required & minimum cleaning frequency for adequate disinfecting of dialysis machines and water supply systems? ☐ yes ☐ no

Has the use of reverse osmosis water supply equipment to reduce the need for formaldehyde cleaning been investigated? ☐ yes ☐ no

Has the reuse of formaldehyde in autopsy and pathology laboratory specimen preservation been investigated? ☐ yes ☐ no

Are airborne emissions from formaldehyde use properly controlled?

Is formalin dispensed via a central distribution system with plumbing connected to each machine? ☐ yes ☐ no

D. PHOTOGRAPHIC MATERIALS

Does storage area have proper temperature/light conditions for photoprocessing chemicals? ☐ yes ☐ no

Is material with expired shelf life tested for effectiveness before being returned or disposed of? ☐ yes ☐ no

Are obsolete or off-spec chemicals returned to manufacturer? ☐ yes ☐ no

Is used and spoiled film sold to a recycler? ☐ yes ☐ no

Are photoprocessing bath solutions optimized chemically to extend bath life by:

- adding ammonium thiosulfate? ☐ yes ☐ no
- using acid stop bath prior to fixing? ☐ yes ☐ no
- adding acetic acid to fixing bath to keep pH low? ☐ yes ☐ no
- keeping baths in covered, air-tight containers to reduce evaporation and oxidation? ☐ yes ☐ no

In non-automated processing systems, are squeegees used to minimize bath solution loss? ☐ yes ☐ no

Is countercurrent washing used in photographic processors to reduce wastewater generation? ☐ yes ☐ no

Is silver recovered from fixing baths to permit bath regeneration? ☐ yes ☐ no

E. RADIOACTIVE MATERIALS

Are isotope containers returned to the distributor? ☐ yes ☐ no

Have processes been evaluated for substitution of long-lived isotopes with short-lived isotopes? ☐ yes ☐ no

Does the facility provide space (100 to 200 square meters) for isolation and interim storage of short-lived radioactive wastes during decay to acceptable levels? ☐ yes ☐ no

Are radioactive wastes properly labelled as to form, isotope, chemical composition; kept segregated; and centrally processed? ☐ yes ☐ no

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

WORKSHEET
7C

WASTE MINIMIZATION: Selected Waste Streams

F. MERCURY

Have solid state electronic sensing devices been substituted for mercury-containing devices?	☐ yes	☐ no
Is mercury recovered for reuse and contaminated mercury turned over to a commercial mercury recycler?	☐ yes	☐ no
Are mercury spill cleanup kits available?	☐ yes	☐ no
If yes, have personnel been trained to use the kits?	☐ yes	☐ no

G. WASTE ANESTHETIC GASES

Is low-leakage anesthetic equipment used?	☐ yes	☐ no
Are inspections and maintenance of anesthesia equipment, scavenging equipment, and ventilation systems performed regularly and by qualified personnel?	☐ yes	☐ no
Are low leakage anesthetic practices employed?	☐ yes	☐ no

H. TOXICS, CORROSIVES, AND MISCELLANEOUS CHEMICALS

In sterile processing, can steam or sonic sterilization be used instead of sterilization using hazardous chemicals?	☐ yes	☐ no
Is ethylene oxide equipment frequently inspected and properly maintained?	☐ yes	☐ no
Are personnel properly trained in handling ethylene oxide equipment?	☐ yes	☐ no
Can volumes of chemicals used in experiments be reduced?	☐ yes	☐ no
Has the use of less toxic or diluted solutions of cleaning agents been investigated?	☐ yes	☐ no

If yes, describe the results: ______

Are automated systems used for dispensing laundry chemicals to reduce spillage?	☐ yes	☐ no
Are chemicals purchased in recyclable containers?	☐ yes	☐ no
Are chemical containers returned to the supplier for reuse?	☐ yes	☐ no
Are mechanical aids used in handling drums of chemicals to reduce spills?	☐ yes	☐ no
Has the use of physical instead of chemical cleaning methods been investigated?	☐ yes	☐ no

If yes, describe the results: ______

Hosp. ____	Waste Minimization Assessment	Prepared By ____
Site ____		Checked By ____
Date ____	Proj. No. ____	Sheet __ of __ Page __ of __

WORKSHEET
7D

WASTE MINIMIZATION: Selected Waste Streams

I. GENERAL PRACTICES

Are high volume chemical inventories minimized to a four-week supply or less? ☐ yes ☐ no

Are spill containment and clean-up kits available?

Are chemicals and liquid wastes stored in areas which do not drain directly to the sewer? ☐ yes ☐ no

Are all chemicals containers property labeled? ☐ yes ☐ no

Are all wastes properly segregated? ☐ yes ☐ no

Has off-site reuse of wastes through waste exchange services been considered?

Or reuse through commercial brokerage firms? ☐ yes ☐ no

If yes, results: ____________________

____

____

Has the feasibility of constructing a pretreatment unit for formaldehyde and other organic solvent wastes been explored? ☐ yes ☐ no

If yes, what type of unit was considered? ☐ yes ☐ no

Oxidation Carbon Adsorption

Other (describe): ____________________

____

____

____

Hosp. ____	Waste Minimization Assessment	Prepared By ____
Site ____	Proc. Unit/Oper. ____	Checked By ____
Date ____	Proj. No. ____	Sheet __ of __ Page __ of __

WORKSHEET
8A

OPTION GENERATION:
Selected Waste Streams

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. Chemotherapy and Antineoplastics		
Segregate chemotherapy wastes		
Reduce cleaning frequency per OSHA regulations		
Optimize size of drug containers purchased		
B. Flammable and Chlorinated Solvents		
Use less hazardous materials		
Use aqueous reagents		
Reduce quantities of reagents		
Use sonic or steam cleaning		
Determine purity of solvent needed		
Countercurrent cleaning using solvents		
Standardize solvent use		
Segregate waste solvents		
Distill/recycle solvents		
Off-site solvent recycling		
C. Formaldehyde		
Use of minimum strength formalin required		
Minimize cleaning frequency		
Automate formalin dispensing		
Reuse formalin preservative		
Employ proper air emission control		

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

WORKSHEET
8B

OPTION GENERATION:
Selected Waste Streams

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

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
D. Photographic Chemicals		
Use proper chemical storage conditions		
Return off-spec chemicals to supplier		
Extend photoprocessing bath life		
Test expired supplies for effectiveness		
Use squeegees to minimize bath loss		
Use countercurrent washing		
Recover silver		
E. Radioactive Materials		
Return containers to supplier		
Use short-lived isotopes		
Store short-lived wastes on site for decay		
to acceptable levels		
F. Mercury		
Use electronic sensing devices		
Provide mercury spill kits		
Recover and recycle mercury		
G. Waste Anesthetic Gases		
Use low-leakage equipment		
Inspect/maintain equipment		
Practice low leakage anesthesia use		

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

WORKSHEET
8C

OPTION GENERATION:
Selected Waste Streams

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

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
H. Toxics, Corrosives, and Miscellaneous		
Inspect/maintain ethylene oxide equipment		
Use steam or sonic sterilization		
Use less toxic cleaning agents		
Provide automatic laundry chemical dispensers		
Reduce chemical volumes in experiments		
Purchase chemicals in recyclable containers		
Provide mechanical handling aids for drums		
Use physical instead of chemical		
cleaning methods		
I. General		
Reduce chemical inventory life		
Provide spill cleanup kits		
Proper waste storage		
Pretreat formaldehyde/solvent waste		
Label chemical containers		
Segregate wastes		
Investigate waste exchange,		
waste brokerage services		

Appendix A
FACILITY ASSESSMENTS OF THREE HOSPITALS

In 1986 the California Department of Health Services commissioned a waste minimization study (DHS 1988) of three general medical and surgical hospitals. The objectives of the waste minimization assessments were to:

- Gather site-specific information concerning the generation, handling, storage, treatment, and disposal of hazardous waste;
- Evaluate existing waste reduction practices;
- Develop recommendations for waste reduction through source control, treatment, and recycling techniques; and
- Assess costs/benefits of existing and recommended waste reduction techniques.

In addition, the results of the waste assessments were used to prepare waste minimization assessment worksheets to be completed by other hospitals in a self-audit process.

The first steps in conducting the assessments were the selection of the three hospitals, and contacting them to solicit voluntary participation in the audit study. During each of the hospital audits, the audit team observed a variety of hospital operations; inspected waste management facilities; interviewed the hospital managers, environmental compliance personnel, and laboratory supervisors; and reviewed and copied records pertinent to waste generation and management. The audits were performed by one or two engineers over a one- to three-day period depending on the size and complexity of the formulating and waste management operations.

This Appendix section presents the results of the assessments of the hospitals here identified as A, B and C and the potentially useful waste minimization options identified through the assessments. Also included are the practices already in use at the facilities that have successfully reduced waste generation from past levels.

Findings of Waste Audit of Hospital A

Hospital A is a general surgical hospital with 323 beds and 2,000 employees. The types of in-house departments are typical for a full-service hospital, although much of the laboratory work is performed through a regional laboratory at a separate location. This regional laboratory manages some of the hazardous waste streams that the hospital would otherwise be required to manage itself. Outpatient clientele consists of approximately 125 to 150 persons per day.

Procurement of hazardous materials is conducted through a central clinic and a separate general purchasing department. Hazardous waste manifests are maintained by the housekeeping department. The hospital has conducted an internal environmental compliance audit and has inventoried hazardous materials on site. Waste minimization, however, has not been specifically addressed.

The laboratory and pathology departments generate primarily xylene and formaldehyde waste, in the amount of about one gallon each per month. In both cases, this waste is discharged to the sewer. Reagents are used in "contained packs" for unit applications. These are disposed of as infectious waste.

Hazardous wastes generated by the radiology/imaging department consist of fixer, developer, and mercury on occasion. Silver from the fixer is extracted and 20% of the solution is recycled. Although mercury disposal does not occur on a routine basis, it is handled regionally.

The central sterile supply department generates only ethylene oxide, which is vented to the atmosphere and sewer.

The engineering department handles various hazardous materials. It generates only about three gallons per month of used oil, which is transported off site for disposal. This department also uses solvents, aerosols, and water-based latex paints, which are consumed. Boiler/water treatment compounds are also consumed.

The pharmacy generates antineoplastic wastes, which are hauled off site for incineration. It also generates outdated drugs, which are returned to the regional pharmacy (see Figure A-1).

The respiratory therapy department generates approximately 16 ounces of 70% alcohol per day, which is discharged to the sewer.

The hemodialysis department generates 4% formaldehyde waste, which is disposed of to the sewer at a rate of about 8 liters per week. It also generates 5.25% sodium hypochlorate, which is also discharged to the sewer, at a rate of about 10 liters per week (see Figure A-2).

Findings of Waste Audit of Hospital B

Hospital B is a general surgical hospital with 415 beds. In-house departments include a laboratory, pathology, engineering, radiology, histology, dialysis, and a pharmacy. Primary sources of hazardous wastes include hemodialysis, the clinical testing laboratory, and the pharmacy. Outpatient clientele consists of approximately 100 persons per day. Hospital B has not conducted any in-house environmental compliance or waste minimization audits.

The pharmacy purchases antineoplastic chemicals, which are inventoried through a computerized central receiving system. Supplies kept in-house at a given time are inventoried to last two weeks. Antineoplastic drugs used as chemotherapy agents are the hospital's largest source of hazardous waste by volume. Approximately two five-gallon disposal cans are filled with liquid chemotherapy waste each week. Gowns, gloves, and other articles contaminated by cytotoxic drugs are bagged and placed in 55-gallon steel drums. All chemotherapy wastes are transported off-site for disposal (see Figure A-3).

Hazardous waste generated through hemodialysis includes 4% formaldehyde that has been pumped through 18 individual dialysis units, at the rate of 250 cc's per day. Effluent lines from these machines are connected to the municipal sewer system. Tubing from the units is discarded as infectious waste (see Figure A-4).

Radioactive tagging in the clinical testing laboratory is also a source of hazardous waste at Hospital B. Approximately 800 ml per week of radioactive water, or tritium, are generated. About five gallons per month of radioactive solid waste are also generated. Tritium is a beta-emitter with a half-life of 57 years. An additional 200 ml per week of toluene are evaporated under a hood. Radioactive wastes are transported off site for disposal (see Figure A-5).

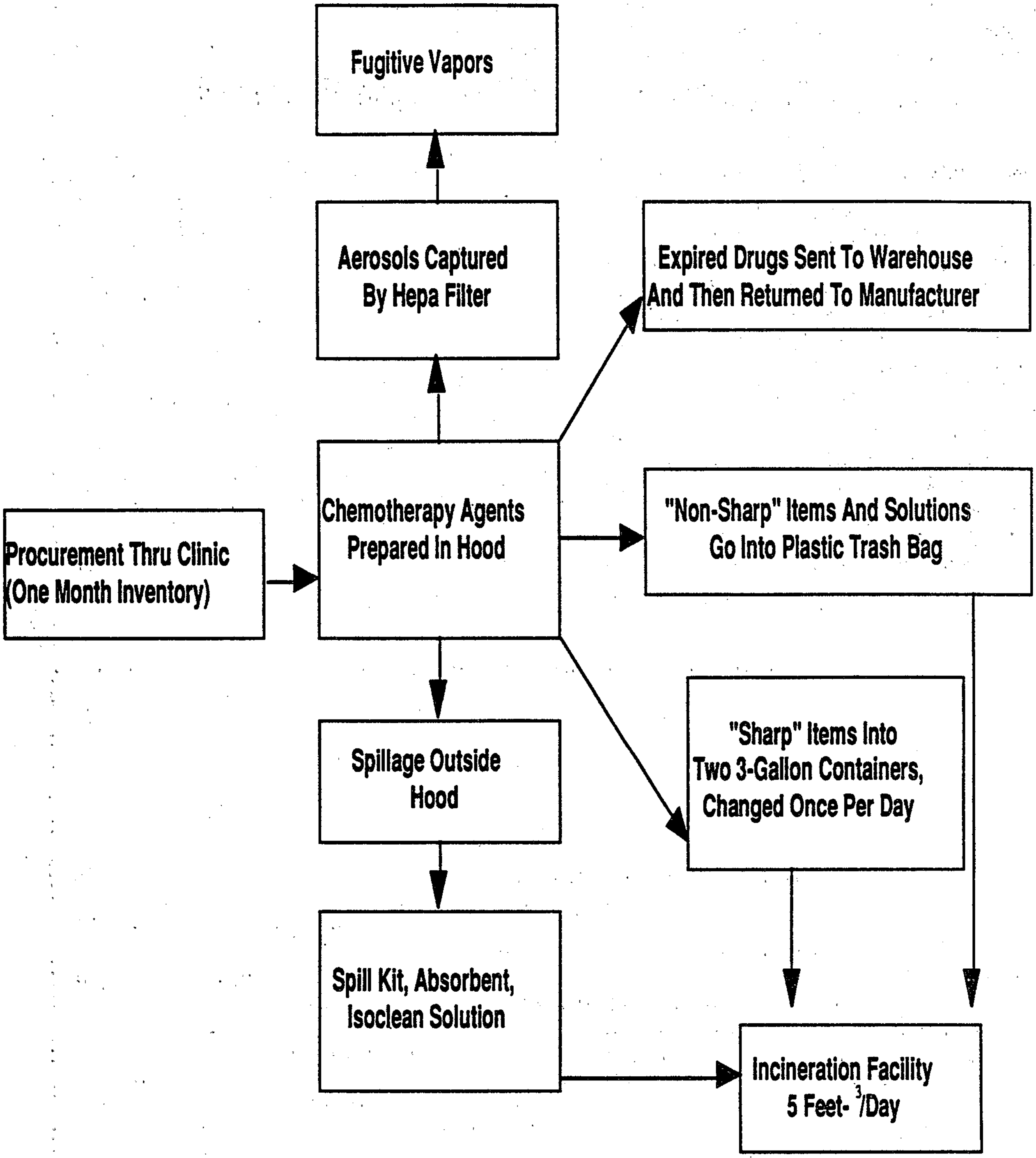

Figure A-1. Hospital A-Chemotherapy Waste Stream

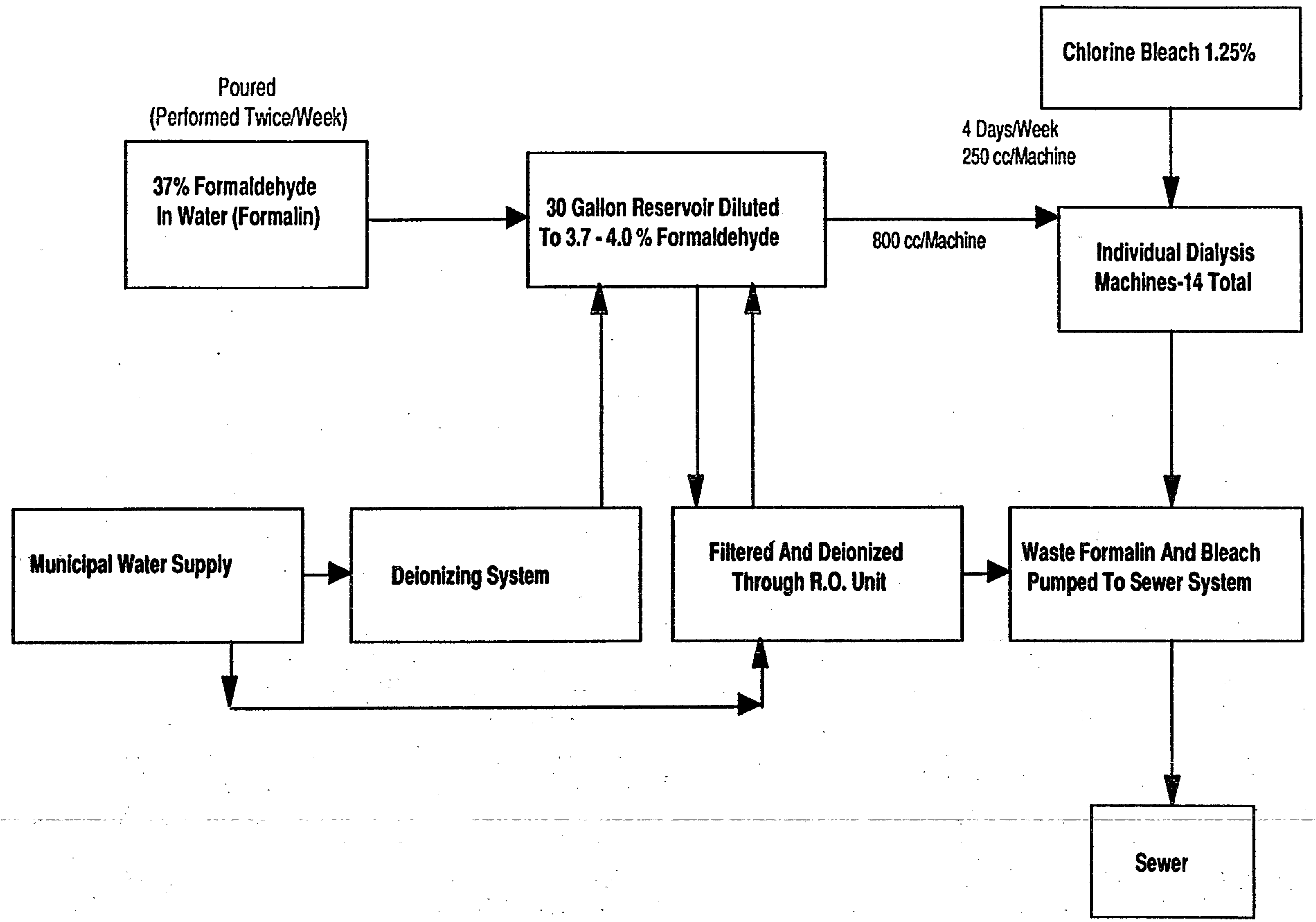

Figure A-2. Hospital A-Dialysis Waste Stream

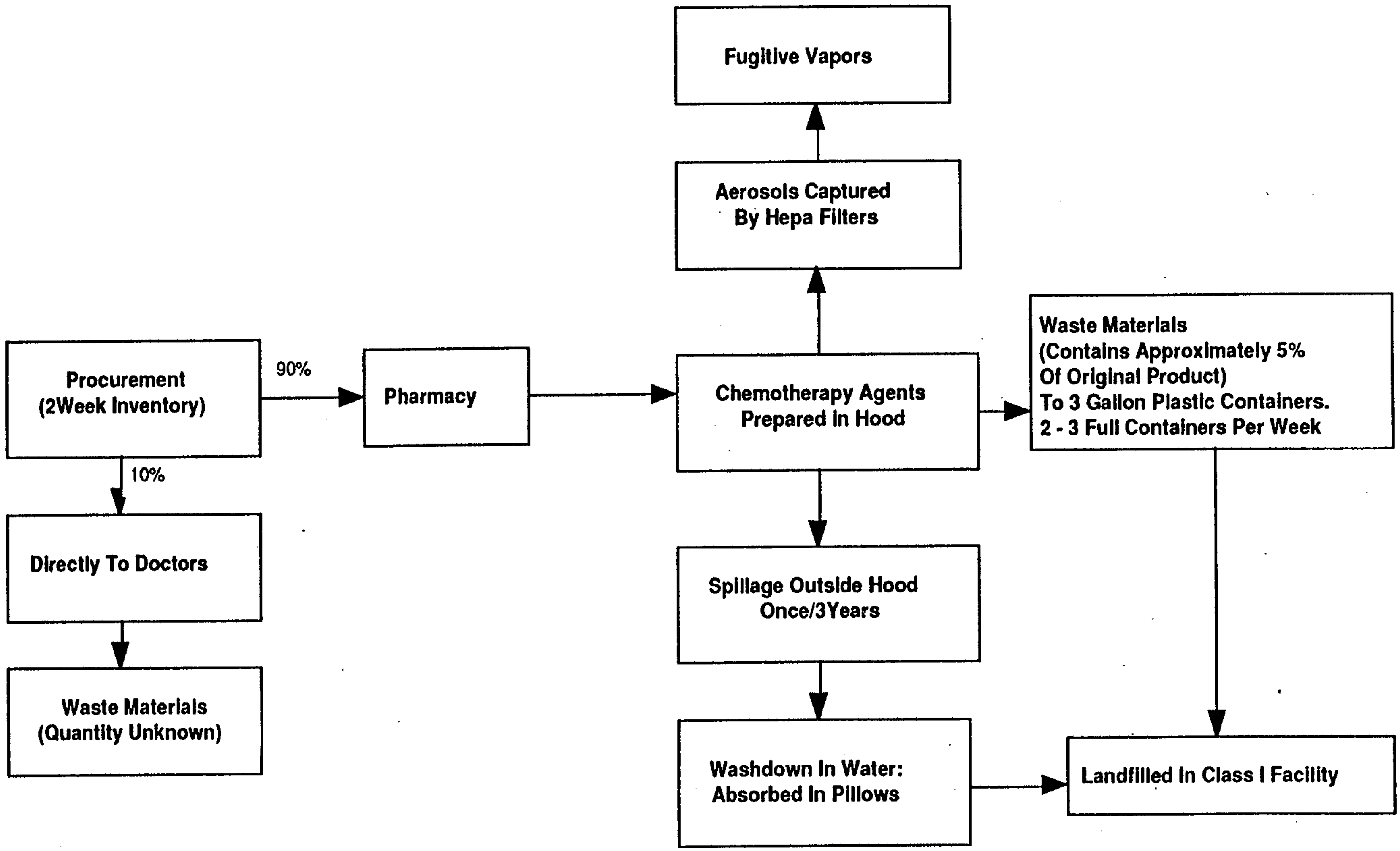

Figure A-3. Pharmacy and Chemotherapy Waste Stream

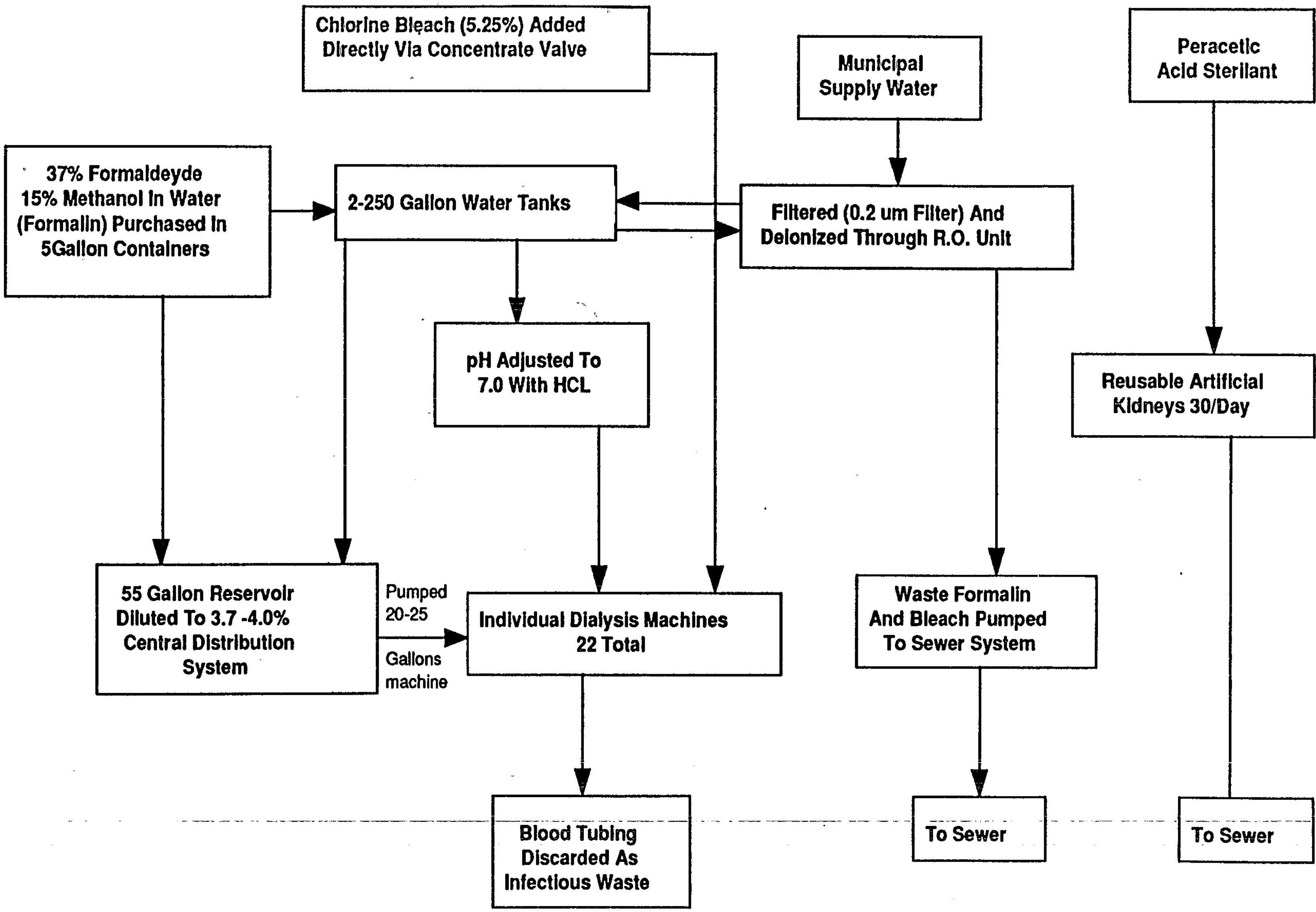

Figure A-4. Hospital B- Dialysis Waste System

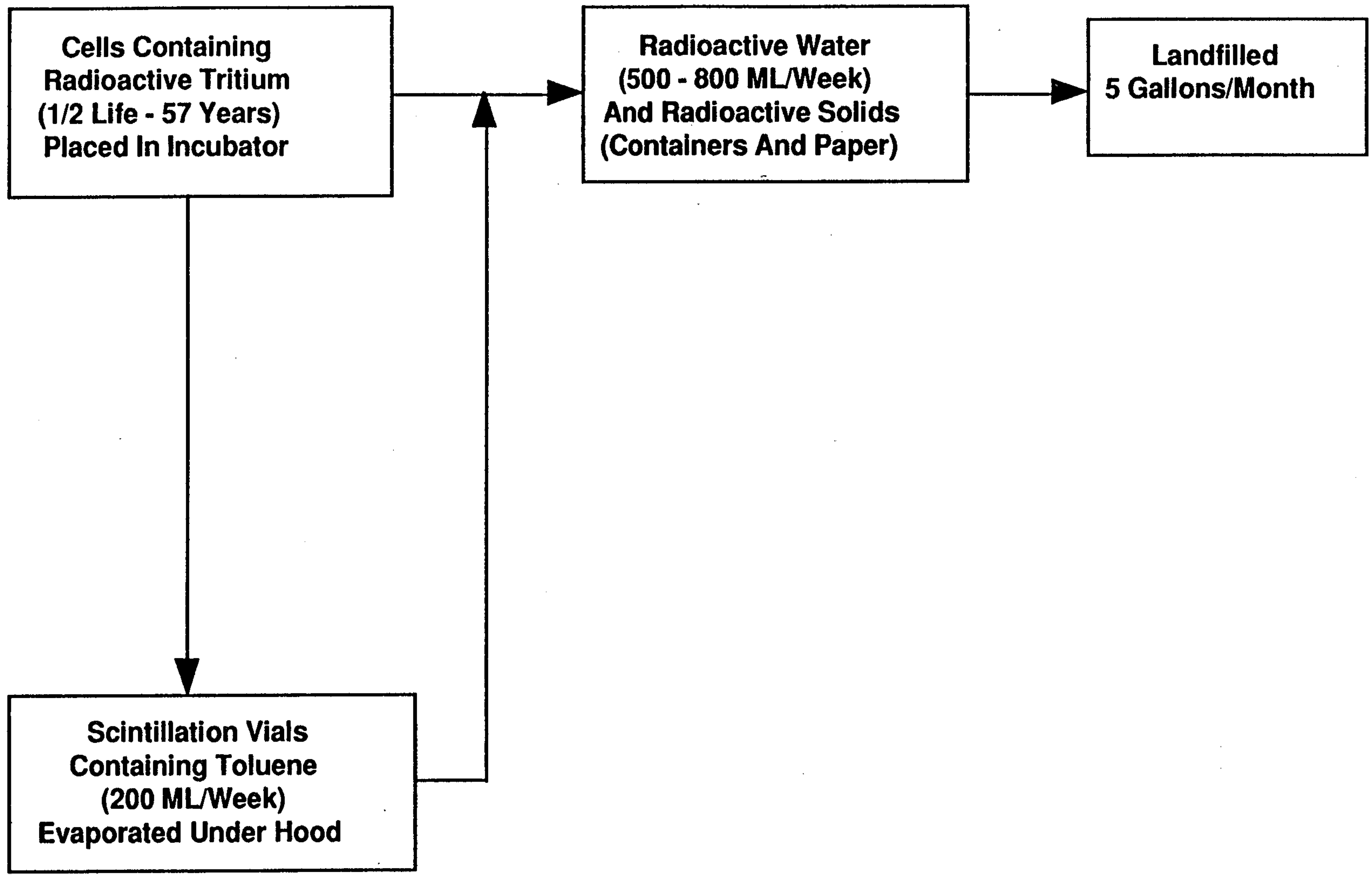

Figure A-5. Hospital B- Clinical Testing Lab (Radioactive Tagging)Waste Stream

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
Releigh, 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

U.S. EPA REGIONAL OFFICES

Region 1 (VT, NH, ME, MA, CT, RI)
John F. Kennedy Federal Building
Boston, MA 02203
(617) 565-3715

Region 2 (NY, NJ)
26 Federal Plaza
New York, NY 10278
(212) 264-2525

Region 3 (PA, DE, MD, WV, VA)
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-9800

Region 4 (KY, TN, NC, SC, GA, FL, AL, MS)
345 Courtland Street, NE
Atlanta, GA 30365
(404) 347-4727

Region 5 (WI, MN, MI, IL, IN, OH)
230 South Dearborn Street
Chicago, IL 60604
(312) 353-2000

Region 6 (NM, OK, AR, LA, TX)
1445 Ross Avenue
Dallas, TX 75202
(214) 655-6444

Region 7 (NE, KS, MO, IA)
756 Minnesota Avenue
Kansas City, KS 66101
(913) 236-2800

Region 8 (MT, ND, SD, WY, UT, CO)
999 18th Street
Denver, CO 80202-2405
(303) 293-1603

Region 9 (CA, NV, AZ, HI)
215 Fremont Street
San Francisco, CA 94105
(415) 974-8071

Region 10 (AK, WA, OR, ID)
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-5810