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Profile and Management Options for EPA Laboratory Generated Mixed Waste

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PREFACE

The high costs of mixed waste management and the limited treatment, storage, and disposal options for mixed waste prompted EPA laboratory staff to approach EPA headquarters staff to investigate mixed waste generated from laboratory procedures. Mixed waste is composed of radioactive waste defined under the Atomic Energy Act (AEA) and hazardous waste is defined under the Resource Conservation and Recovery Act (RCRA). Currently there are only four mixed waste treatment, storage, or disposal facilities (TSDFs) in the United States accepting commercially generated mixed waste. No treatment or disposal options exist for certain classes of mixed waste. Indefinite storage is the only option for mixed waste with no treatment or disposal capacity.

The U.S. Environmental Protection Agency (EPA)'s Office of Radiation and Indoor Air (ORIA), Office of Solid Waste (OSW), and Office of Administration/Safety, Health, and Environmental Management Division (SHEMD) responded to this request and created a cross-office team to investigate the issue of mixed waste generated from EPA laboratories. This report is designed to aid EPA in defining future low-level and mixed waste guidance for EPA laboratories.

The first step in this investigation was to quantify and characterize the low-level radioactive waste and mixed waste generated by EPA laboratories. The second step of the project was to identify and examine the mixed waste management options and technologies applicable to EPA laboratories including pollution prevention, recycling, waste segregation, and treatment.

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ABSTRACT

This report identifies and examines the mixed waste management options and technologies applicable to EPA laboratories including pollution prevention, recycling, waste segregation, and treatment. The results from a 3-year survey of EPA laboratory produced mixed and low-level wastes as relevant information from the technical literature, are presented in this report as well. Ultimately, this report is designed to aid EPA in defining future low-level and mixed waste guidance for EPA laboratories.

CONTENTS

CONTENTS -- (Continued)

CONTENTS – (Continued)

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act
BDAT	best demonstrated available technology
°C	Centigrade (in degrees)
CESQG	conditionally exempt small quantity generator
CFC	chlorinated fluorocarbons
CFR	Code of Federal Regulations
ComEd	Commonwealth Edison
CRL	Central Regional Laboratory, Chicago, IL
CWRU	Case Western Reserve University
DIS	decay-in-storage
DOE	U.S. Department of Energy
DSSI	Diversified Scientific Services, Inc.
EHS	environmental, health, and safety
EPA	U.S. Environmental Protection Agency
ft^3	cubic feet
GED-Gulf	Gulf Ecology Division, Gulf Breeze, FL (EPA)
GL	Geochemistry Laboratory
HPLC	high-performance liquid chromatography counting
HW	hazardous waste
INEL	Idaho National Engineering Laboratory
kg	kilograms
LLRW	low-level radioactive waste
LSC	liquid scintillation counting
m^3	cubic meters
MFRL	Manufacturing and Fabrication Repair Laboratory
MMT	Molten Metal Technology, Inc.
MW	mixed waste
MWIR	Mixed Waste Inventory Report
NAREL	National Air and Radiation Environmental Laboratory, Montgomery, AL (EPA)
NERL-LV	National Exposure Research Laboratory, Las Vegas, NV (EPA)
NERL-RTP	National Exposure Research Laboratory, Research Triangle Park, NC (EPA)
NGA	National Governors Association
NHEERL-AED	National Health & Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI (EPA)
NHEERL-MED	National Health & Environmental Effects Research Laboratory, Mid-Continent Ecology Division, Duluth, MN (EPA)
NHEERL-WED	National Health & Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, OR (EPA)
NHEERL-RTP	National Health & Environmental Effects Research Laboratory, Research Triangle Park, NC (EPA)
NIH	National Institutes of Health

ACRONYMS AND ABBREVIATIONS (contd.)

NLLWMP	National Low-Level Waste Management Program
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRMRL-Breidenbach	National Risk Management Research Laboratory, A.W. Breidenbach Environmental Research Center, Cincinnati, OH (EPA)
NRMRL-Kerr	National Risk Management Research Laboratory, Robert S. Kerr Environmental Research Center, Ada, OK (EPA)
NRMRL-RTP	National Risk Management Research Laboratory, Research Triangle Park, NC (EPA)
NSSI	Nuclear Sources and Services, Inc.
NTIS	National Technical Information Service
ORIA	Office of Radiation and Indoor Air (EPA)
ORNL	Oak Ridge National Laboratory
ORS	Office of Radiological Safety, Texas A&M University
OSW	Office of Solid Waste (EPA)
P2	Pollution Prevention
PFF	Perma-Fix of Florida, Inc.
PPOA	Pollution Prevention Opportunity Assessment
RCRA	Resource Conservation and Recovery Act
RSO	radiation safety officer
RTP	Research Triangle Park, NC (EPA)
SEG	Scientific Ecology Group, Inc.
SHEMD	Safety, Health, and Environmental Management Division (EPA)
SNL	Sandia National Laboratories
TRU	transuranic
TSDF	treatment, storage, and disposal facility
UIUC	University of Illinois at Urbana-Champaign
VRF	volume reduction factor
WREAFS	Waste Reduction Evaluations at Federal Sites
μCi/g	millicuries per gram

SECTION 1: INTRODUCTION AND OVERVIEW

Mixed waste is subject to a dual regulatory framework under the Resource Conservation and Recovery Act (RCRA), as administered by the U.S. Environmental Protection Agency (EPA), and the Atomic Energy Act (AEA), as administered by the U.S. Nuclear Regulatory Commission (NRC). Generators of mixed waste and the offsite facilities which manage this waste must satisfy both NRC, which regulates the radioactive component, and EPA, which regulates the hazardous component. Due to the complex regulatory framework and the lack of approved treatment and disposal options for these wastes, mixed waste management is a difficult responsibility.

The principal focus of this report is to identify and examine the wide spectrum of waste management options and technologies applicable to EPA research facilities including pollution prevention, recycling, waste segregation, and treatment. Ultimately, this report is designed to aid EPA in defining future guidance for these laboratories. Relevant information from the technical literature is presented in this report as a guide for future EPA decisions concerning laboratory generated low-level and mixed waste.

A survey of 11 EPA laboratories and research facilities was conducted to tabulate the volumes of mixed waste (MW) and low-level radioactive waste (LLRW) generated in the 1992-1994 time period. The results of the survey indicate that the generation of mixed waste accounted for 20.6 percent of the total MW and LLRW generated in the 1992-1994 time period. The total volume of mixed waste generated by the 11 EPA facilities totaled 831.16 ft^3 over this 3-year time period. It was discovered that four radionuclides, ^{14}C, ^{3}H, ^{32}P, and ^{35}S, comprised a substantial portion of the total volume of LLRW and MW generated in 1992-1994. A detailed analysis of the results of the survey is attached as Appendix A entitled "Data Summary Report." Appendix B provides a copy of the survey instrument along with a brief discussion of the survey methodology. A list of the most commonly used radionuclides generated from various research activities at the EPA laboratories is in Appendix C.

This Profile Report of EPA laboratory generated mixed waste serves to fulfill the following objectives[1]:

- To review the available literature that examines the state-of-the-art technologies that contribute to improved management of mixed wastes. Emphasis is centered on analysis techniques and waste segregation, pollution prevention, disposal or storage, recycling, and treatment options;

- To highlight the applicability of various waste management options based on the results of the survey of EPA laboratories and identify, to the extent practicable,

[1]A description of the research approach employed to develop this report is included as Appendix D.

the regulatory justifications for these options;

- To outline a suggested integrated waste management framework based on current research and documentation for improving EPA laboratory practices and waste minimization efforts for LLRW and MW;

- To provide a succinct profile of the mixed waste treatment facilities and address treatment availability within the context of the capacity demanded by EPA facilities; and

- To provide recommendations and suggestions specific to EPA research facilities as they relate to improved waste management efforts based on the available literature and surveys of laboratory radiation safety officers (RSOs), academics, and researchers.

The survey of EPA facilities revealed that two waste generating processes were responsible for the production of virtually all of the mixed waste at these laboratories: high-performance liquid chromatography (HPLC) counting and liquid scintillation counting (LSC). Two prior survey analysis efforts conducted by the Oak Ridge National Laboratory (ORNL) and the Department of Energy's National Low-Level Waste Management Program (NLLWMP) revealed that the waste constituents and generating processes of the research laboratories covered are similar to those of EPA. Summaries of the survey results from these two efforts are provided in the "Data Summary Report" in Appendix A. Due to the comprehensive scope of the ORNL study (a national profile on commercially generated mixed waste), Appendix E provides more details of the mixed waste generated by these institutions. Additional material that highlights the results of other mixed waste surveys and databases is contained in Appendix F.

A review of the available literature reveals that limited attention has been devoted to the analysis of specific mixed waste streams. While there is a modest amount of literature focusing on management options related to liquid scintillation counting procedures due to its importance in the scientific community, the research is overwhelmingly aimed at the efficacy of prudent laboratory practices and approaches to improved waste minimization. In fact, there exists considerable acknowledgment of the many challenges facing laboratory directors and Environmental, Health, and Safety (EHS) staff associated with minimization of waste generated from liquid scintillation counting procedures. This discussion is of critical importance for the RSOs and research staff of EPA laboratories. With this in mind, this report addresses, to the extent practicable, the waste management options specific to LSC and HPLC. Special attention is given to the laboratory practices that are conducive to waste minimization and cost-effective waste management. Although the focus of this report is to address the issues associated with mixed waste, low-level radioactive waste will be examined where applicable.

The options summary report is organized into six sections. Following this introduction, Section 2 presents an integrated approach to the management of mixed waste and its applicability to EPA

research facilities. Section 3 outlines the various waste minimization techniques in isolation, followed by a brief profile of the mixed waste treatment facilities and reported capacity in Section 4. Section 5 provides an enumeration of conclusions and recommendations based on the literature collected. Finally, in Section 6, a list of the sources consulted for performing this report is presented.

SECTION 2: AN INTEGRATED APPROACH TO MIXED WASTE MANAGEMENT

A review of the compiled literature pointed to several important themes. Most notably, considerable emphasis was placed on the need to include several components (administrative, regulatory, training, and recording considerations as well as treatment, minimization, and prevention) of waste management into an integrated framework. Individual management options taken in isolation may not be as effective as a more comprehensive approach to waste management. The literature suggests that a goal-based waste management plan based on prudent practices should be the objective of any mixed waste management program. Moreover, the waste minimization program should have top-level management support and direction. Three studies are outlined below that provide constructive frameworks for examining mixed waste management from this conceptualized integrated approach.

2.1 POLLUTION PREVENTION AND WASTE MINIMIZATION IN LABORATORIES

A thorough guide for laboratory directors interested in incorporating pollution prevention practices in laboratory waste management procedures is *Pollution Prevention and Waste Minimization in Laboratories*, edited by Peter A. Reinhardt, K. Leigh Leonard, and Peter C. Ashbrook. This compilation is designed to provide a review of the state-of-the-art practices and procedures that promote safety and facilitate the implementation of a waste minimization or pollution prevention program. The audience for this publication is general in scope and includes professionals in academia, medicine, commercial research, as well as federal officials. Individual chapters, however, detail specific cases.

This compilation by Reinhardt *et al*. is divided into seven sections. The primary topics addressed include:

- an intuitive, conceptual, and legal appeal for pollution prevention including an enumeration of the basic concepts in solving waste minimization problems;
- pollution prevention approaches by media, source, and type;
- pollution prevention and institutional issues (policy, administrative, liability concerns);
- the role that individual laboratories and organizations play in promoting pollution prevention;
- applications of successful pollution prevention programs; and
- the future of waste minimization in the laboratory.

Of particular significance is the discussion of waste minimization in medical and other laboratories. One chapter details the radioactive waste management program at University of Illinois at Urbana-Champaign (UIUC) where LSC waste is the largest single category of solvent waste. Despite the availability of biodegradable cocktails, the University has continued to burn the LSC waste as a fuel supplement at its own power plant due to the realization of cost savings. Since only small amounts are burned, the practice is exempt from RCRA Part B permit requirements and the radioisotopes at the point of release are within specified limits. In connection with requiring researchers to segregate waste by isotopes, the Radiation Safety staff implemented a number of procedures to reduce the amount of radioactive waste generated. One of the most significant policies was the decision to require researchers to decontaminate scintillation cocktail vials instead of disposing of them as radioactive waste.

2.2 DOE's NATIONAL LOW-LEVEL WASTE MANAGEMENT PROGRAM STUDY

Two complementary reports that paralleled this study, the Department of Energy's (DOE) National Low-Level Waste Management Program's *Mixed Waste Minimization and Treatment* (August 1995) and *Mixed Waste Stream Analysis* (August 1994) present the methodology and findings associated with a technical analysis conducted on the mixed waste streams generated by the National Institutes of Health (NIH). The reports characterize the many biomedical waste streams generated and combine the data for similar process categories. Possible waste minimization and treatment methodologies are suggested based on NIH personnel interviews and waste minimization guidelines. For the purposes of this report, considerable focus was devoted to the two mixed waste generating processes present at the EPA laboratories, high-performance liquid chromatography (HPLC) scintillation counting and liquid scintillation counting (LSC).

Over 4½ years of operation from 1989 to June 1993, HPLC scintillation counting accounted for almost 26 percent of the 64,146 liters of nonliquid scintillation cocktail mixed waste generated at NIH. Over the same period, the NIH shipped a total of 696,361 liters of liquid scintillation vials. There were limited suggestions on how to reduce the volume of HPLC scintillation counting fluids. It is cautiously stated that some manufacturers of scintillation fluids claim that EPA has performed aquatic toxicity testing on their fluids and approved them for drain disposal, subject to state and local discharge permits. Another possible method to reduce HPLC volume is to pay careful attention to the buffer flow rates during the running of an HPLC procedure. Higher than normal flow rates can increase the volume of LLMW generated without increasing research benefits.

2.3 THE IDAHO NATIONAL ENGINEERING LABORATORY STUDY

In addressing the vexing issue of identifying disposal options for commercially generated mixed waste, this report endeavored to answer the question: "Which mixed waste has no treatment option?" Performed by the Idaho National Engineering Laboratory, *Mixed Waste Management Options: 1995 Update*, which updates a December 1991 study, estimates the volume of mixed waste requiring jointly regulated disposal (under the Atomic Energy Act (AEA) and the Resource Conversation and Recovery Act (RCRA)) based on the *National Profile* study and presents a methodological approach for generators to use when deciding how to manage their mixed waste. It is estimated that 118 m^3 of mixed waste per year cannot be managed out of existence given current mixed waste treatment, storage, and disposal options. All but 208 millicuries in 1.69 m^3 of the LSC waste are considered to be treatable using commercially available treatment options.

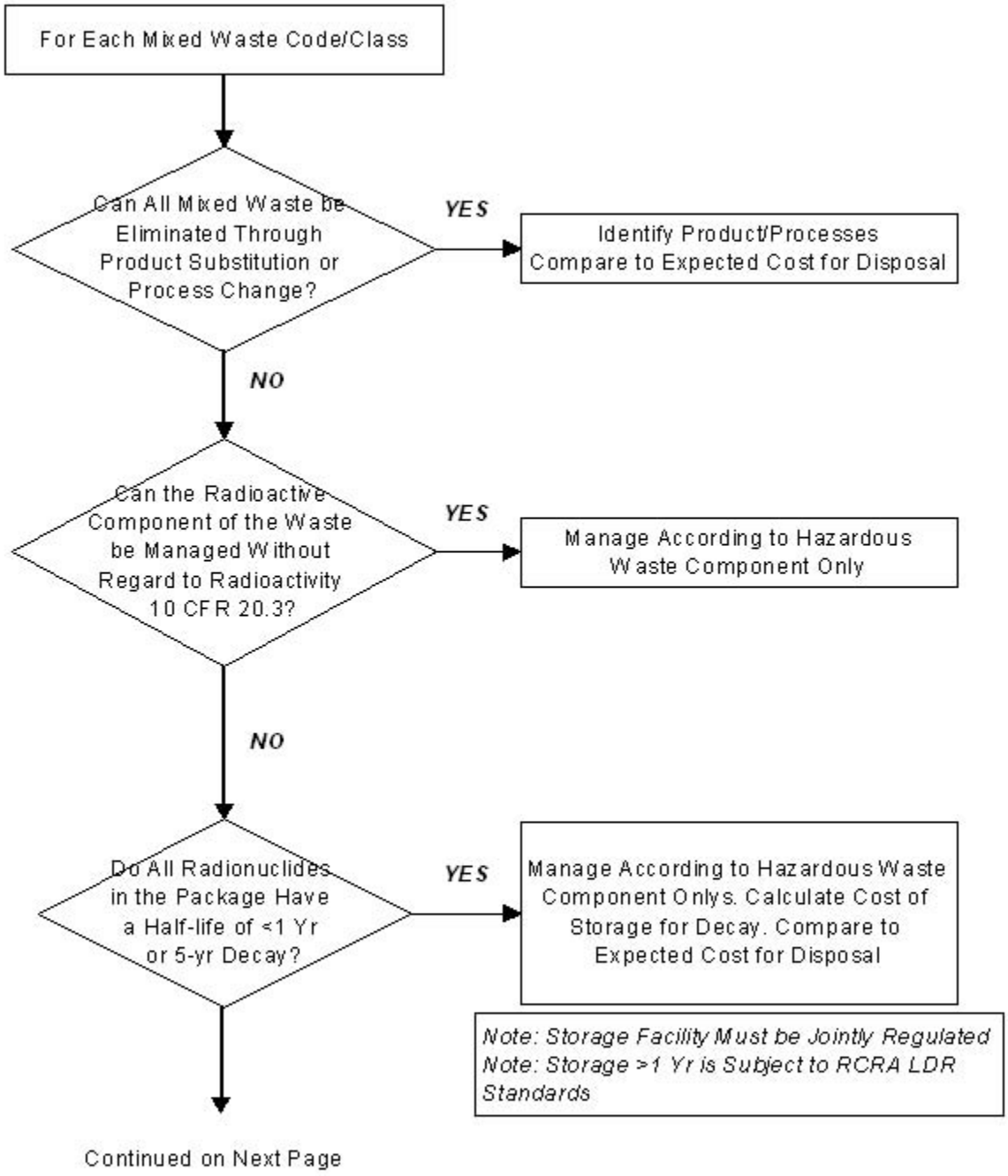
The *Mixed Waste Options* report presents a useful categorization of the regulatory requirements, commercially generated mixed waste streams, and management options. Concerning LSC waste, a description of the purpose of the procedure, waste disposal issues, and waste minimization issues are provided. An attached table details the LSC waste generated and stored in 1990. It is stated that according to 10 CFR 20.2005, LSC fluid wastes can be disposed of without regard to the radioactive component of the waste if they contain only ^3H or ^{14}C with a total concentration of 0.05 microcurie per gram of scintillation liquid. In those cases where radionuclides other than ^3H or ^{14}C are present in the fluid, the exemption may not apply.

For concentrations of nuclides above 0.05 microcurie per gram, waste aggregation is usually employed to reduce the concentration below the allowable level. The primary waste minimization option discussed involves substitution of "aqueous" or "biodegradable" compounds for the more hazardous RCRA-regulated substances. The NIH has implemented a systematic waste aggregation system coordinated through a central waste management facility that involves collecting waste from similar processes and waste constituents. State and local regulatory frameworks dictate the limitations or standards concerning waste aggregation. The NIH, for example, promulgates internal requirements that determine the limitations on waste aggregation.

Waste aggregation, however, does not imply dilution. Federal Regulation 40 CFR 268.3 prohibits dilution as a substitute for adequate treatment "to achieve compliance with Subpart D of [40 CFR 268], to circumvent the effective date of a prohibition in Subpart C of [40 CFR 268], to otherwise avoid a prohibition in Subpart C of [40 CFR 268], or to circumvent a land disposal prohibition imposed by RCRA section 3004."

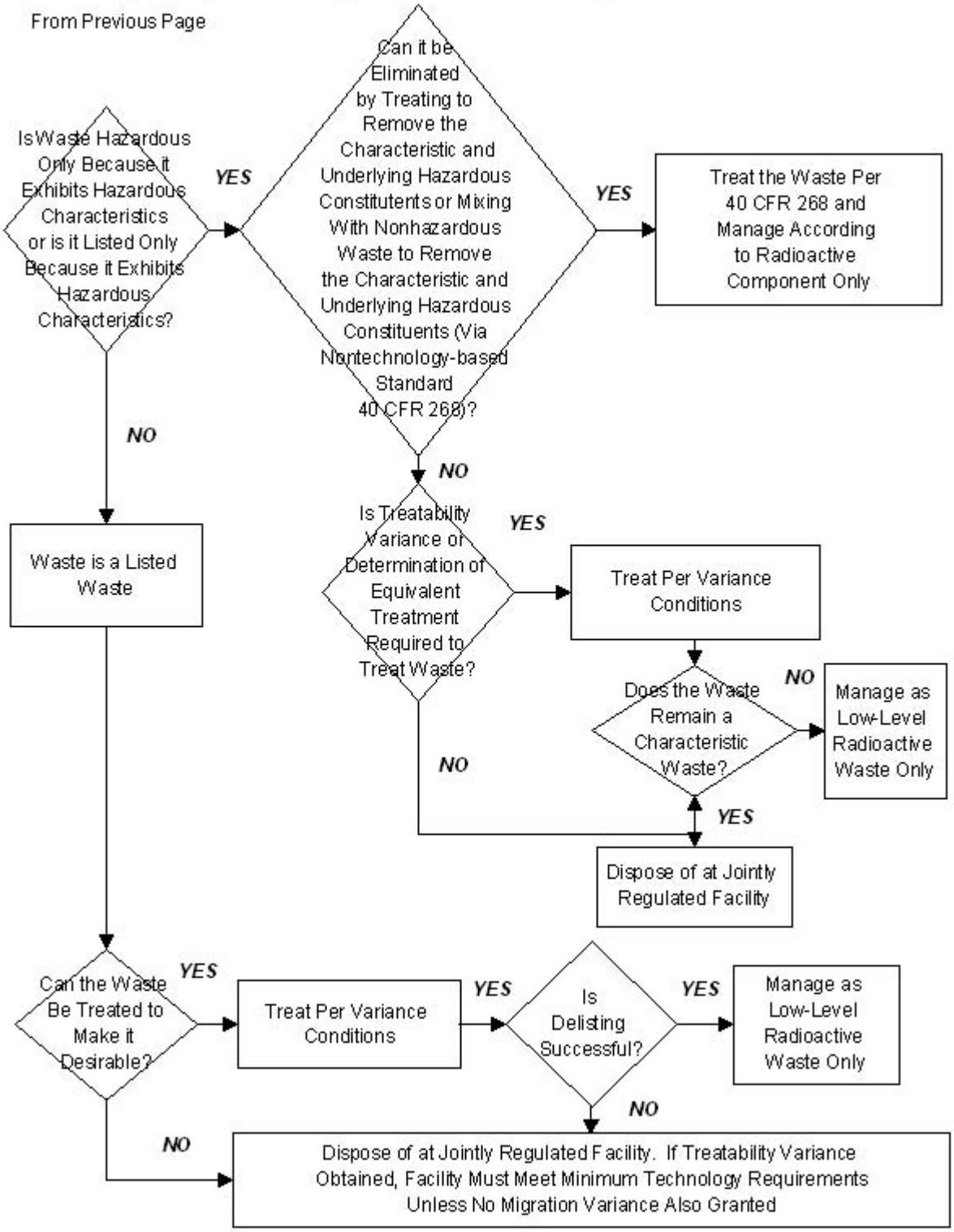
The report includes a useful mixed waste management schematic that is reproduced in Figure 1. Although some of these steps are not applicable for EPA laboratories, the framework and process flow is conceptually useful. A more detailed discussion of the management options presented in

Figure 1: Mixed Waste Management Schematic



Source: Mixed Waste Managment Options: 1995 Update, May 1995

Figure 1 (continued): Mixed Waste Management Schematic



this report is provided in the next section.

Of special significance is the presentation of a three-tiered cost-effectiveness mixed waste management hierarchy: avoidance, treatment, and regulatory. Management options that fall under the rubric of the highest level, avoidance, will result in the most substantial cost savings. RSOs and laboratory staff need to be consciously aware of the importance of this framework and the substantial cost savings realized by focusing waste management efforts at the highest level of this hierarchy.

It is clear that the types of mixed waste generated at EPA facilities are analogous to those of commercial facilities and NIH laboratories. Waste generated from LSC practices comprised a substantial volume of the total mixed waste in both EPA laboratories and the Oak Ridge National Laboratory survey mentioned above. The principal radionuclides generated from commercial sources, the NIH, and the EPA laboratories in their respective time periods of study were strikingly similar.

2.4 THE ROLE OF POLLUTION PREVENTION

An integrated approach to laboratory mixed waste management necessarily implies pollution prevention. The term "pollution prevention" has served as an all-encompassing term for any technique, process, or procedure that minimizes waste. Broadly defined, pollution prevention refers to activities that keep pollutants from being created in any media. There are many strong benefits to pollution prevention including safety, waste minimization, efficiency, regulatory compliance, reduction in liability, and cost reduction. Pollution prevention techniques are a critical component of prudent laboratory practices and have been incorporated into many laboratory waste management procedures. A summary of the materials that address pollution prevention at a laboratory or programmatic level is provided below.

A cooperative program between the federal community and EPA that actively pursues pollution prevention research and enhance its implementation through technology transfer is EPA's Waste Reduction Evaluations at Federal Sites (WREAFS). Two documented cases of the success of this program include work conducted at the Geochemistry Laboratory (GL), which uses a scintillation counter, and the Manufacturing and Fabrication Repair Laboratory (MFRL) at the Sandia National Laboratories (SNL) and the Fort Carson Evans Community Hospital Histology Laboratory in Colorado Springs, CO.

The application of the program at SNL represented a systematic evaluation of project design and implementation, materials management, and recycling/reuse options. This approach is labeled a pollution prevention opportunity assessment (PPOA). The conclusions and recommendations derived from this pollution prevention assessment include the need to:

- incorporate pollution prevention into research proposals;

- continuously update the training and education of staff;
- employ a central purchasing/distribution system;
- establish an escrowed closeout money account which sets aside money at the beginning of a project; and
- focus pollution prevention research on site-wide pollution prevention efforts, as opposed to isolated attempts; these efforts represent the largest potential gain in waste minimization.

Research at the Evans Community Hospital, which produces mixed waste includes tissue processing and slide staining. The PPOA revealed that solvent recovery can be a cost-effective and attractive pollution prevention option to implement. This approach was proven effective for xylene, ethanol, methanol, and other histology solvents. Volume reduction and substitution were also considered. An economic feasibility analysis revealed that the payback period for implementing a solvent recovery program was as low as 11 months.

Distillation as a pollution prevention technique involves heating substances to their boiling point and collecting the vapor that rises into the condensing portion of the distillation column. Two documented solvent recovery techniques to enhance the efficiency of solvent separation include spinning band distillation, which uses a motor driven Teflon band in the distillation column, and a method that utilizes an atomized plating technique. The one disadvantage with these approaches is the inability of these methods to separate pure ethanol from ethanol and xylene mixtures.

These approaches, in microcosm, may be applicable to EPA laboratories. Researchers at the Evans Community Hospital concluded that those approaches with the greatest opportunity for pollution prevention should be considered first. This pollution prevention hierarchy is presented in Section 5 within the context of a suggested framework for a mixed waste management program. These cooperative approaches to pollution prevention foster a more proactive strategy to identify prudent practices and facilitates a more expeditious dissemination of these practices to other laboratories.

Regulatory complexity and the lack of options for treatment of some mixed waste streams present notable concern. The importance of incorporating pollution prevention options in laboratory practices is instrumental to efficient waste management. Specific approaches are discussed below.

2.5 LABORATORY-WIDE POLLUTION PREVENTION PROGRAMS

Pollution prevention approaches employed at the laboratory level that can be categorized under the integrated waste management approach are outlined below. These laboratory-wide

approaches address multiple aspects of waste management and are especially pertinent to EPA mixed waste generating facilities.

Lewandowski, Joseph J.; Moghissi, A. Alan. "Management of Mixed Waste at a Teaching, Research, and Health Care Facility," *Proceedings of the 3rd Biennial Symposium of Mixed Waste*, Baltimore, MD, August 1995.

This report outlineS a strategy to manage the generation and disposal of mixed waste generated at Temple University. Developed in 1993, this strategy is based on five principles relating to legal, technological, and budgetary considerations.

The first stage of this strategy involves separating waste into one of eight categories including waste classified as onsite decay, mixed waste, decay-in-storage, and biological waste. The investigators are required to separate their waste into these eight categories. Despite initial concerns of placing undue burdens on researchers, no more than two different waste containers for the separation of waste were required by any one researcher. The second phase of the strategy entails further separations of waste into manageable groups. The mixed waste, for example, is divided into LSC waste and non-LSC waste.

Under the new waste management strategy the regulated scintillation materials (toluene and xylene) were replaced with other aromatic solvents. These new solvents have nearly the same efficiency as toluene or xylene, but have flash points that are higher than 60°C and are not listed in EPA regulations. The purchase of regulated scintillation fluid was significantly curtailed, and any investigator who submitted a purchase order for regulated scintillation liquid had to provide written justification to be approved by the University's Office of Environmental Health and Safety. Because of this policy, the application of regulated liquid scintillation material has been essentially eliminated.

Another approach in the control of mixed waste production involves the University's Radiation Protection Committee. An investigator who chooses to use radioactive materials must receive an authorization from the Radiation Protection Committee and adhere to certain Committee policies and periodic routine inspections. Alternative protocols are suggested in the Committee review process to avoid future generation of mixed waste.

Methé, Brian M., "Managing Radioactively Contaminated Infectious Waste at a Large Biomedical Facility," *Health Physics*, February 1993, Volume 64, Number 2, pp.187-191.

The Albany Medical Center consists of a 600-bed teaching and medical college and uses radioactive material in the diagnosis and treatment of patients, and in research in the biological and medical sciences. The incinerators at the Medical Center were closed in 1993 in response to air pollution control regulations. Medical waste is shipped to offsite treatment and disposal facilities. This article details the RSOs responsibilities in managing the low-level radioactive waste generated as a result of these activities. Three topical areas are discussed including

screening methods, treatment and storage, and reduction of waste volume.

The medical waste is sent to the waste processing area in 0.4-m^3 carts, which are scanned using an alarming rate meter with a sodium iodide probe sensitive to low-energy photons. All bags containing detectable radioactivity are removed and set aside and prepared by technicians to be shipped. The contaminated bags are placed in cardboard boxes with plastic liners and the hot spots and radioactive isotopes are labeled. It was discovered that a box size of 0.15-m^3 that accepted one bag, conserved storage volume, simplified box handling, and minimized exposure to the infectious waste.

For the purposes of the Albany Medical Center, two mixed waste treatment options were considered: 1) treatment of the hazardous component and disposal or 2) storage-for-decay and disposal as medical waste. This second option is significantly less expensive (by approximately $9.75 per kg), but the space required for storage is a pressing concern since medical waste needs to be stored in a freezer to minimize biological composition.

Three strategies are currently being employed to reduce waste volume at its source, including educating the user, empowering the user, and providing the user meaningful feedback. It is critical that the user is 1) apprised of the importance of waste handling, segregation, and prevention and 2) able to identify at which steps of a particular process the radioactively contaminated material is generated. Finally, it is crucial that constructive feedback that may aid in minimizing waste generation is conveyed to the user.

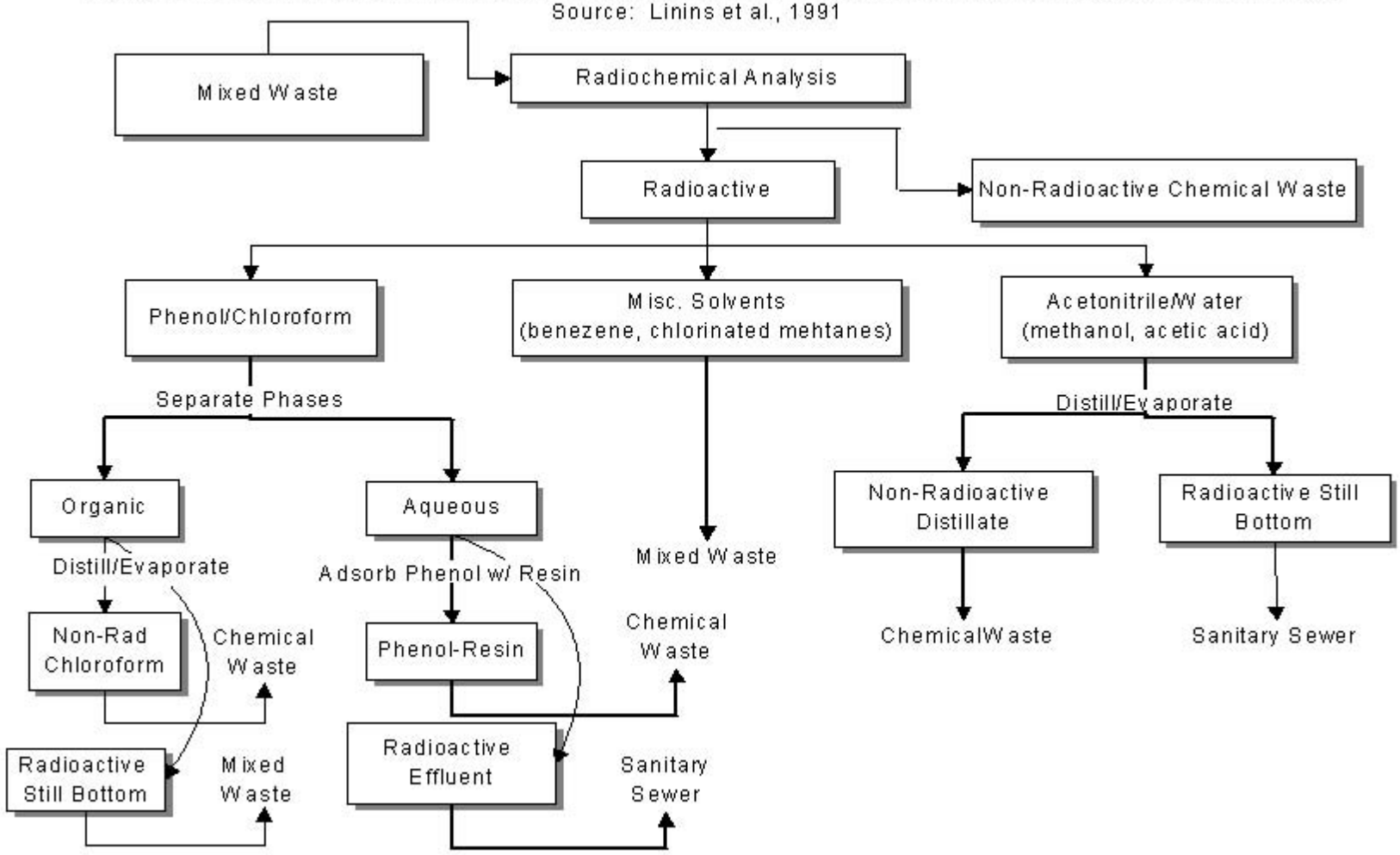
Linens, Ilona; Klein, Robert C.; Gershey, Edward L.; "Management of Mixed Wastes from Biomedical Research," *Health Physics*, September 1991, 61, 3, pp. 421-426.

At the Rockefeller University, mixed waste generated from biomedical research comprises less than 1 percent of the University's total LLRW volume. However, the generation of this waste is integral to this research and will continue to be generated in the future. This article summarizes the characterization of the biomedically generated mixed waste at The Rockefeller University and select separation and treatment protocols. Radioactive and chemical characterization methods are outlined along with separation technologies such as adsorption and extraction, and evaporation and distillation.

The mixed waste was grouped into three categories: phenol/chloroform mixtures, acetonitrile/water mixtures, and mixtures of miscellaneous solvents. Figure 2 schematically portrays this management strategy for biomedical wastes. Effective mixed waste management programs entail careful waste segregation and labeling. It is concluded that the relevant regulations (specifically permits) do not provide for a disposal outlet for some mixed waste nor for extended storage without a RCRA Part B storage permit. Onsite storage remains the only option for dealing with mixed waste. A considerable number of research facilities do not possess the financial resources to obtain a RCRA Part B permit which may engender the need to consider

Figure 2: Mixed Waste Minimization Strategy for Biomedical Waste at the Rockefiller University

Source: Linins et al., 1991



suitability of regulatory flexibility. Available regulatory options for waste management are addressed more thoroughly in Section 5.1.

Lorenz, Steven M., "Decreasing Dry Active Waste Generation by 50% in One Year," *Radwaste Magazine*, Sept. 1995, 2, 5, pp. 47-49.

In October 1994, Commonwealth Edison (ComEd) designated a waste reduction program manager to reduce the generation of dry active waste. The effort resulted in dry active waste generation reduced by over half in less than a year. This summary document highlights some examples of the changes implemented to reduce the generation of the waste. The waste minimization strategy originated with detailed site visits to all 13 ComEd nuclear units. The purpose of the visits was to demonstrate the importance of incorporating waste minimization activities into laboratory practices and aid radiation protection staff in identifying minimization opportunities. The author concludes that the keys to reducing waste minimization include teamwork, standardization, training, cooperation, and support.

Lorenzen, William A. *Operational Aspects of Harvard University's Waste Management Program*, pp. 415-420, August 1995 [Attachment to Fax and Young, August, 1995].

This article provides an overview of the waste management program designed by Harvard University's Radiation Protection Office. The program is configured around centralized waste collection rooms coupled with procedures to minimize handling, a decay-in-storage facility and an on-site incinerator. In terms of personnel, a Group Leader supervises 13 technicians whereby procedures and process steps are reviewed by process improvement teams. These teams evaluate efficiency through process streamlining, and understanding customer and business needs. After staff undergo extensive training which among other things informs the technicians of the waste acceptance and packaging criteria, the operation of the radioactive waste management program begins with waste collection in a centralized room for each campus or hospital. The room is organized for the collection, segregation, and packaging of waste by disposal method.

McCamey, R.B. "Building a Mixed-Waste Prevention Program at Comanche Peak", *Radwaste Magazine*, May 1995, 2, 3, pp.21-28.

The article primarily focuses on the techniques established at a specific nuclear utility facility, Texas Utility's Comanche Peak, for reducing the generation of mixed waste. The techniques described are primarily management related and focus little on specific technical innovations. Additionally, the reduction strategies center on reducing the hazardous waste components of mixed waste rather than the radioactive components.

The prevention techniques primarily involve improving the utility-wide information policy concerning mixed waste and its components and include:

- Establishing a special interdepartmental mixed waste task force to address the

problem of mixed waste reduction and prevention,

- Establishing a company-wide database on all mixed waste producing chemicals,
- Involving managers and staff early on in the mixed waste prevention process to enhance input and ensure rapid program adoption,
- Cooperation and information sharing among departments traditionally isolated,
- Employee education regarding all rules and procedures pertaining to mixed waste and its components, and
- Detailed product labeling and the distribution of product fact sheets to detail specific chemical uses, its potential to generate mixed waste, and a list of any safe alternatives.

Although the article focuses on nuclear power plant facilities, the suggestions for mixed waste reduction and prevention can easily be applied to all producers of mixed waste and its components. The overriding concept is to promote sufficient departmental cooperation, information sharing and accuracy, and employee education.

Party, E.; Gershey, E.L. "Recommendations for Radioactive Waste Reduction in Biomedical/Academic Institutions," *Health Physics*, April 1989, 56, 4, pp. 571-572.

The authors assert that many organizations that generate LLRW do not characterize it sufficiently to achieve maximum volume reduction and waste minimization. It is professed that a significant volume of waste that must be shipped for burial can be reduced dramatically through decay of short-lived radioisotopes onsite. The Rockefeller University experienced a 96 percent reduction in volume of radioactive waste shipped resulting in notable cost savings. To this end, a sufficiently large storage area is needed to store the contaminated material prior to disposal as nonradioactive material.

It is suggested that a detailed and systematic waste identification program be implemented that classifies the source of the material including name of generator, room, department, date, volume, isotope, activity, etc. Specific guidelines are provided for different waste categories including solid waste, liquid waste, animal tissues, scintillation vials. Liquid waste, for example, contains more that 90 percent of the radioactivity disposed at Rockefeller. It is recommended that this waste be collected in polyethylene bottles and where appropriate held for decay. Accurate characterization and segregation of the waste is critical to ultimate reductions in radioactive waste shipped for burial.

Prudent Practices in the Laboratory: Handling and Disposal of Chemicals, The National Research Council, National Academy Press, Washington, DC, 1995.

A National Research Council committee prepared this document to delineate the chemical, regulatory, and educational changes associated with the handling and disposal of chemicals. This guide was designed for those who use chemicals in the laboratory as well as administrative and chemical hygiene staff, and environmental safety officers. The report is partitioned into sections that can be examined individually and address hazard evaluation, risk assessment, management, disposal, and regulatory issues.

For the purposes of this project, multihazardous waste (chemical, radioactive, and/or biological components) is outlined in terms of the regulatory issues and suggested management practices. A recognition of the special problems associated with multihazardous waste is identified. The report provides a general model of the chemical laboratory as the primary mechanism for prudent practices conducive to effective waste management.

A detailed discussion of mixed waste minimization strategies including examples of altering laboratories, source substitution and hazard reduction of mixed waste is outlined. The article briefly touches on innovative treatment solutions which are to be developed and operational in the near future. Some of the recommendations made to regulatory agencies in the report include:

- EPA should extend its permit-by-rule provisions to allow scientifically sound treatment of small quantities of waste generated in laboratories;
- EPA should encourage safe disposal of mixed waste with short half-lives by excluding the decay-in-storage period from the current 90-day limitation on storage of hazardous waste; and
- NRC and EPA should establish *de minimis* levels for radionuclides, below which laboratory waste can be disposed of without regard to radioactivity.

It is mentioned that although a *de minimis* level for all types of radionuclides in laboratory radioactive waste has not been promulgated, licensees can often propose a license-specific *de minimis* level, below which mixed waste can be released for management as chemical waste.

Todisco, L.R.; Smith L.R. "A Manufacturer's Perspective on Low-Level Mixed Waste Treatment, Storage, and Disposal," E.I. Dupont and Co., Inc., NEN Products, *Proceedings of the 3rd Biennial Symposium of Mixed Waste*, August 1995, 10 pp.

This article outlines methods for reducing mixed waste at NEN Products, a manufacturer of radionuclide-labeled research chemicals. A diligent attempt has been made to reduce the generation of radioactive waste. During the past decade, even with a 50 percent increase in production, NEN Products Company reduced mixed waste generation 7-fold. This is in light of the fact that the radioactivity concentrations of mixed waste from the manufacturing processes have a range of over six orders of magnitude.

Mixed waste minimization is centered around five basic strategies: 1) reducing the use of solvents, 2) segregating radioactive constituents of waste, 3) identifying instances where the re-use of material is feasible, 4) shortening the shelf-life of labeled materials, and 5) source separating. Education, awareness, and communication were underscored as critical components of a waste management program. One concern is related to the regulatory stringency of treatment and disposal options which add significant cost to the manufacture and use of the labeled chemicals. Several suggestions were made to alleviate this issue including raising allowable concentration levels, allowing waste to be disposed of at DOE facilities, and providing EPA RCRA Part B permits at costs commensurate with small-scale onsite decay-in-storage and treatment operations.

A clear assignment of accountability is an important component of the waste management program at NEN Products. Estimated costs of the waste generated for each operation are provided with sufficient detail. The itemization of these costs appears on the operations budget and must be managed with respect to both ongoing and proposed operations. Other accountability standards are highlighted in Section 3.2.6 of this report.

Malchman, Warren, "Case Western Reserve University's New 'State-of-the-Art' Low-Level Waste Facility." *Radwaste*, September 1995, pp. 42-46.

Case Western Reserve University (CWRU) constructed a 3,000-square foot, $500,000 waste disposal site for both radioactive and chemical waste in anticipation of the regional facility. The facility has the capacity to hold 500 55-gallon drums of waste for storage which results in approximately 4 ft^3 of storage space per laboratory that generates radioactive waste. Thus, there is a compelling need to improve waste management practices and develop rigorous waste disposal standards so that the current capacity is not exceeded.

This article details the waste management procedures at the CWRU disposal site including stringent labeling practices, safety features, and surveys. Detailed descriptions are also provided for waste segregation strategies, waste type definitions, waste shipping and manifesting, personal protective equipment, and air-handling equipment.

Ring, Joseph; Lorenzen, William; Osborne, Frank; Shapiro, Jacob; *Bio-medical Radioactive Waste Management*, July 19, 1995 [Attachment to Fax and Young, August, 1995].

The effectiveness of the radioactive waste management program at Harvard University is evaluated. The portion of the solid waste shipped to a low-level waste disposal facility was reduced from 98 percent of the total radioactive waste column in 1980 to 1.09 percent in 1993 and the volume of waste generated per laboratory decreased by just under 50 percent [0.35 m^3 (12.31ft^3) in 1987 to 0.19 m^3 (5.29ft^3) in 1993]. The program is operated around a central decay-in-storage (DIS) facility and an incinerator.

The article continues by detailing the waste collection process. Commercial disposal is 5.7 times

more expensive per unit volume (on a total cost basis) than University managed waste. The waste management program, therefore, always begins with a training session designed to educate staff on waste generation, minimization, and general radiation protection. It was found that substituting laboratory absorbent pads, commonly referred to as diapers, for thin plastic-backed bench liners in multiple layers aids in reducing waste volumes. The laboratory technician is the key to effective waste reduction by identifying modifications of procedures to facilitate reducing waste. Improved communication resulted from the meetings.

It was discovered that assigning one technician to an area to monitor, collect samples, and other responsibilities is the most effective means of managing wastes. Prompt feedback and laboratory-based corrective action have sharply reduced waste management problems. When the waste is received at the Waste Management Facility the tag data is recorded into a database that calculates the release date. The decay-in-storage program has proven to be fairly successful in reducing waste disposal at commercial LLRW facilities. The applicability of this program in reducing mixed waste disposal was not discussed.

2.6 SUMMARY FOR SECTION 2

The literature referenced above provides an enumeration of the critical components of a waste management program. Updated information can be found on the EPA Mixed Waste Team Internet HomePage which can be found at (http://www.epa.gov/radiation/mixed-waste/). EPA laboratory directors considering the implementation of an integrated mixed waste management approach should consider the suggestions provided in the literature. The primary focus of the mixed waste management program should be directed at pollution prevention. The following integrated framework is based on the Waste Minimization Program at the University of Minnesota and other materials referenced above:

- engage all levels of management to a strong commitment to pursue established mixed waste minimization goals in the facilities pollution prevention plan;

- periodically evaluate the progress in meeting these goals through an audit or other type of analysis of the current mixed waste generation;

- begin an intensive education and training program for all employees that handle mixed waste to ensure a thorough understanding of the applicable regulations and regulatory guidance. Topics should include which waste can be recycled, the need for source separation, how to segregate waste, importance of a waste minimization program, and costs and technical difficulties of waste disposal;

- embody a team approach to mixed waste management; consciously pursue an active information sharing/dissemination program; ensure that continuous communication is employed between EPA laboratory personnel both inside and outside the laboratory;

- empower the research technicians to identify waste minimization alternatives;
- employ a comprehensive waste separation program; i.e. separate short-lived isotopes from long-lived isotopes; ensure that detailed product labeling is employed including source, stream, volume, isotope, etc. is recorded;
- employ standardized processes for all laboratories to the extent practicable;
- strictly control the use of radioisotopes including the control of purchasing;
- critically evaluate the use of radioisotopes, determine if short-lived radioisotopes can be used;
- encourage the substitution of less toxic or nonhazardous substitute materials with equivalent performance parameters (e.g., biodegradable liquid scintillation cocktails, solid scintillation counting) for hazardous materials; and
- consider the possibility of burning waste containing ^{3}H and ^{14}C in a pathogen incinerator.

It should also be noted that all levels of management should be in full support of waste minimization programs. While these programs will likely incur time and money (new equipment, materials, training, additional procedures, etc.) they will pay for themselves over the long term.

SECTION 3: SUMMARY OF MIXED WASTE MANAGEMENT OPTIONS

The purpose of this section is to define, identify, and present case studies and applications of the management options applicable for low-level mixed waste. Where available, the application of these options to LSC and HPLC is discussed. An overview of mixed waste management options applicable to all types of generating processes is outlined in *Mixed Waste Management Options: 1995 Update.* The option groups fall under three general headings: regulatory-based, avoidance, and treatment; a description of each option group and examples are highlighted below. All of the option groups listed are pertinent to EPA research facilities. As addressed above, a concerted approach is needed to aggrandize the effectiveness of a waste management effort.

3.1 REGULATORY-BASED OPTIONS

Several regulatory-based options are available to managers of mixed waste producing facilities who wish to avoid disposal of certain chemicals and materials in a mixed waste disposal facility. Four such options are: (1) delisting petition, (2) a no migration variance, (3) a treatability variance, and (4) a Determination of Equivalent Treatment Petition. Since the latter option is more applicable to EPA research facilities, it is discussed in more detail below.

3.1.1 Determination of Equivalent Treatment

As the name implies, the Determination of Equivalent Treatment Petition, if granted, would allow a facility to use an alternative treatment method to achieve the same measure of performance as that achieved by the specified methods in the Land Disposal Restriction rules. The petitions must demonstrate that the alternative methods achieve the specified treatment levels, are in compliance with federal, state, and local requirements; and are protective of human health and the environment [40 CFR 268.42 (b)].[2] Unlike treatability variances, Determination of Equivalent Treatment petitions, are more likely to be granted than denied. No sources were identified which contained cost estimates for this type of petition.

3.1.2 Regulatory Flexibility[3]

A management approach that strives for a flexible regulatory framework may alleviate the high costs associated with treatment, storage, and disposal without posing additional risks to human health and the environment. With the exception of the NERL-RTP and NRMRL-Breidenbach, the total volume of mixed waste generated at each laboratory in the 1992-1994 time period was

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[2]Regional EPA offices offer a "permit-by-rule" provision that allows categorical or blanket permitting of certain small-scale treatment methods.

[3]It is important to determine whether or not your authorized state programs may be more stringent than the federal RCRA program before relying on any of the exceptions discussed in this section. Even exceptions adopted by an authorized state may be more narrowly interpreted.

less than 30 ft^3. Given the relatively diminutive volume and curie content of the mixed waste generated at EPA laboratories, these facilities may be able to justifiably exempt themselves from certain NRC or NRC Agreement State or EPA or EPA RCRA Authorized State regulatory provisions. An exception that offers regulatory relief for mixed waste generators from virtually the entire RCRA program, including the permitting requirement, is the "Conditionally Exempt Small Quantity Generator" provision.[4] Although there were no specific examples in the literature of the efficacy of regulatory-based options, this approach may have some applicability for EPA facilities.

For example, a CESQG may treat hazardous waste in an onsite elementary neutralization unit without meeting the requirements in 40 CFR 261.5(f)(3) and (g)(3). Elementary neutralization units, as defined in 40 CFR 260.10, are exempt from RCRA treatment, storage, and disposal standards and permitting requirements. The elementary neutralization unit exclusion does not preclude a CESQG from treating waste in the exempt unit as long as the generator meets the criteria outlined in 40 CFR 264.1(g)(6), 265.1(c)(10), and 270.1(c)(2)(v). Specifically, the elementary neutralization unit must meet the definition of a container, tank, tank system, transport vehicle, or vessel; and be used for neutralizing waste that are hazardous only because of corrosivity characteristic (RCRA/SF Hotline Report, February 1996)

For large quantity generators (LQG) and small quantity generators (SQG), EPA has consistently maintained that a permit or interim status is not required of generators if the generator treats hazardous waste in accumulation units such as tanks or containers that are in full compliance with the requirements of 40 CFR 262.34 and the special unit-specific requirements found in Part 265 (March 24, 1986; 51 FR 10146, 10168). This treatment must be completed within the specified regulatory time limitations (RCRA/SF Hotline Report, April 1996).

Used in conjunction with other management options, regulatory approaches can be used to mitigate the costs associated with the use of a TSD facility. For example, the Oklahoma Medical Research Foundation recently filed a petition to amend their license. Their radionuclide half-life license limit allowed for decay-in-storage was extended to 120 days. 40 CFR 260, Subpart C outlines the general requirements of the petition process.

Currently, there are only a few *de minimis* levels for onsite radioactive waste disposal. Permitted sanitary sewer disposal was the management option chosen for 615.4 ft^3, or 19.2 percent of the LLRW generated by EPA laboratories in 1992-1994. Under 10 CFR 20.2003, an NRC licensee may release licenced radioactive material that is readily soluble or readily dispersible biological material into any one sewerage system. Total permitted yearly curie loads and concentration

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[4]Special requirements for HW generated by conditionally exempt small quantity generators, less than 100 kg HW or 1 kg of acute HW in a calendar month are contained in 40 CFR 261.5. Note that this provision includes all HW generated at the facility and not just mixed waste. However, the generator need not count those HW (or mixed waste) that are excluded from RCRA regulation.

levels are detailed in the above Part 20 reference. As indicated previously, NRC licensees can also propose a license-specific *de minimis* level for specific radionuclides, below which mixed waste can be released for management as a chemical waste.[5] EPA laboratories may wish to explore the potential opportunities for filing a petition or proposing a license-specific exemption based on the curie content of the mixed waste generated.

Under RCRA certain laboratory waste waters are excluded from the definition of hazardous waste. These provisions are found in 40 CFR 261.3 (a)(2)(iv)(E). These laboratory waste waters which would otherwise be regulated as a hazardous waste because they contain a listed waste containing toxic constituents are not considered hazardous. To qualify for this exclusion, the generator must show that the laboratory wastewater discharge:

- is subject to regulation under either Section 402 (NPDES program) or Section 307(b) (pretreatment program) of the Clean Water Act and
- the annualized average flow of laboratory wastewater does not exceed one percent of total wastewater flow into the headworks of the facility's wastewater treatment or pretreatment system; or
- provided the wastes' combined annualized average concentration does not exceed one part per million in the headworks of the facility's wastewater treatment or pretreatment facility.

[Note: Toxic (T) waste used in laboratories that are demonstrated not to be discharged to wastewater is not to be included in the above calculation.]

This exemption does not cover laboratory wastewaters that exhibit a RCRA hazardous characteristic (ignitable, corrosive, toxic, or reactive). However, as noted in 40 CFR 261.3(a)(2)(iii), if wastes which were listed solely for exhibiting a characteristic were mixed with other solid wastes, such as a wastewater, and ceased to exhibit any characteristic they would no longer be considered hazardous wastes (RCRA/SF Hotline Report, May 1996). Also, as noted in 40 CFR 268.1(e)(5), land disposal prohibitions for hazardous characteristic waste do not apply to laboratory waste displaying ignitability (D001), corrosivity (D003), or organic toxicity (D012-D043) that are managed in accordance with the previously mentioned laboratory wastewater exclusion.

A flexible regulatory scheme may also reduce timely reporting requirements associated with compliance, and eliminate regulatory overlap. Although none of the EPA laboratories surveyed reported significant regulatory hurdles, some commercial and academic laboratories have articulated substantial regulatory burdens resulting in increasing the cost associated with mixed

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[5]NRC allows LSC fluid with less than 1.85 kBq/g of ^{3}H or ^{14}C to be disposed of without regard to its radioactivity. See 10 CFR 20.2005(a)(1) for more details.

waste management. Specifically, representatives from these laboratories have expressed consternation with both 1) the regulatory stringency of treatment and disposal options and 2) the regulatory overlap which add to the cost in the use of radioactive materials. One researcher estimated that meeting all the reporting and training requirements requires approximately 10 percent of laboratory personnel time[6].

3.2 SOURCE REDUCTION/AVOIDANCE OPTIONS

Source reduction and avoidance and involve actions that eliminate the production of LLRW/MW which would require extended storage or access to offsite disposal. The management options that fall under this activity include substitution, waste segregation and separation, process modification, pollution prevention, recycling, storage for decay, and administrative controls. Figure 3 depicts an overview of general volume reduction methods for four types of waste including solid, liquid, animal, and gas.

3.2.1 Source Reduction

Over the past 2 decades, laboratory protocols for biomedical and basic research have been progressively scaled down from the liter to milliliter to microliter scale, reducing both reagent costs and the volume and radioactivity of resulting waste (Linins *et al*. 1991). EPA laboratory researchers should try to identify ways to reduce the amount of materials used in experiments. Significant reductions could be obtainable through a refinement in protocols. These protocol modifications can greatly reduce the waste volumes, sample preparations, and disposal costs at EPA laboratories. The following are examples of some protocol modifications which might be applicable to EPA laboratories.

- Replacing conventional liquid scintillation counting vials (20 ml) with smaller vials (7 ml) can result in a 3:1 volume reduction (Dagan, 1993).

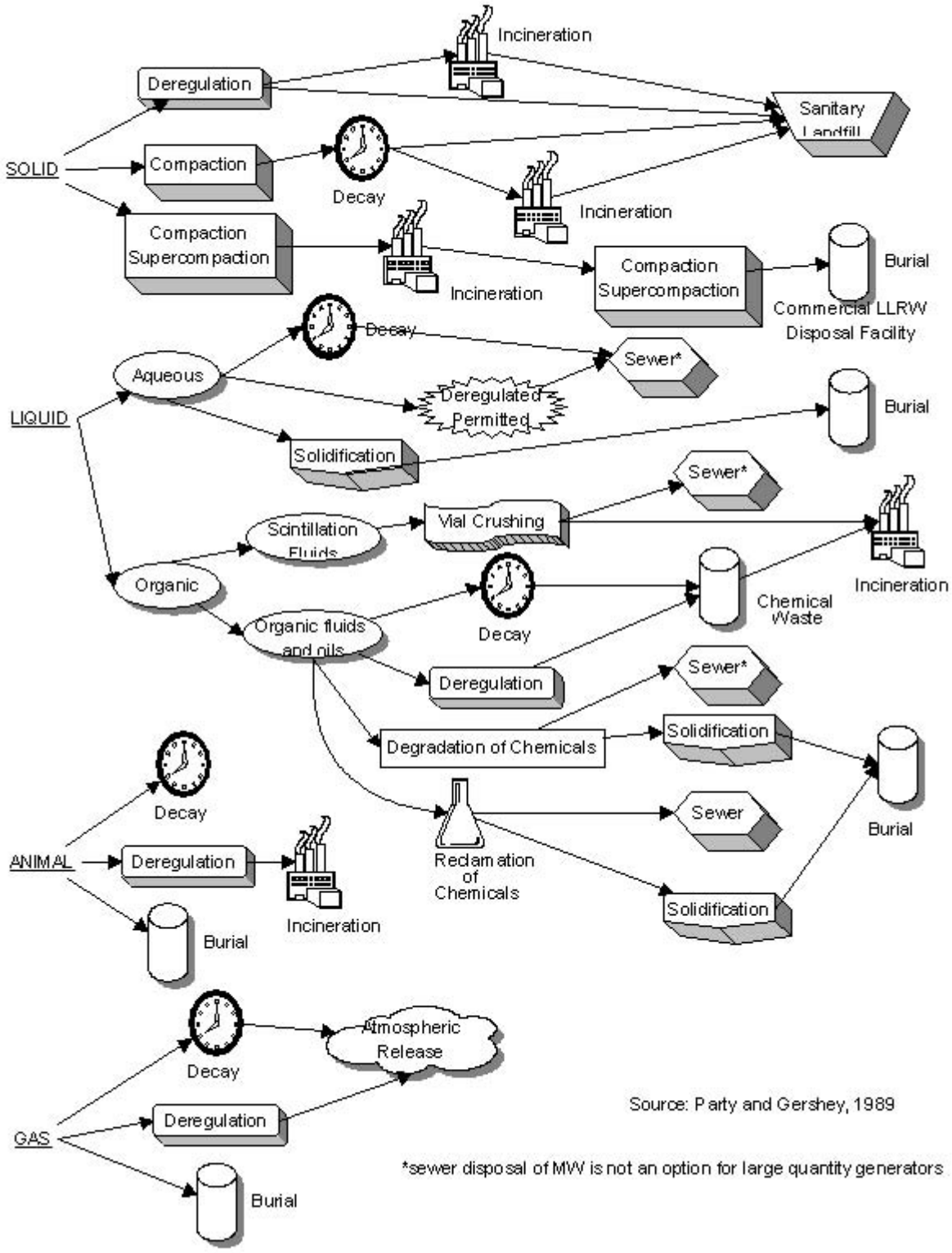
- Using 2-ml microcentrifuge tubes in place of 7-or 20-ml liquid scintillation vials during counting of aqueous or filter samples can result in a 50 -75 percent reduction in waste volume (Elliott, 1993).

3.2.2 Substitution/Use of Biodegradable Solvents

In reference to laboratory procedures, substitution involves the displacement of nonhazardous or

[6]Personal correspondence with Margaret C. Neville, Ph.D., Professor of Physiology, University of Colorado School of Medicine, March 25, 1996.

Figure 3: General Volume Reduction Methods for Laboratories



nonradioactive materials to perform functions formerly requiring radioisotopes and hazardous materials. Several commercial, academic, and government laboratories have successfully substituted nonhazardous solvents to perform various research activities. The primary waste minimization option discussed involves substitution of "aqueous" or "biodegradable" compounds for the more hazardous RCRA-regulated substances.

Material substitution is one of the easiest and more cost-effective methods for reducing the level of mixed waste generated. The example of using water-based solvents instead of other solvents such as toluene or chloroform is often cited as an example of chemical substitution. Using enzymes and fluorescent labels instead of radioactive tracers is an example of substitution to reduce radioactive wastes. Substituting radionuclides with shorter half-lives (^{32}P for ^{3}H or ^{14}C) can also be used to decrease the amount of mixed waste sent to treatment or long-term storage facilities.

Certain compounds that have not been identified as hazardous under 40 CFR 261 of RCRA or 40 CFR 122 of the Clean Water Act are being used as solvents in LSC cocktails. Rockefeller University evaluated a variety of cocktails deemed "biodegradable" based on three criteria: efficiency, toxicity, and potential for biodegradation (Klein *et al*., 1990). The results indicated that, for a majority of the biodegradable LSC assayed, the cocktails are comparable to RCRA identified hazardous compounds in terms of efficiency, sample capacity, and viscosity. The studied compounds were also less acutely toxic and are susceptible to biodegradation. Pacific Northwest National Laboratory switched to a nonregulated brand (Ultima Gold) and eliminated the generation of mixed waste from most liquid scintillation counting (Dagan *et al*., 1993). Further research is needed to ensure that 1) widespread environmental contamination does not occur from the use of these compounds and 2) the efficacy of sewer disposal is fully explored.

Xylene substitutes were examined in detail at the Fort Carson Evans Community Hospital Histology Laboratory in Colorado Springs, CO. The criteria that were considered in the selection of a substitute included toxicity, physicochemical characteristics, compatibility with other materials, performance, availability, recycling requirements, disposal requirements, and cost. Some of the drawbacks with the use of these substitutes are the relative high cost and their poor performance for tissue cleaning.

Phenol, chloroform, and 1:1 mixtures of these chemicals are routinely used in molecular biology laboratories to extract nucleic acids from radiolabeled biological materials and denature proteins that remain after treatment with enzymes (Linins, *et al*., 1991). New procedures that do not use phenol and chloroform are available in kit form from several suppliers. This avoidance of phenol and chloroform eliminates the need to treat a toxic and corrosive extraction effluent.

A successful example of waste minimization at the University of Wisconsin-Madison is the substitution of a toluene-based LSC fluid with nonignitable LSC fluid. This practice alone eliminated the generation of thousands of gallons per year of waste toluene solutions from liquid scintillation. The nontoluene based solution reduces the risk of exposing workers to toluene, as

well as reducing the risk of fire, the environmental hazards of spills, disposal costs, and paper work requirements.

In the 1992-1994 time period, some of the EPA laboratories used biodegradable cocktails in LSC procedures, reducing the generation of mixed waste. The EPA researchers who used these non-hazardous cocktails did not report any substantial loss in efficiency in performing laboratory experiments[7]. To minimize mixed waste volumes, one EPA laboratory RSO reported that written justification is required to use xylene in any laboratory procedure. Given that toluene and/or xylene was a constituent in 98.2 percent of the total MW volume generated in EPA laboratories in 1992-1994, there exists continued potential to reduce MW generation.

3.2.3 Waste Segregation and Separation

Waste segregation describes the practice of keeping different waste streams segregated from the time they are placed in the collection container through transport, storage, treatment, and disposal. Waste segregation options do not represent formal technologies as much as systematic procedures to label and codify MW and LLRW. This also entails grouping wastes of similar characteristics and identifying opportunities for recycling.

Components of source separation programs in laboratories include: 1) training laboratory personnel, 2) using sanitary sewer and normal trash properly[8], 3) supplying easy-to-use waste collection containers, 4) establishing waste collection stations, 5) labeling waste collection containers appropriately, 6) monitoring and minimizing errors, and 7) examining where changes can be made for improvement.

A common waste segregation approach is the "multicolor bag" system. This has proven successful in the reuse and reduction of waste material. Two utilities documented reductions of 87 and 74 percent in the volume of LLRW shipped using this approach. Figure 4 schematically portrays the "multicolor bag" system. Although this model diagrams waste segregation issues associated with a nuclear utility, the same approach can be extrapolated to a facility that generates LLRW/MW from few processes.

Source separation aids in minimizing the quantity of mixed waste by preventing waste that does not need special management considerations from entering the waste stream. Although very similar in scope to waste segregation, source separation refers to the practice of separating different types of waste at their point of generation and discard. Waste segregation relies on

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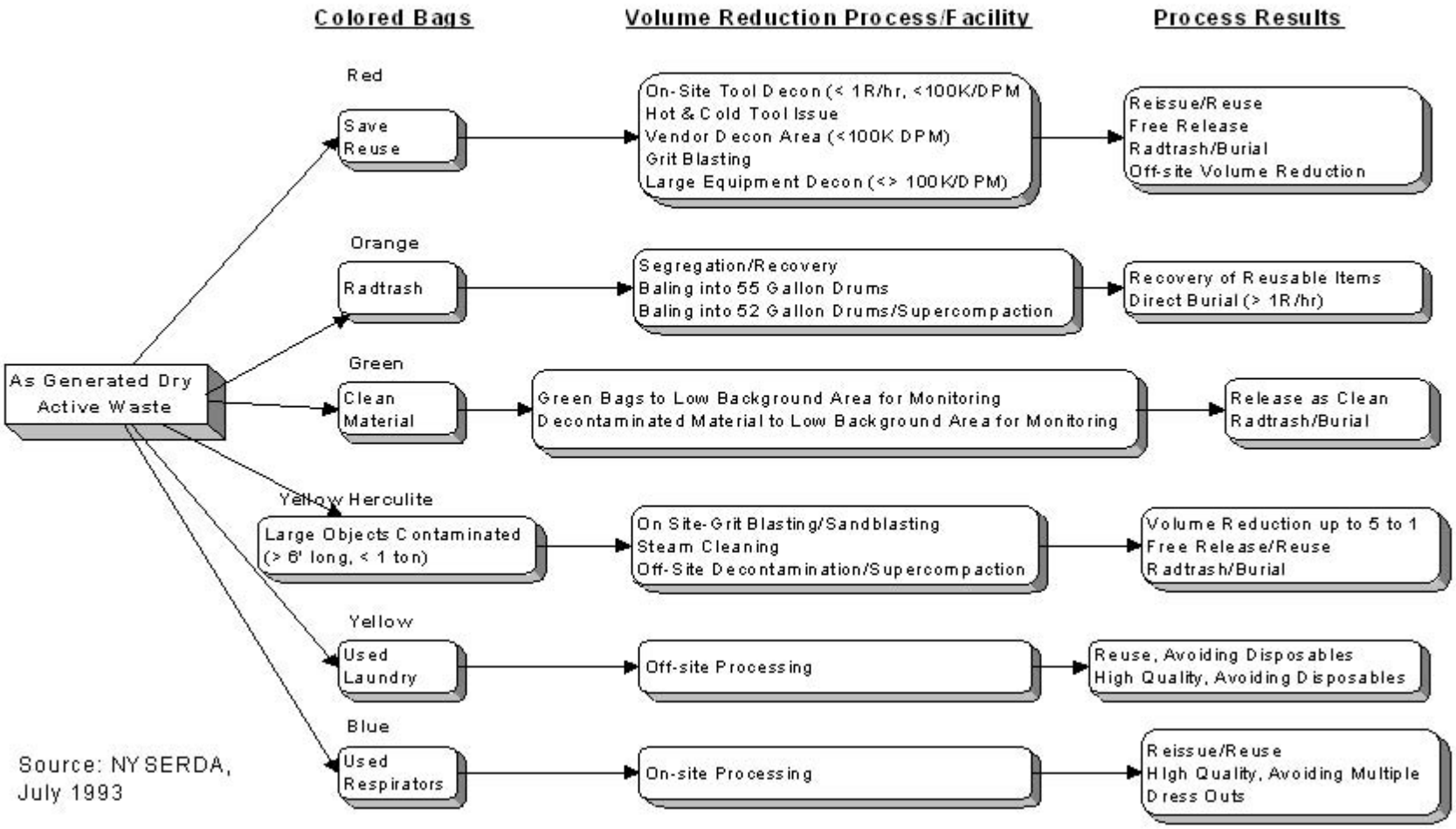
[7]The specific products reported to be used included Opti-fluor, Ultima Gold, and Cytoscint.

[8]Of the LLRW generated by EPA laboratories in 1992-1994, low-level waste stream #202, trash and/or solid waste, accounted for 39.5 percent of the total.

Figure 4: Multi-Color Bag Volume Reduction System



proper labeling by the original generator to ensure that waste streams are not pooled unnecessarily as "organic solvents" or "unknowns."

Careful attention should also be given to the separation of chemicals that are difficult to treat from other waste streams. These difficult to treat waste streams include RCRA listed hazardous waste, organometallic mercury, and arsenic compounds. These wastes generally have fewer disposal options. Residues from treating listed waste are also considered hazardous unless delisted. Separating this waste from other hazardous waste will result in lower volumes of waste that are difficult. This will then help to drive down overall treatment costs.

Separate collection of certain waste will also prevent the creation of untreatable mixtures. For example, waste containing toxic heavy metals should be separated from organic waste. Generally, the treatment requirements for these two different waste streams differ significantly.

Liquid scintillation cocktails and animal carcasses containing ^{3}H and ^{14}C, which fall below the NRC *de minimis* level of 1.85 kBq/g (10 CFR 20.2005) should be separated from other non-*de minimis* waste. There are generally more disposal options, and lower costs.

3.2.4 Process Modifications

Process modifications can occur at any point during the mixed waste generating process, as well as during the design of the equipment or facilities and in the management of the people and/or materials coming in contact with the waste. Three components of the process modification management option are reformulating or redesigning a process, altering procedures and guidance for material handling and waste segregation, and inventory control.

Examples of reformulating or redesigning a process include everything from changing the way facilities are designed in order to minimize waste during decommissioning to using small-bore tubing on high-performance liquid chromatography (HPLC) to reduce the amounts of solvents required to perform analytical procedures.

Changing LSC methods to avoid the use of vials can also significantly reduce waste volumes. An alternative to vials is a flat-bed geometry in which multiple samples are deposited within discrete areas on a well plate or filter sheet. Counting liquid scintillation cocktail samples on a 96-well plate, each well having a capacity of 0.2 ml can result in 100:1 total waste volume reductions per sample as compared to the use of 20 ml standard vials (Dagan *et al*., 1993). If filtered paper is used, then the filter paper is dried, sealed in a plastic bag with a small quantity of scintillant and mounted on a rigid metal support plate and counted. Using 12 ml of scintillant per 96 samples on filter paper, some 5,000 samples can be contained in a 10-cm cube, giving a reduction of more than 95 percent in the waste volume and a proportional reduction in the cost of scintillant and plastic consumables (Warner *et al*., 1985 and 1986). A possible disadvantage for these methods is the requirement of using flat-bed geometry liquid scintillation counters.

Other methods have been suggested to reduce waste volumes. Party and Gershey (1989) suggest counting ^{32}P without scintillation fluid by the Cerenkov method on the ^{3}H setting of a liquid scintillation counter (~40 percent efficiency). These vials should be kept separate, held for decay, crushed, and discarded. They also suggest counting ^{125}I without scintillation fluid in a gamma scintillation counter, hold for decay, and discard as nonradioactive waste.

Even more dramatic reductions in mixed waste production can be accomplished using dry counting procedures. Wunderly (1989) and Hawkins (1991) have demonstrated that improved solid scintillation counting methods now offer counting performance similar to LSC for nonvolatile substrates of less than 200µL, with only moderate solute concentrations (less than 1 M). Using the solid scintillator ReadyCap™ with XtalScint™ the liquid sample is added and then dried onto the solid scintillator. No new instrumentation is required for this system. Because of its compactness (small size) and dry form, one drum of ReadyCap™ sample is equal to 30 drums of the same number of liquid scintillator samples in vials.

Altering procedures and guidance for material handling and waste segregation for all operational practices and procedures should be examined to determine if modifications can reduce the volume of chemicals and materials ultimately ending up as mixed waste. Analysis should focus on usage, handling, and storage of materials and chemicals to optimize waste minimization. A simple technique to prevent an accidental production of a very difficult to treat mixed waste is to eliminate the use of mercury thermometers with radioactive materials. This will prevent leakage or breakage of these thermometers into radioactive materials. If a mercury thermometer is to be used with radioactive materials then the thermometers should be enclosed in protective sleeves.

Inventory control throughout the agency or company will also help reduce the amount of mixed waste production. Purchases should be specifically based on volume used rather than volume prices or a particular vendor selection. Such practices will reduce the quantity and volume of contaminated material (e.g., containers) and reduce the overall volume of chemicals to aid in inventory control and management.

3.2.5 Recycling

Recycling involves the collection and reuse of material. As a laboratory mixed waste management option, recycling opportunities are limited. Laboratory uses tend to require high purity materials to minimize experimental error. Recycling of solvents, for example, may introduce unacceptable levels of impurities. However, Miyatake and Saito (1984) have shown that spent LSC containing toluene, dioxane, and [methyl-^{3}H]thymidine can be distilled and purified by additional refining steps which provide complete removal of radionuclides. In general, markets for recycled lab materials are limited or nonexistent.

Large-scale laboratories such as Agracetus, Inc. identified unwanted and unused chemicals at each of their research facilities to find other laboratories that could use these materials. This simple efficiency initiative resulted in cost savings of several thousand dollars in purchase and

disposal costs. Likewise, a program at the University of Minnesota recycled 6570 kg of chemicals in fiscal year 1990-1991, resulting in an estimated cost savings of $155,000.

Of potential interest to EPA laboratories, the redistillation of solvents for recycling has been shown to be worthwhile. B/R Instrument Corporation experienced considerable success in the extraction of solvents including xylene, ethanol, toluene, and HPLC wastes using a spinning band distillation device. Other recycling efforts at EPA laboratories might include the following:

- Recycling laboratory glassware and supplies,
- Washing and reusing empty glass liquid scintillation vials. (McElroy *et al*., 1982);
- Decontaminating and reusing lead shielding blocks. (Lussiez, 1993); and
- Contacting the Conference of Radiation Control Program Directors, 502/227-4543 for an update on their lists of radioactive materials that are available for adoption and those sought by others.

3.2.6 Storage for Decay[9]

The relatively short half-lives of the radioactive components of some mixed waste warrant storing the waste for a period of time until the radioactive levels are undetectable.[10] If approved by NRC or an Agreement State, as well as the proposed disposal facility, the waste may then be disposed of as a hazardous waste without regard to its radiological component. This is known as storage for decay. NRC considers materials with half-lives of under 65 days to be appropriate for the storage for decay management option. NRC may also consider storage for decay for isotopes with half-lives greater than 65 days on a permit-by-permit basis.

As indicated in *Mixed Waste Management Options: 1995 Update*, estimates for storing chemicals and materials for decay vary depending on the source and initial quantity. Decay-in-storage requires segregating LLRW by the half-life of the isotopes contained and storing it until the contained activity and measurable radiation exposure rates are indistinguishable from natural background. Rockefeller University, NY, used decay-in-storage to reduce their LLRW required for storage by more than 95 percent (Party *et. al.* 1989). Party also estimates in the same article that the decay of short-lived radionuclides on-site can eliminate 74 percent of the LLRW materials now shipped for burial.

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[9]The U.S. EPA is extending its "Policy on Enforcement of RCRA Section 3004(j) Storage Prohibition at Facilities Generating Mixed Radioactive/Hazardous Wastes," until April 20, 1998. Storage of mixed waste subject to Land Disposal Restrictions is unlawful under the section 3004(j) storage prohibition. The policy states, however, that violators who (1) are faced with an impossibility of complying with the RCRA regulations and (2) are storing their waste in an environmentally responsible manner will be a low enforcement priority for EPA. The low priority applies to that waste in which no treatment or disposal option exists.

[10]Refer to 10 CFR 35.92 for more details.

Recently EPA and NRC issued joint guidance on the storage of mixed waste, *NRC/EPA Low-Level Mixed Waste Storage Guidance* (60 FR 40204 - 40211, August 7, 1995). This draft guidance states that storage for decay meets the definition of treatment as defined in 40 CFR 260.10, insofar as it is a method or technique designed to change the physical character or composition (amount of radioactivity) in mixed waste. Decay-in-storage subsequently makes the treatment of the hazardous constiutents safer, and renders them safer for transport. EPA considers decay-in-storage a necessary and useful part of the best demonstrated available technology (BDAT) treatment process. Thus, limited periods of approved decay-in-storage of mixed waste do not violate the RCRA section 3004(j) storage prohibition. As indicated in 40 CFR 268.50, a hazardous waste generator may store this waste for the sole purpose of accumulation[11] to facilitate proper recovery, treatment, or disposal. The generator may store the waste for up to 1 year unless EPA can demonstrate that storage was not completed solely for the purpose of accumulation. After 1 year, the generator must bear the burden of proving that the waste is stored solely for this purpose.

It should be noted that even under this proposed guidance, facilities are still required to obtain a RCRA hazardous waste storage permit if they store hazardous waste (including mixed waste) for longer than the allowed accumulation period (90, 180, or 270 days).

For the mixed waste generated in the 1992-1994 time period, EPA laboratories have not exercised the storage-for-decay management option. However, the storage-for-decay option was employed for 77 ft^3 of LLRW generated in the 3-year study period. Many laboratories and research facilities in the commercial sector rely on the storage-for-decay management option as the principle means of managing LLRW. It is recommended that liquid waste should be collected in polyethylene bottles (4-20 L) which, unlike those of glass, are unbreakable, produce less bremsstrahlung, are impervious to most organic chemicals, and do not form sharp edges when compacted (Party *et al*. 1989).

Two articles summarized below provide examples of existing decay-in-storage facilities.

Fax, Gene and Young, Chuck. *Site Visit to the Harvard University Storage and Incinerator Facility*, The Cadmus Group, August 8, 1995.

This document provides a summary of a site visit to the Harvard University low-level radioactive waste Decay-In-Storage (DIS) facility and incinerator. Most of the approximately 20,000 cu ft of radioactive waste generated per year is derived from the biological and medical waste programs at Harvard. The DIS facility has a storage capacity of 6,000 drums (54,000 cu ft), a freezer of 266-drum (2,000 cu ft) capacity, and a 25-drum facility for storing flammable liquid scintillation fluid. Management of radioactive waste is completed through the DIS facility. Decay-in-storage

[11]The total volume of mixed waste stored for accumulation by the EPA laboratories in 1992-1994 was 0.06 ft^3.

waste that has half lives of 180 days or less are packed, stored for 10 half-lives plus 1calendar year, and surveyed for radiation levels. Animal waste is stored for decay using the same release criteria for DIS waste and then processed at the onsite incinerator.[12] Tritium/C-14 waste has half-lives greater than 180 days and are disposed of by burial at the Barnwell site. A broker arranges for the LSC waste to be disposed of at a fuel blending facility.

Hamawy, George and Passler, Carl; "The Decay-in-Storage Room at the Einstein College of Medicine," *Radwaste Magazine*, March 1995, 2, 2, pp. 14-17.

A decay-in-storage room to handle radioactive waste at Albert Einstein College of Medicine was constructed to anticipate the closing of the waste burial site at Barnwell. The determination of maximum volume stored, area required, location of facility, room preparation, waste collection, and postoperation is discussed. It was estimated that the maximum accumulated waste volume was 1880 ft^3 and would stabilize in an elapsed period of 3 years.

3.2.7 Administrative Controls/Incentives/Accountability Standards

Administrative Controls refer to actions taken to reduce the need for extended LLRW storage. Examples include using radionuclides with short half-lives, prohibiting research that would produce problematic waste streams, and exercising the option to discharge limited amounts of nonhazardous liquid waste under permitted conditions into a sanitary sewer system[13].

Berry, Robert O.; Jablonski, Susan M.; "Low-Level Radioactive Waste Management at Texas A&M University," *Radwaste Magazine*, September 1995, 2, 5, pp. 39-41.

The Office of Radiological Safety (ORS) at Texas A & M University is responsible for the management and regulation of radioactive materials associated with the research activities at the University and established a program to control the type and amount of waste generated from research activities. The program is designed to minimize both the waste that is transported to the Barnwell facility (an expensive option) and the waste housed at the temporary storage onsite facility that is destined for disposal.

The waste management and waste minimization incentive procedures consist of four components: intensive training, source substitution, segregation, and a fee-based generation schedule. Two notable practices employed at the University include written justifications on the

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[12]Treatment of radioactive carcasses by vacuum drying has proved to be a simple and cost effective solution at S&G Enterprises, Inc. in Germantown, WI.

[13]Permitted sanitary sewer disposal was the management option chosen for 615.4 ft^3, or 19.2 percent of the LLRW generated by EPA laboratories in 1992-1994. Under 10 CFR 20.2003(a)(4), an NRC licensee may release 1curie per year of radioactive material into any one sewerage system, with the exception of ^3H which has a release limit of 5 curies per year.

part of the researcher for the use of longer-lived radionuclides (more than 300 days) and an accountability standard that entails a per pound disposal fee (depending on the nature of the radionuclides involved) charged to the sublicensee. The results of the comprehensive waste management program implemented by ORS has led to a decrease in the volume of the waste generated.

3.3 TREATMENT OPTIONS

Treatment involves the physical or chemical processes that produce a smaller waste volume or more stable waste form. In general there is treatment for mixed waste streams containing regulated metals or organic liquids while there is little or no treatment available for mixed waste streams containing organic solids. The treatment technologies appropriate for the EPA generated MW and LLRW are:

- Compaction and supercompaction reduce the volume of dry MW/LLRW by applying external pressure. These processes are measured by a volume reduction factor (VRF) which for laboratory waste can be a high as 10 to 1.

- Incineration is a thermal treatment technology that involves the combustion of material through contact with a controlled flame in enclosed chambers.

- Solidification is a process where a solidification agent (usually cement, asphalt, or polymers) is applied to immobilize liquid waste and sludge not acceptable for disposal.

- Absorption is a conditioning technique used to treat institutional liquid MW/LLRW. The liquid is stored within a porous material such as silica, vermiculite, or organic materials.

- Amalgamation with copper, zinc, or other reagents is an immobilization method applied to mercury waste before land disposal. The method of amalgamation was successfully used at INEL on radioactively contaminated elemental mercury waste which was then able to pass TCLP for mercury (Tyson 1993).

- Decontamination and free release involve the removal of radioactive material from a surface of an object by either chemical or physical means.

- Chemical oxidation processes use a chemical oxidizing agent or a combination of agents (e.e., hypochlorite, hydrogen peroxide, or ozone) to react with the contaminant. The process can be enhanced with the addition of ultraviolet light. Chemical oxidation is used in many industrial processes and in the treatment of potable water to remove a broad range of natural and synthetic organic compounds (Anderson 1994). NIH developed an ultraviolet peroxidation system

that is primarily used to treat aqueous solutions.

- Biological treatment uses established, maintained, and controlled microbial communities to breakdown toxic organic compounds to cellular mass, carbon dioxide, water, and other inert inorganic residuals. This treatment has realized moderate success for processing stored liquid scintillation waste.

In addition to the treatment options described above, there are incinerators using controlled air, excess air, fluidized bed, rotary kiln, and slagging pyrolysis technologies. Another research option, supercritical water oxidation, is a process that destroys the hazardous component of certain mixed wastes.

The study conducted by the National Low-Level Waste Management Program based on mixed waste generated at NIH identified five minimization techniques to reduce organic volumes:

Phase Separation - Where a nonpolar hydrophobic nonaqueous organic phase separates from the aqueous phase, the organic liquid phase can be separated and disposed of offsite at a facility or by a steam-reforming technology.

Chemical Oxidation - The process uses UV light and hydrogen peroxide to oxidize organic compounds to carbon dioxide and water.

Carbon Adsorption - The use of commercially available granulated activated carbon (GAC) to absorb organics contained in aqueous feed streams.

Solvent Extraction - The process uses a nonpolar organic compound with a low solubility in water which would be contacted concurrently with the waste stream in a liquid/liquid contacting vessel where the organic reagents would be transferred out of the aqueous phase and into the extraction solvent phase.

Steam Reforming - Reforming reactions occur in a near oxygen free environment under high pressure and temperature and allow an extremely high conversion of organics (wastes) to the primary conversion products of CO_2, H_2O, and H_2.

The NLLWMP recommended technique for removal of organics is physical phase separation followed by chemical oxidation.

3.3.1 Treatment Options Applicable to LSC

Although there is a limited discussion of the waste management options for HPLC and LSC, two sources devoted considerable attention to this topic. A dated but comprehensive examination of the alternative methods for the management of LSC waste was performed by Lidia Roché-Farmer in 1980. A survey of the handling and disposal problems associated with LSC waste is presented

along with a discussion of disposal methods. This article performs a critical analysis of: evaporation, distillation, solidification (microencapsulation and polymerization), conversion, and combustion (incineration and addition to fuel), as applied to LSC waste.

The NLLWMP study reviews the management options associated with both HPLC and LSC. The following sections summarize the materials that address these waste streams specifically.

3.3.1.1 Distillation. Distillation entails heating a mixture to separate the more volatile from the less volatile parts, and condensing the resultant vaport to produce a more nearly pure substance. The two primary types of distillation include simple distillation, for liquids with boiling points more than 30°F apart, and fractional distillation for mixtures with boiling points of only a few degrees apart. This process is not effective for separating ethanol and toluene. As mentioned previously, Miyatake and Saito (1984) have shown that spect LSC containing toluene, dioxane, and [methyl-^{3}H]thymidine can be distilled. Distillation followed by several simple refining treatments may be useful as a preliminary step before the disposal of the waste scintillation cocktail. However, distillation is time consuming, requires an elaborate monitoring scheme, and may be more appropriate for large laboratories.

3.3.1.2 Solidification. The purpose of solidification is to immobilize the hazardous materials to reduce vapor pressure, and thus the fire hazards. Two solidification methods that have been used for immobilizing LSC cocktails include microencapsulation, which entraps LSC waste in a polymer matrix and polymerization, which involves the chemical union of small molecules into large ones. This latter process generally entails high costs and requires specialized personnel, technology, and equipment. The application of both of these processes produces a waste form that is relatively safe to transport. Unlike the polymerization technique which involves direct chemical bonding, applying microencapsulation does not produce a thermodynamically stable state. Both techniques require further treatment and/or disposal considerations.

3.3.1.3 Conversion to a Less Hazardous Chemical Form. Conversion of organic solvents to other chemical forms facilitates disposal of this waste. Conversion of these materials may include several different processes such as oxidation and salting-out techniques. Some of the solvents; e.g., toluene and xylene, may be oxidized, under mild conditions, to give less hazardous chemical forms (Roché-Farmer, 1980). Toluene and xylene oxidize to benzoic acid and phthalic acid respectively. This method would not work for 1,2,4-trimethylbenzene as it does not oxidize under mild conditions. This process is of special significance for small research facilities like the EPA laboratories that generate liquid scintillation counting waste since it can be performed onsite.

3.3.1.4 Incineration and Fuel Blending. Incineration reduces the volume and toxicity of waste materials by destroying hazardous organic compounds to nonhazardous products such as water and carbon dioxide. Currently most of the LSC and HPLC wastes generated at EPA facilities are sent offsite to the Perma-Fix, Gainesville, FL, cement kiln facility where they are used as supplemental fuel. Advantages of the technique are: it is proven and well-understood; it results

in almost complete reduction of toxic organics if strict monitoring procedures are emphasized; it is a low-treatment technology if operated properly; and it eliminates liquids, producing a waste that is dense and easy to transport. Some of the notable drawbacks of incineration include the relatively high cost, the risks associated with transportation, and the potential for release of radioactive materials into the environment. There are also costs associated with disposal of radioactive ash generated from incineration. The HW standards for owners and operators of incinerators are contained in 40 CFR 264, Subpart O.

One final waste management option that has been utilized at different laboratories is the incorporation of LSC waste into fuel. The combustion of toluene and xylene has the capacity to produce a considerable amount of energy. This represents a simple method of disposal, although like incineration, radioactive materials are released into the environment. As discussed earlier, the University of Illinois has burned LSC cocktails as a fuel supplement at its own power plant. This approach has been approved by NRC and the Illinois Department of Nuclear Safety provided that the levels of radioisotopes at the point of the release are within specified levels as defined in 10 CFR 20, Subpart D and 10 CFR 20, Appendix B. In addition, an air quality permit issued by the Illinois Environmental Protection Agency was required. The regulatory limitations surrounding fuel mixing are included in Boiler-Industrial-Furnace rules in 40 CFR 266, Subpart H.

Although public opposition limits the widespread use of fuel blending, this option would provide a viable waste management option given that EPA laboratories possess the appropriate facilities (such as an onsite utility boiler or incinerator). Fuel blending is especially conducive to burning ^{3}H and ^{14}C. NERL-RTP currently uses its incinerator to treat LLRW onsite. Small quantity onsite burner exemptions from obtaining a RCRA Part B Permit are listed in 10 CFR 266.108 based on the allowable HW burning rate in gallons per month. In addition, a conditionally exempt small quantity generator (CESQG) may treat or dispose of hazardous waste onsite provided the generator meets certain requirements in 40 CFR Sections 261.5(f)(3) and (g)(3). At the Mayo Clinic in Rochester, Minnesota, approximately 15,000 gallons of nonhalogenated organic solvents such as xylene, alcohols, and acetone are burned annually as a source of fuel for a campus boiler. Extensive use of nonhazardous solvents limits the opportunities for fuel blending.

3.3.1.5 Bioprocessing. Bioprocessing is an alternative technology that involves the use of microorganisms which can metabolize aromatic solvents of the type used in LSC waste. The use of microorganisms serving as biocatalysts in a continuous flow system designed for the processing of stored liquid scintillation waste has demonstrated success in processing stored, "hot" LSC waste. Details of the applicability of bioprocessing to treating mixed waste was presented at the 3rd Biennial Symposium of Mixed Waste in a report entitled "'Bioprocessing' of Mixed Waste: A Success Story."

A bioprocess demonstration was conducted on commercial formulation of LSC; the initial results

of this technology indicate that hazardous organic solvents, xylene, and pseudocumene[14] have been removed due to processing. The process was applied to two barrels containing LSC waste with a tritium radioactive component and pseudocumene-based hazardous constituent. Further research will determine the applicability of the process to treat EPA generated mixed waste. Initial results have revealed that bioprocessing can satisfactorily remove certain hazardous constituents from mixed waste. The technology is considered an alternative to incineration and could be considered a more environmentally friendly means of treating this waste.

3.3.2 Treatment for HPLC Waste

There is limited documentation on the applicability of specific treatment technologies to HPLC waste. Generally, the technologies applicable to LSC are also pertinent to treat HPLC waste. However, the HPLC analyses generally require a wide variety of solvents warranting the need for management options that are able to isolate these chemicals. Solvent recovery processes such as distillation may provide as a suitable technology to segregate the target waste.

Separation of the HPLC waste constituents may be another method of reducing the amount of waste needed to be treated. HPLC waste containing acetonitrile, methanol, and water can be separated into fractions that can be disposed of. Distillation and flash evaporation (70-90 ^{o}C) yielded a nonradioactive distillate of acetonitrile, methanol, and water that can be disposed of as aqueous chemical waste. The still bottom, which represents about 40-50 percent of the original waste volume, can be discharged to the sanitary sewer as permitted under 10 CFR 20.2003 (Linins *et al*., 1991).

Using any of the previously mentioned mixed waste treatment procedures onsite for anything larger than bench-scale experiments will require a RCRA Part B permit as a treatment, storage, and disposal facility which for small generators can be difficult and expensive to meet.

[14]Pseudocumene and xylene were the hazardous constituents in 277.42 ft^3 (33 percent) of the total volume of mixed waste generated at EPA laboratories in 1992-1994.

SECTION 4: PROFILES OF MIXED WASTE TREATMENT INDUSTRIES

In situations where the generation of mixed waste is unavoidable, several options (referred to as treatment, storage, and disposal or TSD options) are available depending upon resources, treatment facility availability and capacity, and the type of material being treated. The hazardous component may be separated from the radioactive component(s) or destroyed, or the radioactive component may be decayed to undetectable levels.

There are currently four operating commercial facilities which treat mixed waste:

- Diversified Scientific Services, Inc. (DSSI)
- Envirocare of Utah, Inc. (Envirocare)
- Perma-Fix of Florida, Inc. (PFF)
- Nuclear Sources and Services Inc./Recovery Services Inc. (NSSI)

Three of these TSD facilities, DSSI, NSSI, and Perma-Fix, represented the management option for 814.1 ft^3 or 97.9 percent of the mixed waste generated by the EPA facilities in 1992-1994. Perma-Fix was the option employed for 95.7 percent of the waste generated in the3-year study period.

In addition, two facilities not currently operational are seeking to enter the mixed waste treatment industry.

- Scientific Ecology Group, Inc. (SEG)[15]
- Molten Metal Technology, Inc. (MMT)

A summary of the treatment facilities' primary waste handled, treatment and disposal process, as well as planned future treatment or disposal processes for each facility can be found in Table 1.

4.1 DSSI

Opened in 1989, DSSI primarily provides thermal treatment of mixed waste (liquids only) by combustion of organic-containing waste for energy production. The facility is recognized as a beneficial reuse facility for RCRA regulated waste because the energy generated through the thermal process is recovered. DSSI operates a 22,000-square-foot facility located in Kingston, Tennessee.

DSSI currently has seven permits and licenses associated with the management of mixed waste which allow them to process wastes with EPA waste codes of D001, D004 - D043, F001 - F005, and various U- and P-listed materials. Although thermal destruction is the primary treatment

[15]SEG is awaiting a Hazardous Waste Part B Permit for mixed waste treatment.

Table 1
Commercial Facilities Overview

Facility	Primary Waste Treated	Primary Treatment Processes (in use)	Disposal Processes	Future Processes
DSSI	Organic containing waste (Liquids only)	Combustion for energy recovery	Stabilization of solid treatment residue and burial in Envirocare Facility	None
Envirocare	Solid waste (metals contamination)	Stabilization (including chemical oxidation, chemical reduction, neutralization, and deactivation in reaction)	Landfill - Envirocare operates the only mixed waste landfill site	Macro/Micro-encapsulation
NSSI	Organic liquids	Blending to reduce radioactivity below MPC values	None (transport blended waste, as nonradioactive, to offsite facilities)	None
Perma-Fix	Scintillation cocktail waste (including vials)	Blending for offsite treatment for energy recovery	None (transport blended fuel off-site)	Stabilization
SEG	None	None	NA	Stabilization Steam Reforming
MMT	None	None	NA	Q-CEP™

Source: *Mixed Waste Treatment Study* (Draft) prepared by Duke Engineering & Services, Inc. for Electric Power Research Institute.

process, they are also permitted to process waste through decanting of liquid waste and the blending of waste. The radioactivity concentration limits can be summed as follows:

- Allows receipt of 2000 isotopes
- The facility can not possess more than 10 curies onsite for atomic numbers 1-83.
- Process or feed stream can not exceed a level of 0.05μCi/g for ^{3}H and ^{14}C
- Process or feed stream can not exceed 0.002μCi/g for all other isotopes (combined)

Waste with activity levels higher than those described above can be accepted but must be blended with lower activity waste prior to processing in order to meet the feed limits. The cost to generators for disposal of low-level mixed waste varies depending on waste characteristics. The costs to treat low-level mixed waste can be as low as $30 per gallon.

4.2 ENVIROCARE

Envirocare, located 75 miles west of Salt Lake City, Utah, was licensed to treat and dispose of mixed waste in 1993. The treatment technologies used at their facility include chemical stabilization, chemical oxidation, chemical reduction, chemical deactivation, and neutralization. The facility has the capacity to treat 150 tons of mixed waste per day. Envirocare has also applied for a Part B permit for macroencapsulation of contaminated lead shielding. Mixed waste that is eligible for treatment at Envirocare include EPA waste codes D001-D043, F001-F012, F019, F024, F028, K011, K013, K050-K052, K061, K069, as well as many P- and U- listed waste. Envirocare does not publicize any costs relating to waste disposal.

4.3 PERMA-FIX OF FLORIDA (PFF)

Located in Gainesville, Florida, PFF operates two waste management processes, one of which is for the treatment of mixed waste. This facility provides handling and disposal of liquid scintillation vials regulated as mixed waste. The vials are processed for ultimate use as a supplemental fuel in a cement kiln operated by a local corporation. The other facility provides handling, storage, and disposal of hazardous and nonhazardous wastes.

PFF's current license permits a total of 30 nuclides for liquid scintillation materials and the materials received, processed, and transported to the kiln may not exceed 0.05 microcuries per gram of medium. The facility is also trying to receive approval to process additional liquid scintillation nuclides and other nonliquid scintillation fluids contaminated with radionuclides. In addition, PFF plans to apply for approval for alternative treatment capabilities such as stabilization. Depending on waste stream specifics, quantity, and generator location, the cost of disposing a 7.5 cubic-foot drum of liquid scintillation vials could be $180.

4.4 NSSI

NSSI is located in southeastern Texas and operates a facility which processes radioactive, hazardous, and mixed wastes, although their primary market is hazardous waste. The mixed waste that is treated is processed to remove hazardous characteristics and/or to reduce the levels of radioactivity to below regulatory concentrations. Examples of technologies employed by NSSI in the treatment process include blending of waste for use as fuel, oxidation, neutralization, reduction, filtration, solidification or stabilization of waste in containers, etc. NSSI's classification as a (Texas) Class B facility limits it to a 100-Ci site possession limit. The facility can process a total of 58,530 gallons of waste at any one time. There is also a total of 179,093 gallons of container storage available. An estimate of treatment costs ranges from $100-$150 per gallon of waste.

4.5 SEG

As described above, this facility, located in Oak Ridge, Tennessee, is currently only permitted to

process radioactive waste and not mixed waste. The facility has a Part B permit which is pending which would allow it to process low-level radioactive waste. SEG has applied for permits to treat mixed waste through both incineration and a steam reforming process. The steam reforming process is not expected to treat waste having ^{14}C or ^{3}H concentrations greater than 2 millicuries per drum. The projected cost for treatment of a typical dry active waste is currently $300 per cubic foot.

4.6 MMT

Molten Metal Technology, Inc. is currently in the process of commercially deploying Quantum-Catalytic Extraction Process™ (Q-CEP™), a patented technology that can process radioactive and mixed waste streams to decontaminate and recover resources of commercial value while reducing volume and stabilizing radionuclides. Fundamental to the Q-CEP™ process is a liquid metal bath which facilitates the dissociation of waste into their constituent elements. The addition of co-reactants leads to targeted radionuclide partitioning and recycling of waste components to commercial products. Q-CEP™ has experienced success in its application to RCRA waste, spent ion exchange resins, and contaminated scrap metal. Major DOE low-level mixed waste streams in which Q-CEP™ was applied include soils, inorganic sludges, organic sludges, combustible debris, and inorganic debris. In cooperation with Lockheed Martin Corp, a facility designed for processing DOE mixed waste is currently under construction. Cost estimates of this technique are not published.

4.7 COMPARISON OF TREATMENT AVAILABLE VERSUS DEMAND AVAILABLE

The volumes of mixed waste generated at EPA research facilities will not pose any discernible constraints on the capacities of these five TSD facilities. As indicated above, EPA faciities generated 831.16 ft^3 of mixed waste in 1992-1994. This is compared to the over 1.28 million ft^3 of annual capacity for the incineration of LSC wastes at the TSD facilities highlighted above.

SECTION 5: CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

This report has provided a review of the state-of-the-art waste management technologies as they relate to mixed waste from laboratories and research facilities. This study is to serve as a guide to EPA research facility directors and staff in pursuing waste minimization and pollution prevention efforts. Due to considerable attention in the literature, an integrated waste management framework is outlined and discussed. The application of integrated approaches to mixed waste management has experienced encouraging success.

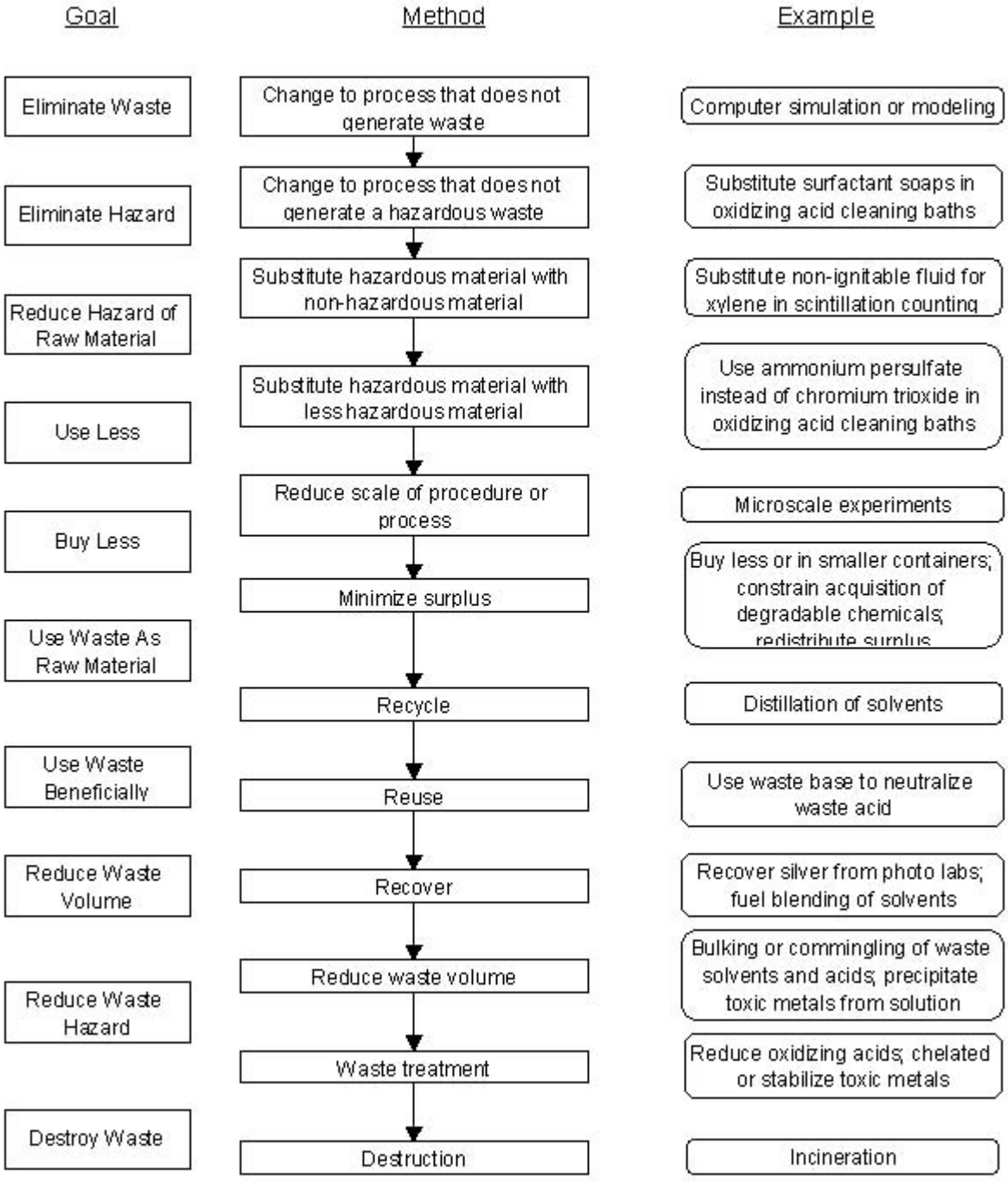
Based on survey data, it was discovered that the processes and mixed waste streams generated at EPA laboratories were quite similar to those generated at commercial and NIH laboratories. However, the volumes and curie content of the MW produced from 1992-1994 at the EPA research facilities was substantially less than these other facilities.

Several of the materials reviewed for this effort presented recommendations and suggestions for future research that are directly applicable to EPA laboratories. A list of these items is provided below.

- Systematically evaluate all mixed waste generating processes and identify the potential for waste minimization and pollution prevention[16];
- Formally define pollution prevention goals and evaluate how the goals are to be met;
- Understand the importance of the waste minimization hierarchy as exemplified in Figure 5. The hierarchy ranks waste minimization practices in order of preference, based on their overall efficiency, effectiveness, and environmental impact. It is important to focus on those methods at the top of the hierarchy;
- Explore the opportunities for the applicability of a flexible regulatory framework; i.e. filing petitions to demonstrate equivalent treatment or proposing a license-specific *de minimis* level for certain radionuclides;
- Establish a formal communication conduit with EPA, commercial, federal, and academic laboratories to distribute research, suggestions, or innovative approaches to mixed waste management. The development of programs

[16]The pollution prevention documents filed by each EPA laboratory may serve as a starting point.

Figure 5: A Hierarchy of Waste Minimization
(ranked by increasing environmental, occupational, and accidental risk)



Source: Reinhardt, 1995

analogous to EPA's Waste Reduction Evaluations at Federal Sites (WREAFS) may serve as a model;

- Build on existing attempts to improve pollution prevention that embody the integrated approach to waste management;

- Develop a standardized methodology to evaluate specific waste management options based on cost, efficiency, and environmental considerations. This implies the development of a "cradle-to-the-grave" life cycle cost approach; and

- Identify barriers to the integrated waste management approach and involve lab personnel in planning and evaluation.

SECTION 6: SOURCES CONSULTED

The 1993 Massachusetts Low-Level Radioactive Waste Survey Report, The Massachusetts Low-Level Radioactive Waste Management Board, [data collection and analysis conducted by Richard B. Fairfull] November 1994.

Albrect, L.B., Childress, T.A. *Infectious and Hazardous Waste Protocol for Medical Facilities*,March 1991, 129 pp., Report no. AL-TR-91-0047.

American Chemical Society Task Force on Laboratory Waste Management, *Less is Better: Laboratory Chemical Management for Waste Reduction*, 2nd edition, 1993.

Anderson, William C. (Edited) "Innovative site remediation technology: Chemical Treatment Vol. 2", September 1994, EPA 542-B-94-004.

Berenyi, Eileen Brettler. "MRFs are Bustin' Out All Over," *Resource Recycling: North America's Recycling*, April 1, 1995, 14, 4, pp. 28.

Berry, Robert O.; Jablonski, Susan M.; "Low-Level Radioactive Waste Management at Texas A&M University," *Radwaste Magazine*, September 1995, 2, 5, pp. 39-41.

Community Partnering Plan Summary, Bureau of Radiation Protection, Pennsylvania Department of Environmental Protection.

Dagan, E.B.; Selby K.B. Mixed Waste and Waste Minimization; The Effect of Regulations and Waste Minimization in the Laboratory, *Proceedings of the 2nd Biennial Symposium of Mixed Waste*, Baltimore, MD, August 1993.

Elliott, John C. "Liquid Scintillation Sample Analysis in Microcentrifuge Tubes," *Health Physics*, January 1993, Volume 64, Number 1, pp.86-90.

Fax, Gene; Young, Chuck. *Site Visit to the Harvard University Storage and Incinerator Facility*, The Cadmus Group, August 8, 1995.

Gibbons, J.H. *Partnerships Under Pressure. Managing Commercial Low-Level Radioactive Waste*, November 1989, 159 pp., Report no. OTA-O-426.

Gershey, Edward L.; Klein, Robert C.; Party, Esmeralda Perry; Wilkerson, Amy. *Low-Level Radioactive Waste: From Cradle to Grave*, New York: Van Nostrand Reinhold, 1990.

Gillins, R.L.; DeWitt, L.M.; Wollerman, A.L. *Mixed Waste Integrated Program Interim Evaluation Report on Thermal Treatment Technologies*, February 1993, Report No. DOE/MWIP-2.

Hamawy, George; Passler, Carl; "The Decay-in-Storage Room at the Einstein College of Medicine," *Radwaste Magazine*, March 1995, 2, 2, pp. 14-17.

Hawkins, Edward F. "Solid Scintillators for Receptor Assays: An Environmentally Safe Alternative to Liquid Scintillation Cocktails," *J. Receptor Research*, 11 (1-4): pp. 91-99.

Health Physics Positions Data Base (Rev 1), "Disposal of Solid Scintillation Media," February 1994, Report No. NUREG/CR-5569, pp.140.

Incineration of Low-Level Radioactive and Mixed Wastes: Applicable Regulations and Policies, July 1993, prepared for EPA - ORIA.

Incineration of Low-Level Radioactive and Mixed Wastes: Waste Handling and Operational Issues, April 1993, 142 pp., Report No. EPA/402/R-93/012.

Issue Paper From the NGA FFCA Commercial Mixed Waste Subgroup, The National Governors Association, 1995.

Kirner, N.P.; Faison, G.P.; Johnson, D.R. *National Institutes of Health: Mixed Waste Stream Analysis*, August 1994, Report No. DOE/LLW-208.

Kirner, Nancy; Kelly, James; Faison, George, Johnson, Dave. *Mixed Waste Management Options: 1995 Update*, Idaho National Engineering Laboratory, prepared for the U.S. Department of Energy, May 1995, Report No. DOE/LLW-219.

Klein, J.A.; Mrochek, J.E.; Jolley, R.L.; Osborne-Lee, I.W.; Francis, A.A.; Wright, T. *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, December 1992, Report no. NUREG/CR-5938.

Klein, Robert C. and Gershey, Edward L. "'Biodegradable' Liquid Scintillation Counting Cocktails," *Health Physics*, October 1992, 59, 4, pp.461-470.

Krolewski, J.F.; Augsburger, S.T. *Consolidated Incineration Facility Model Videotape*, 1988, 12 pp., Report no. DP-MS-88-68.

Lewandowski, Joseph J.; Moghissi, A. Alan. "Management of Mixed Waste at a Teaching, Research, and Health Care Facility," *Proceedings of the 3rd Biennial Symposium of Mixed Waste*, Baltimore, MD, August 1995.

Linins, Ilona; Klein, Robert C.; Gershey, Edward L.; "Management of Mixed Wastes from Biomedical Research," *Health Physics*, September 1991, 61, 3, pp. 421-426.

Lorenz, Steven M. "Decreasing Dry Active Waste Generation by 50% in One Year," *Radwaste*

Magazine, Sept. 1995, 2, 5, pp. 47-49.

Lorenzen, William A. *Operational Aspects of Harvard University's Waste Management Program*, pp. 415-420, August 1995 [Attachment to Fax and Young, August, 1995].

Low-Level Radioactive Waste Management in North Carolina, Briefing prepared by the North Carolina Department of Environment, Health and Natural Resources, Division of Radiation Protection, 1994.

Low-level Radioactive Waste Storage Study: Interim Report, prepared by the New York State Energy Research and Development Authority, July 1993.

Low-level Radioactive Waste Storage Study: Volume I: Storage Capacity at Generator Sites, prepared by the New York State Energy Research and Development Authority, September 1993.

Lussiez, G.W. "Decontaminating Lead Bricks and Shielding," *Proceedings of the 2nd Biennial Symposium of Mixed Waste*, Baltimore, MD, August 1993.

Malchman, Warren. "Case Western Reserve University's New 'State-of-the-Art' Low-Level Waste Facility," *Radwaste*, September 1995, pp. 42-46.

Methé, Brian M. "Managing Radioactively Contaminated Infectious Waste at a Large Biomedical Facility," *Health Physics*, February 1993, Volume 64, Number 2, pp.187-191.

McCamey, R.B. "Building a Mixed-Waste Prevention Program at Comanche Peak", *Radwaste Magazine*, May 1995, 2, 3, pp.21-28.

McElroy, N.L.; Sauerbrunn, B.J.L.; Eckelman, W.C. "The Feasibility of Recycling Glass Liquid Scintillation Vials," *Health Physics*, February 1982, Volume 42, Number 2, pp. 236-238.

"Mixed Lab Waste: Is it All Radioactive?" *Research & Development*, August 1, 1994, 36, 9, pp. 27-32.

The Mixed Waste Inventory Report, Idaho National Engineering Laboratory, Prepared for the U.S. Department of Energy, November 1995.

Mixed Waste Treatment Study (Draft), Prepared for the Electric Power Research Institute, Research Project 3800-22, December 1995.

Miyatake, H; Saito, K. "Distillation of Used Liquid Scintillation Cocktail and the Possibility of Re-utilization of the Recovered Solvent," March 1984, *Radioisotopes*, 33(3): pp.146-149.

Monthly RCRA/Superfund IEPCRA Hotline Report, February 1996.

Monthly RCRA/Superfund IEPCRA Hotline Report, April 1996.

National Institutes of Health: Mixed Waste Minimization and Treatment, Prepared for Lockheed Idaho Technologies Company and U.S. DOE, August 1995, Report # DOE/LLW-218.

Oden, L.L.; O'Connor, W.K.; Turner, P.C.; Hartman, A.D. *Evaluation of the Three-Phase, Electric Arc Melting Furnace for Treatment of Simulated, Thermally Oxidized Radioactive and Mixed Wastes*, 1995, 26 pp., Report No. BUMINES-RI-9528.

Party, E.; Gershey, E.L. "Recommendations for Radioactive Waste Reduction in Biomedical/Academic Institutions," *Health Physics*, April 1989, Volume 56, Number 4, pp. 571-572.

*Prudent Practices in the Laboratory: Handling and Disposal of Chemical*s, The National Research Council, National Academy Press, Washington, DC, 1995.

Radioactive and Mixed Waste Incineration. Background Information Document Volume 1: Technology, May 1991, prepared for U.S. EPA, Office of Radiation Programs.

Ed. by Reinhardt, Peter A; Leonard, K. Leigh; Ashbrook, Peter C.; *Pollution Prevention and Waste Minimization in Laboratories*, Boca Raton, FL: CRC Press, 1996.

Ring, Joseph; Lorenzen, William; Osborne, Frank; Shapiro, Jacob; *Bio-medical Radioactive Waste Management*, July 19, 1995 [Attachment to Fax and Young, August, 1995].

Roché-Farmer, Lidia. *Study of Alternative Methods for the Management of Liquid Scintillation Counting Wastes*, Division of Fuel Cycle and Material Safety, NRC, February 1980, Report No. NUREG-0656

Rupp. G.L. *Characterizing Containerized Mixed Low-Level Waste for Treatment: A Workshop Proceeding*, May 1993, 312 pp., Report no. EPA/600/R-94/149.

Schwinkendorf, William E.; Brown, Clifton H. "Mixed Waste Separation Technologies," *Separation Science and Technology*, 1995, 30, 7-9, pp. 1725-40.

Science Applications International Corporation. *Pollution Prevention Opportunity Assessment for Two Laboratories at Sandia National Laboratories*, U.S. EPA Risk Reduction Engineering Laboratory, March 1993, Report # EPA/600/SR-93/015.

Todisco, L.R.; Smith L.R. "A Manufacturer's Perspective on Low-Level Mixed Waste Treatment, Storage, and Disposal," E.I. Dupont and Co., Inc., NEN Products,

Proceedings of the 3rd Biennial Symposium of Mixed Waste, Baltimore, MD, August 1995, 10 pp.

Tyson, D. R. "Treatability Study for the Amalgamation of a Radioactively Contaminated Elemental Mercury Waste at the Idaho National Engineering Laboratory," *Proceedings of the 2nd Biennial Symposium of Mixed Waste*, Baltimore, MD, August 1993.

Vavruska, J.S.; Borduin, L.C.; Hutchins, D.A.; Koenig, R.A.; Warner, C.L. *Los Alamos Controlled Air Incinerator for Hazardous Chemical and Mixed Radioactive Wastes*, 1986, 11 pp., Report no. LA-UR-86-614.

Wahl, George; Stamm, Deana; Driver, Jeffrey; Cravens, Joe Bob. *Pollution Prevention Opportunity Assessment: Histology Laboratory Xylene Use Fort Carson, Colorado*, U.S. EPA Risk Reduction Engineering Laboratory, October 1992, Report # EPA/600/SR-92/187.

Warner, G.T.; Potter, C.G.; Yrjonen, T.; Soini, E. "A New Design for a Liquid Scintillation Counter for Micro-Samples using a Flat-Bed Geometry," *International J. Applied Radiation Isotopes*, 1985, 36(10) pp.819-821.

Warner, G.T.; Potter, C.G. "New Liquid Scintillation Counter Eases Vial Disposal Problems," *Health Physics*, 1986, 51(3): pp. 385.

Wolfram, J.H. and Rogers, R.D. [Idaho National Engineering Laboratory] and Finney, R.; Attala A.; Silver, G.L.; and Hertwick, F. Jr. [Mound Applied Technologies] "Bioprocessing of Mixed Waste: A Success Story," *Proceedings of the 3rd Biennial Symposium of Mixed Waste*, Baltimore, MD, August 1995.

Wunderly, Stephen W. "Solid Scintillation Counting: A New Technique for Measuring Radiolabeled Compounds," Appl. Radiat. Isot., 1989, 40(7), pp. 569-573.

APPENDIX A: RESULTS OF EPA LABORATORY SURVEY: DATA SUMMARY REPORT

A.1 INTRODUCTION AND OVERVIEW

The high costs of mixed waste management and the limited treatment, storage, and disposal capacity for mixed waste prompted EPA laboratory staff to approach EPA headquarters staff to investigate mixed waste generated from laboratory procedures. Mixed waste is composed of radioactive waste defined under the Atomic Energy Act (AEA) and hazardous waste defined under the Resource Conservation and Recovery Act (RCRA). Currently there are only four mixed waste treatment, storage, or disposal facilities (TSDFs) in the United States accepting commercially generated mixed waste and no treatment or disposal options exist for certain classes of mixed waste. Indefinite storage is the only option for mixed waste with no treatment or disposal capacity.

The U.S. Environmental Protection Agency's (EPA) Office of Radiation and Indoor Air (ORIA), Office of Solid Waste (OSW), and Office of Administration/Safety, Health, and Environmental Management Division (SHEMD) responded to this request and created a cross-office team to investigate the issue of mixed waste generated from EPA laboratories. The first step in this investigation was to quantify and characterize the low-level radioactive waste and mixed waste generated by EPA laboratories. This report details the results of a survey of 11 EPA facilities that were presumed to generate low-level radioactive waste or mixed waste. Comparisons of findings will be made with other surveys, notably the *National Profile on Commercially Generated Low-Level Radioactive Mixed* and the *NIH: Mixed Waste Stream Analysis.*

Ten laboratories submitted completed surveys. The remaining laboratory, EPA Region 9 Laboratory, does not generate either mixed waste or low-level radioactive waste. A preliminary investigation of the survey results indicates that the waste produced is generated from relatively few processes. Thus, waste minimization efforts can be centrally focused on the use, distribution, and management of these processes.

This data summary report is organized into six sections. Following this introduction, profiles of the nine EPA laboratories are presented in Section 2. Sections 3 and 4 provide an overview of low-level radioactive waste and mixed waste, respectively. Section 5 examines the results of this effort within the context of other survey efforts that parallel this study. The final section, Section 6, provides a conclusion to this report.

A.2 PROFILES OF NINE EPA LABORATORIES GENERATING MW OR LLRW

Generation of mixed waste accounted for 20.6 percent of the total mixed and low-level radioactive wastes generated in the 3-year time period studied (Figure A-1). Of the EPA laboratories queried, the leading generator of low-level radioactive and mixed wastes in 1992-1994 was the North Carolina Research Triangle Park (RTP) laboratory complex. This complex is composed of components of three labs - NHEERL, NERL, and NRMRL. The mixed waste generated at the EPA RTP laboratory complex is almost exclusively produced by NHEERL researchers.[17] Combined these RTP laboratories generate 82.9 percent of the total low-level radioactive waste (Figure A-2) and 65.9 percent of the total mixed waste (Figure A-3) in these 3 years. The second leading generator for both categories of waste was the National Risk Management Research Laboratory in Cincinnati with 4.4 percent of the LLRW and 29.3 percent of the mixed waste. Attachment A-1 lists the applicable hazardous and radioactive waste permits for the nine EPA laboratories that provided survey responses. Table A-1 provides a summary of the volumes of the mixed and low-level wastes generated by each laboratory.

Table A-1: Summary of the MW and LLRW Volumes for EPA Laboratories: 1992-1994

	Volume (ft^3) by Year							
	1992		1993		1994		3-Year Totals	
Laboratory	MW	LLRW	MW	LLRW	MW	LLRW	MW	LLRW
CRL	0	4	0	4	0	47.3	0	55.3
GED-Gulf	0	34	0	34	0	34	0	102
NAREL	0	7.5	0	7.5	0	7.5	0	22.5
NERL-LV	0	23.5	0	22	4	31	4	76.5
NERL-RTP	210.5	1038	127.5	632.5	210	987.9	548	2658.4
NHEERL-AED	0	9	0	6	2	3.5	2	18.5
NHEERL-MED	0.02	0.25	0.02	0.25	0.02	0.27	0.06	0.77
NHEERL-WED	1.4	50.3	1.7	5.1	2.64	12.72	5.74	68.12
NRMRL-Breidenbach	86.5	23.84	42.55	39.84	114.81	76.5	243.86	140.18
NRMRL-Kerr	4	26.5	16	29.5	7.5	8.1	27.5	64.1
Totals	302.42	1216.89	187.77	780.69	340.97	1208.79	831.16	3206.37

[17] Personal correspondence from Todd Baker (RTP) to Jeff Davidson (OA/SHEMD), July 23, 1996.

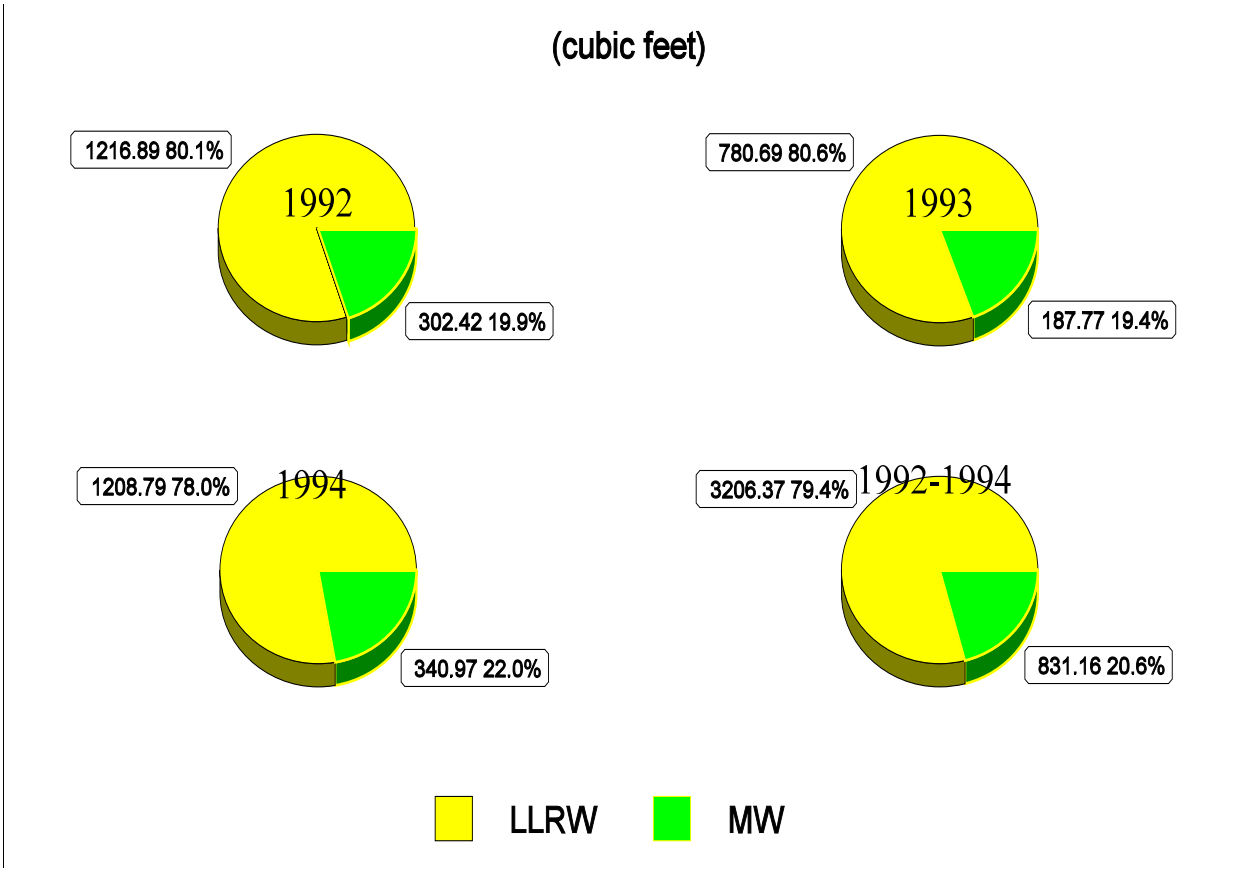


Figure A-1. EPA LLRW/MW Production

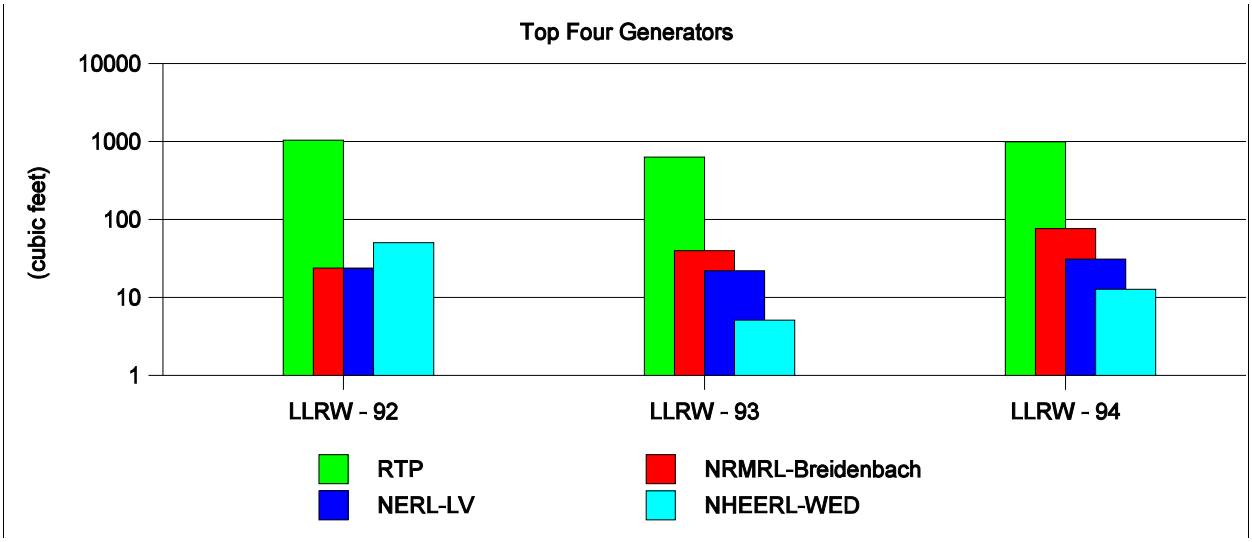


Figure A-2. LLRW Production

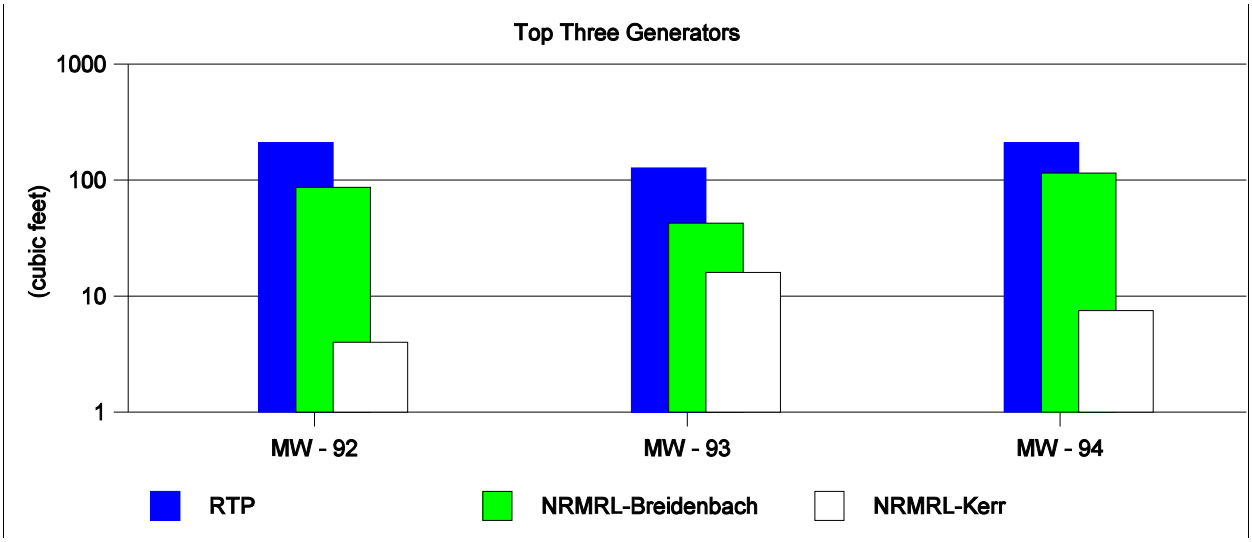


Figure A-3. MW Production

The trend in low-level waste to mixed waste production can be seen in Figure A-1 to be fairly uniform at 4:1. This 4:1 ratio from the 3-year survey should be representative of current and future EPA laboratory LLRW/MW production ratios if no further future action is taken.

As shown in Figures A-2 and A-3, there are few observable trends from a 3-year analysis of each EPA facilities' LLRW and MW production rates. The largest LLRW and MW producer, NERL-RTP facility with 82.9 percent of the total LLRW production and 65.9 percent of the total MW production, has no observable trend in LLRW and MW production. Both NERL-RTP LLRW and MW production rates seem relatively constant. There is, however, a threefold increase in LLRW production rates from the NRMRL-Breidenbach facility from 23.84 ft^3 (1992) to 76.5 ft^3 (1994). The other noticeable trend is the fourfold decrease in MW production from the NHEERL-WED facility from 50.3 ft^3 (1992) to 12.72 ft^3 (1994).

A.3 OVERVIEW OF LOW-LEVEL RADIOACTIVE WASTE GENERATED AT EPA LABORATORIES

As indicated in Table A-1, 3206.37 ft^3 of low-level radioactive waste were generated over the 3 study years by EPA facilities. It is worth noting that in 1993 total LLRW produced by all EPA facilities dropped 64 percent from 1992 production rates; but production rates climbed back to 1992 levels in 1994. Figure A-4 shows the major LLW stream numbers (LLW#) that contribute to the total LLRW production for all EPA facilities over the 3 years studied. Attachment A-2 describes each LLW stream number and waste management option used in this survey. The top four LLW# categories which contribute the largest percentages by volume are: 1) trash and/or solid waste (LLW #202): 1266.5 ft^3 or 39.5 percent; 2) liquid scintillation fluids or vials (LLW #215): 730.54 ft^3 or 22.8 percent; 3) Other (LLW #226): 539.2 ft^3 or 16.8 percent; and absorbed aqueous liquids (LLW #212): 309.5 ft^3 or 9.7 percent. Tables 2 and 3 display the volumes generated by each laboratory grouped by LLW number and the volume associated with each waste management option, respectively.

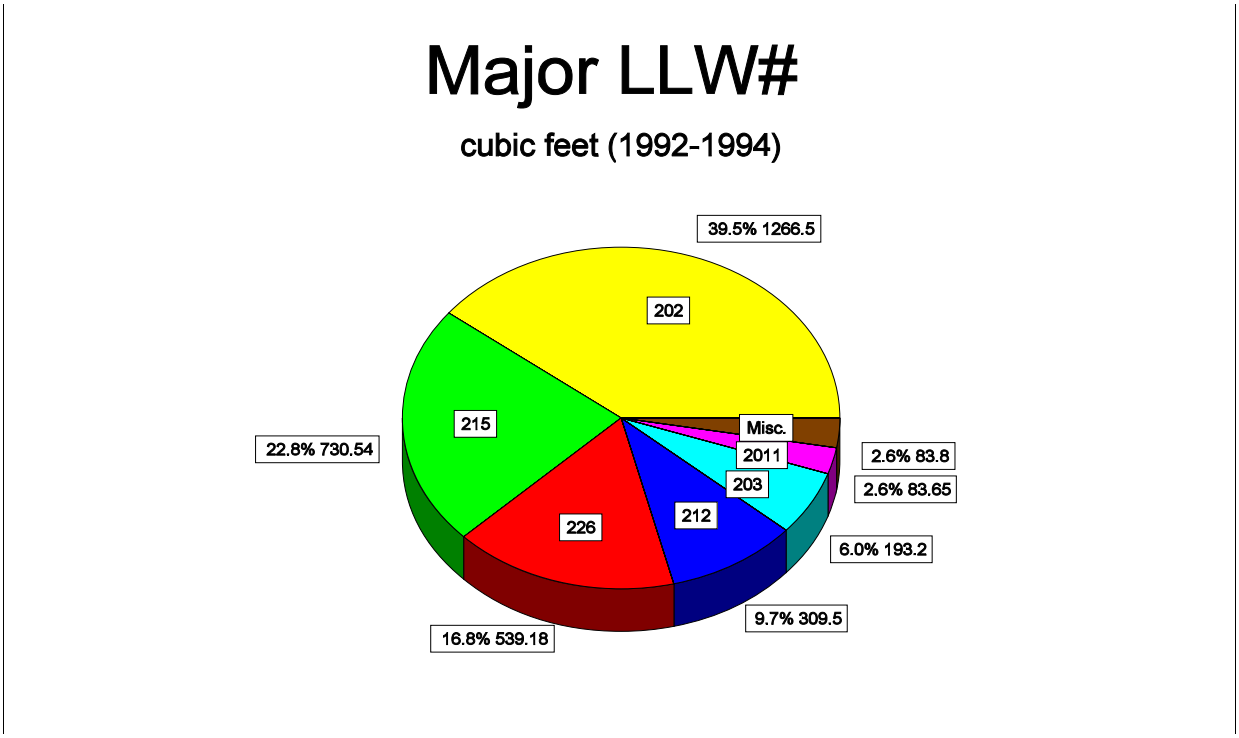


Figure A-4. Major LLW# Volumes

Twelve waste management options were reported by these laboratories. A brief discussion of each of these designations is presented in Attachment A-2. As shown in Figure A-5 and Table A-3, permanent offsite disposal/treatment facilities (Barnwell, Hanford, Perma-Fix, and SEG)

Table A-2:Volumes of LLRW for Each EPA Laboratory Grouped by LLW#: 1992-1994															
		LLRW Stream #													
Laboratory	Year	201	2011	2011/2012	2013	202	203	207	212	215	216	216/219	219	226	Totals
CRL	92	0	0	0	0	0	0	0	0	4	0	0	0	0	4
	93	0	0	0	0	0	0	0	0	4	0	0	0	0	4
	94	0	0	0	0	0	23.2	0	0	19.7	0	0	4.4	0	47.3
GED-Gulf	92	0	0	0	0	30	0	0	4	0	0	0	0	0	34
	93	0	0	0	0	30	0	0	4	0	0	0	0	0	34
	94	0	0	0	0	30	0	0	4	0	0	0	0	0	34
NAREL	92	0	0	0	0	7.5	0	0	0	0	0	0	0	0	7.5
	93	0	0	0	0	7.5	0	0	0	0	0	0	0	0	7.5
	94	0	0	0	0	7.5	0	0	0	0	0	0	0	0	7.5
NERL-LV	92	0	0	0	0	22.5	0	0	0	1	0	0	0	0	23.5
	93	0	0	0	0	21	0	0	0	1	0	0	0	0	22
	94	0	0	0	0	30	0	0	0	1	0	0	0	0	31
RTP	92	0	0	29.5	0	343	87.5	0	200	183	6	0	0	189	1038
	93	0	33	0	13	274	0	0	8.5	138	0	0	0	166	632.5
	94	0	14.9	0	0	341	60	0	86.5	321.5	4	0	0	160	987.9
NHEERL-AED	92	0	0	0	0	0	7	0	1	0	0	0	0	1	9
	93	0	0	0	0	0	5	0	1	0	0	0	0	0	6
	94	0	0	0	0	0	3	0	0.5	0	0	0	0	0	3.5
NHEERL-MED	92	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0.25
	93	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0.25
	94	0	0.25	0	0	0	0	0	0	0	0	0	.02	0	0.27
NHEERL-WED	92	2	0	0	0	12	0	14	0	2.7	0	0	0	19.6	50.3
	93	0	0	0	0	2	0	0	0	0.8	0	0	0	2.3	5.1
	94	0	0	0	0	8.5	0	0.7	0	2.24	0	0	0	1.28	12.72
NRMRL-Breidenbach	92	0	0	0	0	22.5	0	0	0	0	0	1.34	0	0	23.84
	93	0	15	0	0	23	0	0	0	0	0.5	0	1.34	0	39.84
	94	0	20	0	0	54.5	0	0	0	0	1.5	0	0.5	0	76.5
NRMRL-Kerr	92	0	0	0	0	0	0	0	0	25.5	1	0	0	0	26.5
	93	0	0	0	0	0	7.5	0	0	20	2	0	0	0	29.5
	94	0	0	0	0	0	0	0	0	6.1	2	0	0	0	8.1
Totals	92	2	0.25	29.5	0	437.5	94.5	14	205	216.2	7	1.34	0	209.6	1216.89
	93	0	48.25	0	13	357.5	12.5	0	13.5	163.8	2.5	0	1.34	168.3	780.69
	94	0	35.15	0	0	471.5	86.2	0.7	91	350.54	7.5	0	4.92	161.28	1208.79
Totals (1992-1994)		2	83.65	29.5	13	1266.5	193.2	14.7	309.5	730.54	17	1.34	6.26	539.2	3206.37

Table A-3: LLW Management Option Volume Grouped by EPA Laboratory: 1992-1994													
	Waste Management Option*												
Laboratory	Air Release	Barnwell	Decay	Hanford	In-storage	Manu.	Und.	Perma-Fix	SEG/ Barnwell	Self	Sewer	Wash.	Totals
CRL	0	27.6	0	0	0	0	0	0	0	0	27.7	0	55.3
GED-Gulf	0	0	45	0	51	0	0	0	0	0	6	0	102
NAREL	0	22.5	0	0	0	0	0	0	0	0	0	0	22.5
NERL-LV	0	0	0	43.5	30	0	0	0	0	0	3	0	76.5
RTP	0	147.5	3	0	4	0	0	7.5	0	1981.4	515	0	2658.4
NHEERL-AED	0	0	0	0	0	0	18.5	0	0	0	0	0	18.5
NHEERL-MED	0	0	0	0	0.75	0.02	0	0	0	0	0	0	0.77
NHEERL-WED	14.7	0	17	24.5	0	0	0	4.84	0	0	7.08	0	68.12
NRMRL-Breidenbach	0	96.84	4.5	0	0	0	0	0	15	0	0	23.84	140.18
NRMRL-Kerr	0	0	7.5	0	0	0	0	0	0	0	56.6	0	64.1
Totals	14.7	294.44	77	68	85.75	0.02	18.5	12.34	15	1981.4	615.38	23.84	3206.37

* See Attachment A-2 for further explanation.

represented the waste management option for 389.78 ft^3 (12.2 percent) of the total LLRW.[18] An onsite incinerator and disposal facility at the National Exposure Research Laboratory in Research Triangle Park (designated "self") was the disposal option for 1981.4 ft^3 (61.8 percent). Permitted sanitary sewer disposal was used for 615.4 ft^3 (19.2 percent) at four of the EPA queried laboratories.

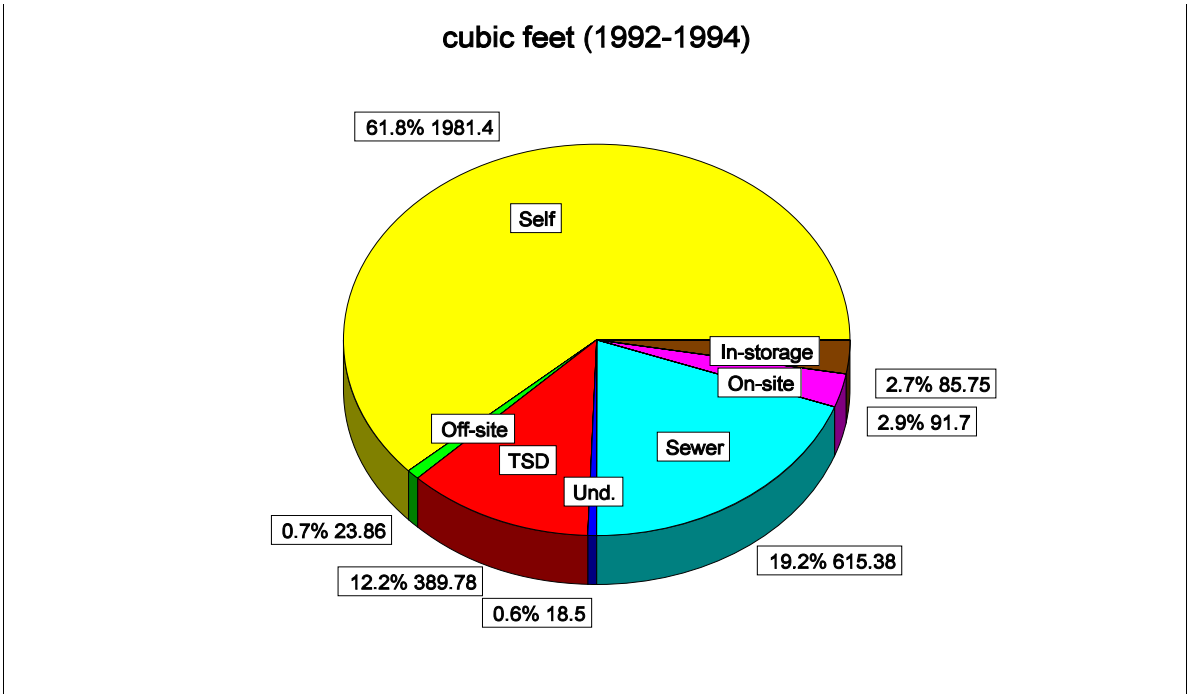


Figure A-5. LLW Management Option Volumes

Table A-4 summarizes the volume and activity of LLRW generated by radioactive waste grouping as reported by the laboratory staff.[19] It should be noted that while a wide variety of radionuclides are used in EPA facilities, the four most common radionuclides, ^{14}C, ^{3}H, ^{32}P, and ^{35}S, make up at least 2,615.71 ft^3 or 81.6 percent of the total LLRW volume (3,206.37 ft^3) and at least 1,479.0 mCi or 88.9 percent of the total LLRW activity (1,664.1 mCi).

[18]For the purposes of Figure A-5, the "offsite" option includes both Wash. and Manu. whereas the "onsite" designation encompasses air-release and decay. Attachment A-2 describes these options in more detail.

[19]Volumes for each radionuclide and each waste generating process were not itemized in the survey.

Table A-4: Volume of Radionuclide Groupings for EPA Laboratory Generated LLRW: 1992-1994		
Radionuclide Group	Volume (ft^3):1992-1994 Totals	Cumulative Activity (mCi)
NERL-LV[20]	76.5	16.49
^{45}Ca	2	0.033
^{14}C	180.34	421.8925
^{14}C,^{73}As	4	0.1
^{14}C,^{3}H,^{63}Ni	1.34	181.097
^{36}Cl	2	0.004
^{51}Cr	0.1	0.2
^{125}I	10	0.1
^{125}I,^{73}As,^{51}Cr	87.5	16.2
^{59}Fe	8.5	0.0020045
^{63}Ni	3.56	135
^{63}Ni,^{241}Am,^{226}Ra,^{60}Co,^{238}U,^{3}H,^{14}C,^{137}Cs	0.5	118.5
^{32}P	17.5	179.925
^{32}P,^{51}Cr	7	decayed
^{32}P,^{35}S	6	0.03
^{32}P,^{33}P,^{35}S,^{73}As,^{125}I	189	14.3
^{106}Ru,^{204}Tl	0	0.001
^{35}Su	51	16.35
^{3}H	100.4	284.095
^{3}H,^{14}C	1477.13	173.479
^{3}H,^{14}C,^{51}Cr, ^{125}I	60	14.6
U,Th,Eu	1	not provided
^{3}H,^{14}C,^{32}P,^{35}S	572.5	91
^{241}Am, ^{239}Pu	7.5	0.7
^{90}Sr, ^{234}U, ^{238}U, ^{230}Th, ^{232}Th, ^{60}Co, ^{137}Cs, ^{109}Cd, ^{226}Ra, ^{228}Ra	15	0.003
Totals	3206.37	1664.1

[20]Approximately 40 radionuclides existed for each generating process at this laboratory.

A.3.1 LLRW Deemed Undisposable

One EPA laboratory labeled a portion of their LLRW as undisposable. The National Health & Environment Effects Research Laboratory in Narragansett reported that a significant portion of the waste generated in 1992-1994 was undisposable. The two LLRW generating processes, trash and counting (LLW Stream #s 203 and 212, respectively), accounted for 17.5 ft^3 of undisposable LLW generated over the 3-year period. The Narragansett facility was only able to dispose of one ft^3 of LLW over the 3-year period studied. The principal radionuclides in the Narragansett undisposable waste consist of ^{3}H and ^{14}C. While management options are currently being examined, the state of Rhode Island is a noncompact state and generators of radioactive waste must store the material on-site until an agreement with a disposal facility has been established.

A.3.2 Cost Information for Treatment and Disposal of LLRW

Incomplete cost information for ultimate disposal was provided for four of the waste disposal facilities. These facilities included Barnwell, Hanford, Perma-Fix, and a combination of SEG and Barnwell. The table below provides a summary of the cost information provided for each of these facilities along with the number of instances in which cost information was not provided. Based on the data provided, the typical cost for LLRW at the Barnwell facility, in 1994 dollars, is 101 $/$ft^3$.

Table A-5: Cost Information for Disposal Facilities: LLRW

Facility	Year	Cost ($/$ft^3$)	Number of No Responses
Barnwell	1992	60	5
	1994	67	
	1994	135	
Perma-Fix	1994	30	3
SEG/Barnwell	not provided	not provided	1
Hanford	1993	524	7

A.4 DETAILED MIXED WASTE PROFILE OF EPA LABORATORIES

Of the 10 EPA laboratories surveyed, 8 reported to have generated mixed waste in the 1992-1994 time period totaling 831.16 ft^3. This section is designed to provide detailed investigations into the processes, activity, volumetric parameters, and waste management options of this mixed waste. The information is presented in tabular and graphical format to help elucidate the waste characteristics. The hazardous and radioactive components are also analyzed.

Tables A-6 and A-7 delineate the volumes of waste generated by LLW Stream Number and mixed waste generating process. The survey results indicate that only four LLW Stream Numbers and two generating processes are generally applicable for the mixed waste produced by EPA laboratories. Liquid Scintillation Fluids containing ^{14}C or ^{3}H (LLW #215) represented the largest volume, 423.91 ft^3 or 51.0 percent by LLW Stream Number (Figure A-6) and waste produced for liquid scintillation counting procedures represent the largest volume 598.66 ft^3 or 72.0 percent by process category (Figure A-7).

There are no discernible trends in the quantities of mixed waste generated in the 1992-1994 time period, although the greatest volume of mixed waste was produced in 1994 (340.97 ft^3 or 41.0 percent of the 3-year total). This is largely attributable to the increase in the amount of LLW Stream # 215 (liquid scintillation fluids or vials) generated in 1994. Similarly, mixed waste generated from HPLC counting procedures in 1994 accounted for 105 ft^3, which represented a 75 percent increase from 1993.

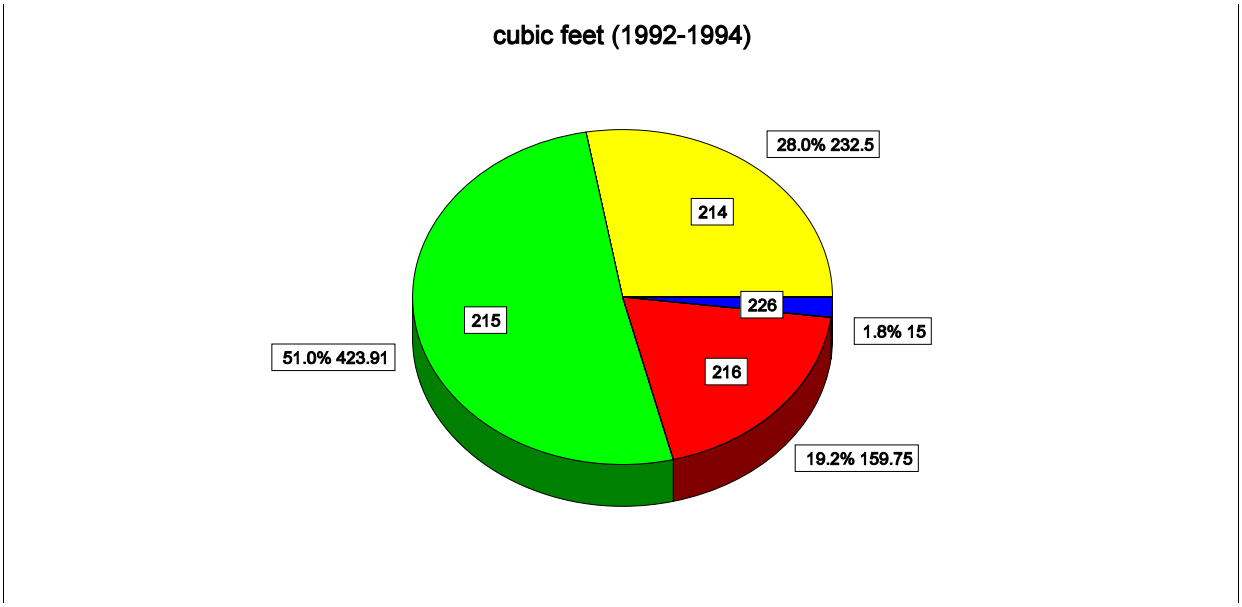


Figure A-6. MW Volume by LLW#

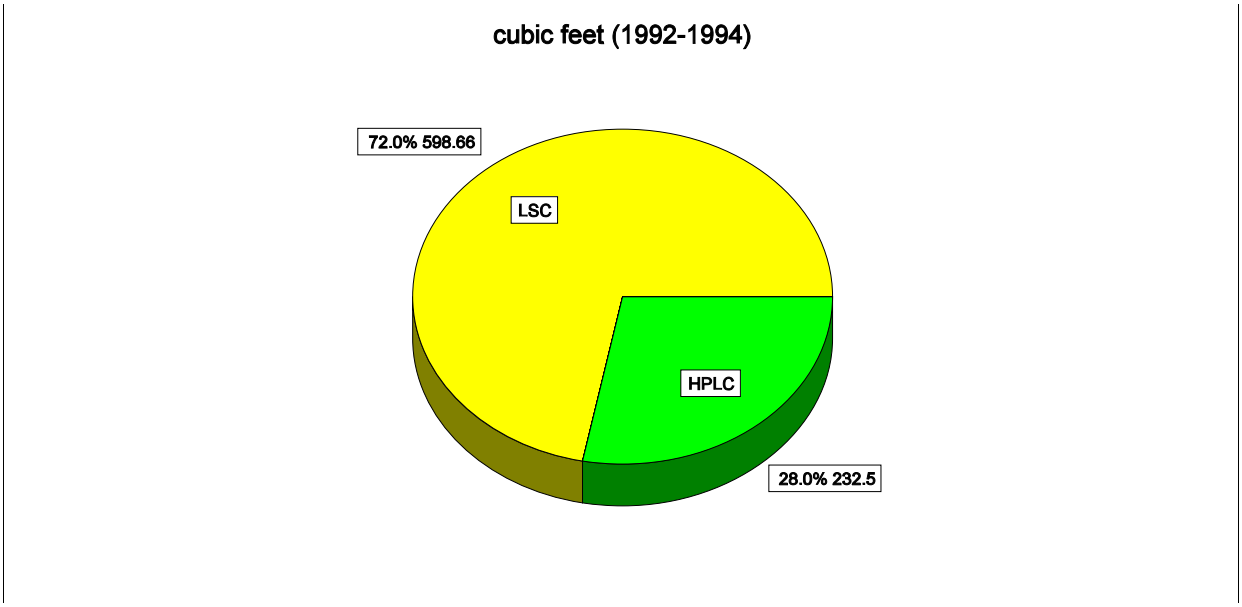


Figure A-7. MW Volume by Process

Table A-6: Volume (ft^3) of MW Grouped by LLW Stream No.: 1992-1994						
		LLW Stream No.				
Laboratory	Year	214	215	216	226	Totals
NERL-LV	94	0	4	0	0	4
RTP	92	67.5	71.5	71.5	0	210.5
	93	60	33.75	33.75	0	127.5
	94	105	52.5	52.5	0	210
NHEERL-AED	94	0	0	2	0	2
NHEERL-MED	92	0	0.02	0	0	0.02
	93	0	0.02	0	0	0.02
	94	0	0.02	0	0	0.02
NHEERL-WED	92	0	1.4	0	0	1.4
	93	0	1.7	0	0	1.7
	94	0	2.64	0	0	2.64
NRMRL-Breidenbach	92	0	86.5	0	0	86.5
	93	0	42.55	0	0	42.55
	94	0	114.81	0	0	114.81
NRMRL-Kerr	92	0	4	0	0	4
	93	0	1	0	15	16
	94	0	7.5	0	0	7.5
Totals	92	67.5	163.42	71.5	0	302.42
	93	60	79.02	33.75	15	187.77
	94	105	181.47	54.5	0	340.97
Totals 1992-1994		232.5	423.91	159.75	15	831.16

Table A-7: Volume (ft^3) of MW Grouped by Process: 1992-1994				
		Generating Process		
Laboratory	Year	HPLC Counting	LSC	Totals
NERL-LV	94	0	4	4
RTP	92	67.5	143	210.5
	93	60	67.5	127.5
	94	105	105	210
NHEERL-AED	94	0	0	2
NHEERL-MED	92	0	0.02	0.02
	93	0	0.02	0.02
	94	0	0.02	0.02
NHEERL-WED	92	0	1.4	1.4
	93	0	1.7	1.7
	94	0	2.64	2.64
NRMRL-Breidenbach	92	0	86.5	86.5
	93	0	42.55	42.55
	94	0	114.81	114.81
NRMRL-Kerr	92	0	4	4
	93	0	16	16
	94	0	7.5	7.5
Totals	92	67.5	234.92	302.42
	93	60	127.77	187.77
	94	105	235.97	340.97
Totals 1992-1994		232.5	598.66	831.16

A.4.1 Analysis of Hazardous Component of Mixed Waste Generated

Tables A-8, A-9, and A-10 provide the details of the hazardous components of the mixed waste reported by the EPA laboratories. Volume and activity of the grouped hazardous waste component of the MW is presented in Table A-8, while the volume percent of waste with chemicals present versus RCRA HW # are depicted in Tables A-9 and A-10, respectively. The principal hazardous chemicals included methanol, toluene, xylene, and 1,2,4 trimethylbenzene. RCRA hazardous waste numbers D001, F003, and F005 represented the primary HW#s cited.

Table A-8: Volume and Activity of Grouped Hazardous Waste Components of MW: 1992-1994 Totals

Grouped Hazardous Component	Waste Generating Process and Volume (ft^3)		Cum. Activity (mCi)
	HPLC Counting [LLW #]	LSC [LLW #]	
methanol; toluene; 1,2,4 trimethylbenzene	67.5 [214]	0	0.4
methanol; toluene; chloroform; 1,2,4 trimethylbenzene	60 [214]	0	0.8
methanol; toluene; 1,2,4 trimethylbenzene; acetone	105 [214]	0	1
pseudocumene	0	15.06 [215, 226]	0.0300059
pseudocumene; xylene	0	4 [215]	0.000004
pseudocumene; xylene; benzene	0	7.5 [215]	0.0000052
toluene	0	5.74 [215]	0.515
toluene; xylene	0	247.86 [215]	53.4676
toluene;1,2,4 trimethylbenzene	0	143 [215, 216]	1.8
toluene;1,2,4 trimethylbenzene; chloroform	0	67.5 [215, 216]	1.5
toluene;1,2,4 trimethylbenzene; chloroform; ethanol	0	105 [215, 216]	1.4
xylene; TCE; PCE; BTEX	0	1 [215]	0.0000086
xylene	0	2 [216]	not provided
Totals	232.5	598.66	60.9126237

Table A-9: Volume Percent of Waste with Chemicals Present versus Waste Generating Process		
	Process	
Hazardous Component	HPLC Counting	LSC
methanol	100	0
toluene	100	95.1
1,2,4 trimethylbenzene	100	52.7
chloroform	25.8	28.8
acetone	45.2	0
pseudocumene	0	4.4
xylene	0	43.8
benzene	0	1.3
ethanol	0	17.5
TCE	0	0.17
PCE	0	0.17
BTEX	0	0.17

Table A-10: Volume Percent of Waste using RCRA HW # versus Waste Generating Process		
	Process	
RCRA HW #	HPLC Counting	LSC
D001	100	99.9
D002	0	5.6
D006	0	0.33
D018	0	1.4
D022	25.8	23.2
D039	0	0.17
D040	0	0.17
F003	100	41.4
F005	100	94.1
F006	0	0.34

A.4.2 Analysis of Radioactive Component of Mixed Waste Generated

Table A-11 details the radioactive components of the mixed waste generated by EPA laboratories in the 1992-1994 time period. It is notable that the principal radionuclides are quite similar to the one produced in the LLRW waste analysis highlighted above. The ^{14}C and ^{3}H combination used in the liquid scintillation counting procedure accounted for 374.91 ft^3 or 45.1 percent of the mixed waste generated over the 3-year study period. The activity of this grouped component was 55.78 mCi or 91.6 percent which by far represented the largest activity of any other radionuclide group. If ^{32}P, ^{45}Ca, and ^{35}S are also included with ^{14}C and ^{3}H, these radionuclides represent 596.66 ft^3 or 99.7 percent of the total mixed waste generated and virtually all of the total mixed waste activity.

Table A-11: Volume and Activity of Grouped Radioactive Waste Components of MW: 1992-1994 Totals

Grouped Radioactive Component	Process Volume (ft^3)		Cum. Activity (mCi)
	HPLC Counting	LSC	
^{14}C	0	15	0.0000059
^{45}Ca, ^{32}P, ^{35}S	0	86.25	0.4
^{3}H	0	4	0.01
Ni, Cd	0	2	not provided
^{32}P, ^{45}Ca	0	71.5	0.1
^{3}H, ^{14}C	0	374.91	55.782618
^{3}H, ^{14}C, ^{32}P	60	0	0.8
^{3}H, ^{14}C, ^{36}Cl	0	45	2.42
^{3}H, ^{14}C, ^{32}P, ^{45}Ca	67.5	0	0.4
^{3}H, ^{14}C, ^{35}S, ^{32}P, ^{45}Ca	105	0	1
Totals	232.5	598.66	60.9126237

A.4.3 Mixed Waste in Storage

The results of the survey indicate that .06 ft^3 of the mixed waste generated in the 1992-1994 time period is being stored for accumulation. The National Health & Environmental Effects Research Laboratory in Duluth has produced .02 ft^3 of mixed waste from liquid scintillation counting

procedures each year consisting of ^{14}C, ^{3}H, and pseudocumene. The waste is to be disposed pending production of sufficient volume to make it economically reasonable to ship. NHEERL-MED staff are currently negotiating with TSD facilities to determine the most cost-effective treatment option. It is anticipated that the accumulated waste will be shipped to a TSD facility in the summer of 1996.

A.4.4 Waste Management Options for EPA Laboratory Mixed Waste

Six identifiable waste management options were selected for the mixed waste generated by the seven laboratories. Figure A-8 displays aggregated waste management option information. The details of the volumes of these options for each laboratory are presented in Table A-12. Overwhelmingly, the three treatment/disposal facilities, DSSI, NSSI, and Perma-Fix, represented the most extensively used management option. Of the mixed waste generated in 1992-1994, 814.1 ft^3 or 97.9 percent was transported to one of these facilities. Perma-Fix received 95.7 percent of this amount.

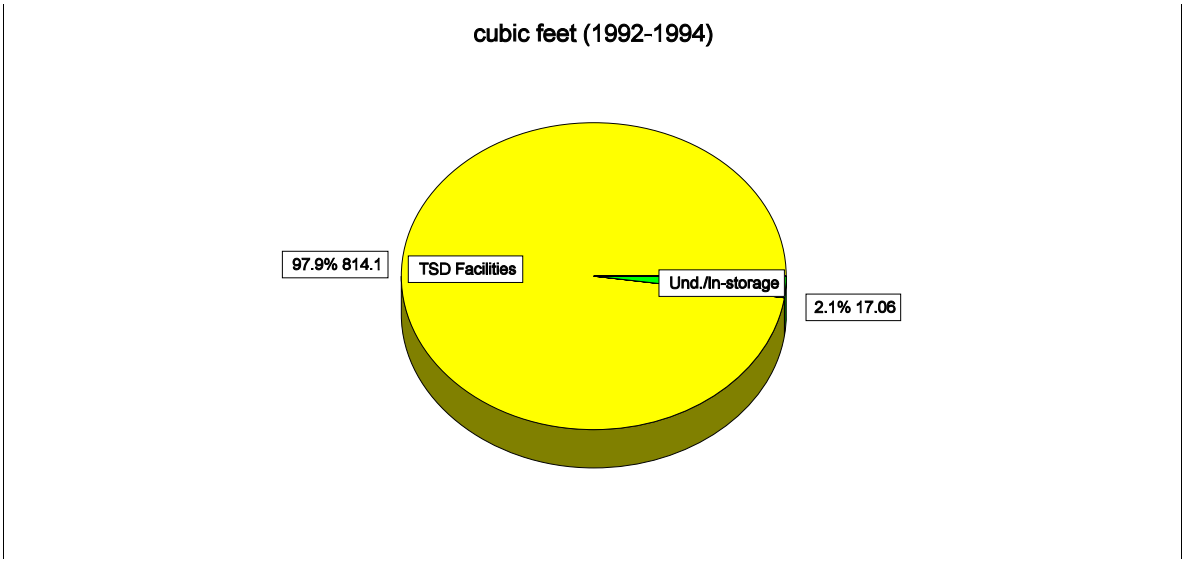


Figure A-8. MW Management Option Volume

Table A-12: MW Management Option Volume (ft^3): 1992-1994						
	Waste Management Option					
Laboratory	DSSI/NSSI	In-storage	NSSI	Perma-Fix	Und.	Totals
NERL-LV	0	0	4	0	0	4
RTP	0	0	0	548	0	548
NHEERL-AED	0	0	0	0	2	2
NHEERL-MED	0	0.06	0	0	0	0.06
NHEERL-WED	0	0	0	5.74	0	5.74
NRMRL-Breidenbach	6.01	0	0	237.85	0	243.85
NRMRL-Kerr	0	0	8.5	4	15	27.5
Totals	6.01	0.06	12.5	795.59	17	831.16

A.4.5 Profile of Undisposable Mixed Waste

Two waste streams generated over the 1992-1994 time period by the EPA laboratories were deemed undisposable.

In 1993, the Robert S. Kerr Environmental Research Center (Ada, OK) generated 15 ft^3 of liquid scintillation counting fluid (LLW stream #226) with a pseudocumene hazardous component that was determined to be undisposable. The cumulative activity of this waste (labeled as ^{14}C) is .0000059 mCi. The RSO indicated that a facility that handles solid low-level mixed waste was unidentifiable. However, this waste may not be undisposable.

The *Health Physics Positions Data Base - Revision 1* (NUREG/CR-5569) is a collection of NRC staff positions on a wide range of topics involving radiation protection. The database was developed by NRC Headquarters and Regional Offices to help ensure uniformity in inspections, enforcement, and licensing actions. A short discussion and decision regarding the disposal of solid scintillation media is found on page 140. It concludes that, "If samples meet the specific activity requirements of 10 CFR 20.2005(a), then the samples may be disposed of without regard to their radioactivity." Federal Regulation 10 CFR 20.2005(a) allows for the disposal of liquid scintillation media containing 0.05 microcuries or less of tritium (H-3) or carbon-14 (C-14) per gram of medium without regard to its radioactivity. Therefore it would appear that the Kerr

waste could be disposed of without regard to its radioactivity, if it meets the following guidelines:

- Waste is generated from liquid scintillation counting procedures, and
- Waste meets the specific activity limits identified in 10 CFR 20.2005(a) [i.e., H-3 or C-14 levels less than or equal to 0.05 μCi/g].

The second waste stream deemed undisposable was generated through liquid scintillation counting in 1994 in the NHEERL in Narragansett, RI, and totaled 2 ft^3. The radioactive components consist of cadmium and nickel while the hazardous component is xylene. The RSO is reportedly unable to find a transporter for this waste. Table A-13 summarizes this information.

Table A-13: Hazardous and Chemical Properties of Undisposable MW Generated at EPA Laboratories: 1992-1994

Waste Stream	Year	Radionuclides [LLW #]	Hazardous Component [RCRA #]	Volume (ft^3)	Cumulative Activity (mCi)
liquid scintillation vials	1994	Ni, Cd [LLW #216]	xylene [D001, D006, R006]	2	not provided
liquid scintillation counting	1993	^{14}C [LLW #226]	pseudocumene [D001]	15	0.0000059

A.4.6 Cost Information

Of the mixed waste that was generated by EPA laboratories in 1992-1994, only three TSD facilities (Perma-Fix, NSSI, and DSSI) served these laboratories. Table A-15 summarizes the cost information and lists the number of responses that did not provide these figures.

Table A-14: Cost Information for Disposal Facilities: Mixed Waste

Facility	Year	Cost ($/$ft^3$)	Number of No Responses
Perma-Fix	1992	180	9
	1992	40	
	1993	48	
	1994	50	
NSSI	-------	-------	11

A.5 COMPARISON WITH OTHER MIXED WASTE SURVEYS

It is useful to place the results of this analysis within the context of other parallel surveys. A literature search was conducted to identify other surveys that would serve as a basis of comparison. The two survey efforts identified include the *National Profile on Commercially Generated Mixed Waste (NUREG/CR -5938)* performed by the Oak Ridge National Laboratory and the DOE National Low-Level Waste Management Program's *National Institutes of Health: Mixed Waste Stream Analysis (DOE/LLW-208)*.[21] Although these surveys were much larger in scope, the results yield interesting comparisons. Both studies show that laboratory/research facility generated mixed waste is almost entirely composed of liquid scintillation fluid.

The *National Profile*, sponsored by NRC and EPA, was based on 1990 mixed waste generation by 1,016 industrial, medical, nuclear utility, NRC/state-licensed government facilities and academic institutions. Table A-15 lists the *National Profile* results for liquid scintillation fluid production (ft^3) and as a percentage of the total mixed waste produced in 1990. A more detailed enumeration of the waste generated from this survey is presented in Appendix E.

Table A-15: EPA/NRC 1990 National Profile Mixed Waste Survey Results: Liquid Scintillation Fluid Production and its Percentage in Generator's Mixed Waste

Mixed Waste Generator	Number of Generators	LSF Produced (ft^3)	LSF Percentage of Generator's Total Mixed Waste
Medical Facilities	149	18,800	94
Academic	256	26,680	92
NRC/State Licensed Gov. Facilities	134	20,790	77
Industrial Facilities	397	34,000	68
All Generators	1,016	140,000	71

[21] A third identified survey was the 1995 *Mixed Waste Inventory Report* (DOE/LLW-223) (MWIR-1995), a detailed, nationwide compilation of information on DOE mixed waste streams and treatment systems. Since the DOE mixed waste streams are fundamentally different processes, the information collected in this survey is incommensurate with the *National Profile* and the *Mixed Waste Stream Analysis.* Approximately 6 of the 3201 waste streams highlighted in the MWIR-1995 were derived from scintillation counting procedures.

DOE's *NIH: Mixed Waste Stream Analysis* revealed that 46,155 ft^3 of liquid scintillation vials were produced by NIH from 1986-1992. In the same 1992 time frame, NIH produced 4,590 ft^3 of liquid scintillation vials while six EPA facilities produced only 242.92 ft^3. The top three non-LSF mixed waste produced at NIH are listed below in Table A-16. NIH non-LSF mixed waste streams are more diverse than EPA non-LSF mixed waste streams, but there are some similarities. Notably, NIH HPLC waste ranks second volumetrically only to Gel Fixing/Washing. Both studies point to the fact that HPLC wastes are common in both EPA and NIH facilities and make significant contributions to non-LSF mixed waste. One difference between the two studies is that NIH's number one and three non-LSF mixed waste generating processes are not commonly found in EPA's facilities.

Table A-16: Top Three Mixed Waste Processes at NIH (not including LSF) over the 1989 to June 1993 time period

Process Description	Volumes (ft^3)	Contents volume percent of total mixed waste (not LSF) produced
Gel Fixing/Washing	642.78	28.4
HPLC wastes	586.74	25.9
Filter Washes	291.74	12.9

In both the *National Profile* and the *NIH: Mixed Waste Stream Analysis*, the principal radionuclides were identical in proportion to the ones produced by EPA laboratories. These radionuclides include ^{14}C, ^{3}H ^{32}P, ^{45}Ca, and ^{35}S. Similarly, the dominant hazardous components in all three studies were toluene and xylene. The NIH study and the *National Profile* produced information of the specific hazardous components of the mixed waste generated. The principal hazardous constituents of the liquid scintillation counting waste generated by commercial facilities in 1990 included xylene, toluene, and 1,2,4-trimethylbenzene. PCE was the only hazardous chemical found in EPA laboratory generated mixed waste and not in NIH mixed waste. EPA also used the label BTEX (benzene, toluene, ethylbenzene, and xylene) for some of the hazardous constituents in its mixed waste while NIH did not.

The similarities of the findings of this effort and the two above mentioned surveys indicate that EPA facility generated mixed waste is representative of other U.S. laboratory and research facility mixed waste. In all three studies there are similar generating processes producing similar radionuclides and hazardous components. Process changes that minimize mixed waste at EPA facilities would have direct applicability in other non-EPA facilities as well. Regulatory modifications affecting the generation of mixed waste from liquid scintillation counting procedures could affect many different organizations.

A.6 CONCLUSION

The results of the survey indicate only two processes are responsible for the generation of mixed waste at the EPA laboratories, HPLC counting, and liquid scintillation counting. Similarly, the hazardous components of this waste are few in number (12). Considerable attention can be focused on the use, distribution, and management of these waste generating processes to facilitate the application of waste minimization techniques. Other surveys that parallel this effort (notably the NIH study referenced above) reveal that mixed waste is produced from comparable waste generating processes. Although relative to the commercial sector and other federal research institutions, the EPA laboratories generate minute quantities of low-level radioactive waste and mixed waste. EPA and other commercial and Federal laboratories might be able to pool their resources to explore substantive research and develop solutions that minimize the mixed waste generated by these processes.

Attachment A-1

List of Applicable Hazardous Waste Permits and Radioactive Material Licenses for EPA Laboratories				
Laboratory	Hazardous Waste Permit	Governing Authority	Radioactive Material License	Governing Authority
NHEERL-WED Newport, OR	OR868009991	Oregon	36-12343-02	NRC
	OR7680030924	Oregon		
	OR9680059681	Oregon		
RTP	NC 668 009 0002-R3	RCRA RD&D Permit	32-14048-04 (former SC permit)	NRC
NHEERL-AED Narragansett, RI	none listed	NA	38-11957-01	NRC
NRMRL-Kerr Ada, OK	none listed	NA	NR-162-D-101-S	NRC
NERL-LV Las Vegas, NV	none listed	NA	27-05861-02 (former WA permit)	NRC
NRMRL-Breidenbach Cincinnati, OH	none listed	NA	34-12736-02	NRC
			South Carolina RW Transport Permit	South Carolina
NREERL-MED Duluth, MN	NPDES#MNG250078	Minnesota	22-13390-01	NRC
	Industrial Wastewater Discharge Permit #012	Local		
GED-Gulf Breeze Gulf Breeze, FL	FL1680009338	Florida	09-10672-03	NRC
CRL Chicago, IL	none listed	NA	12-10243-01	NRC
NAREL Montgomery, AL	none listed	NA	01-07317-01	AL

Attachment A-2

Descriptions of Waste Management Option Designations:

Option	Description
Air Release	Onsite release of contaminated material in containment device[22]
Barnwell	Disposal/Treatment facility
Decay	Waste stored for decay onsite and appropriately disposed
Hanford	Disposal/Treatment facility
In-storage	Waste stored for disposal pending sufficient volume
Manu.	Waste management is provided by the manufacturer
Und.	LLRW deemed undisposable (waste management option not yet identified)
Perma-Fix	Disposal/Treatment facility
SEG/Barnwell	Disposal/Treatment facility
Self	Onsite incinerator and disposal
Sewer	Disposal in sanitary sewer
Wash.	Waste distributed to the State of Washington

Description of LLW Stream Numbers

LLW Stream No.	Waste Stream Name
201	Biological Waste (Non-infectious) 1. Animal carcasses containing ^{14}C and/or tritium 2. Animal carcasses containing radioisotopes other than ^{14}C or tritium 3. Other biological waste
202	Trash and or Solid Waste (not lead) - non-compacted
203	Trash and or Solid Waste (not lead) - compacted
204	Filter Media - Dewatered
205	Filter Media - Solidified
206	Filters, Mechanical
207	Gaseous Sources
208	Incinerator Ash or Residuals
209	Ion Exchange Resins - Dewatered
210	Ion Exchange Resins - Solidified
LLW Stream No.	Waste Stream Name

[22]This management option involves permitted releases from a ventilation hood during routine experiments and has regulatory justification from the following references: 10 CFR 20.1301, 10 CFR 20.2002(a)(3), 10 CFR 20.1302, 10 CFR 20.10001-20.2401, and 10 CFR 20.1302(b)(2)(I).

211	Irradiated Reactor or Pool Components
212	Liquids Aqueous - Absorbed
213	Liquids Aqueous - Solidified
214	Liquids Organic - (Solvents, Chlorinated Solvents, etc.)
215	Liquids Scintillation, containing ^{14}C and/or tritium - (fluids or vials)
216	Liquids Scintillation, containing radioisotopes other than ^{14}C and/or tritium - (fluids or vials)
217	Mineral Extraction Waste
218	Uranium Sludges
219	Radioactive Sealed Sources, Devices, or Gauges
220	Solidified Evaporator Bottoms/Concentrates/Sump Sludge
221	Vitrified Ash or Resins
222	Waste Oils (Seal Oils from pumps for example) 1. Solvent-contaminated waste oil 2. Waste oil free from solvent contamination
223	Lead-Containing Waste 1. Blankets 2. Sheeting 3. Shielding
223	Lead Containing Waste 4. Batteries 5. Aqueous liquids 6. Organic liquids 7. Lead-contaminated equipment 8. Lead-contaminated trash 9. Other
224	Mercury-Containing Waste 1. Elemental mercury 2. Hydraulic oil 3. Solids 4. Liquids 5. Other
225	Paint 1. Water-based 2. Oil-based 3. Epoxy-based 4. Lead-based
226	Other - (Specify)

APPENDIX B: SURVEY INSTRUMENT DISTRIBUTED TO EPA LABORATORIES

Approach to Dissemination of Survey

Initially, EPA staff contacted the RSOs at 11 EPA laboratories presumed to be generators of low-level radioactive waste (LLRW) and/or mixed waste (MW) to inform them of the nature of this survey effort. Ten of these laboratories were discovered to be generators of LLRW or MW. An EPA approved survey was then disseminated to each laboratory through the requested medium: e-mail or facsimile. Upon the receipt of the surveys, followup conversations were made with laboratory staff to clarify individual responses. After clarifications were made, the data were processed and analyzed (see Appendix A). A copy of the survey instrument follows.

Mixed and Low Level Radioactive Waste Questionnaire: Administered to EPA Mixed Waste Generating Facilities by the U.S. Environmental Protection Agency, Radiation Protection Division & Safety, Health, and Environmental Management Division

Introduction: Goals and Overview of the Survey

The completed profile will also assist the EPA/SHEMD in defining future guidance for facilities working with mixed waste. The **ultimate objective** will be to reduce cases of indefinite storage and the resulting high costs as well as to assist laboratory directors to re-evaluate the way in which mixed waste is managed.

The following survey is divided in sections A through C outlined below. Information is being requested for the calender years 1994, 1993, and 1992. A brief description and explanation, if necessary, of the information requested is provided in the introduction for each section.

Section A: General Information - Self explanatory

Section B: Low-Level Radioactive Waste (LLRW)
- B-1. Generation
- B-2. Undisposable LLRW

Section C: Mixed Waste (MW)
- C-1. Generation
- C-2. Undisposable MW

Definitions:

The following terms are used in the questionnaire. For clarification purposes, their definitions are provided below.

Management Option: the mixed/low-level waste management option chosen which may include treatment, disposal, or onsite storage as described below.

Treatment: any method, technique, or process designed to change the physical and chemical characteristics of waste to render it less hazardous, safer to transport, store, or reduce in volume. For the purposes of this study, storage for decay is considered a treatment option while disposal is not considered a treatment option.

Disposal: (for the purposes of this study) permanent **offsite** storage at a permitted disposal facility.

OnSite Storage: waste that is stored at the site of the waste generating facility (EPA research laboratory).

Undisposable: waste remaining after all current treatment techniques have been exhausted and is the waste which, under current conditions, cannot be disposed of.

Low-Level Radioactive Waste (LLRW): is defined as radioactive material that (a) is not high-level radioactive waste, spent nuclear fuel, or byproduct material as defined in section 11e. (2) of the Atomic Energy Act of 1954 (AEA); i.e., uranium or thorium mill tailings and (b) NRC classifies as LLRW consistent with existing law and in accordance with (a).

Source Material: Materials that contain Uranium or Thorium ores.

Biological Hazard: Materials that contain infectious agents, sharps, or animal carcasses.

Mixed Waste: is defined as waste that satisfies the definition of LLRW and contains hazardous waste that (1) is listed as hazardous waste in Subpart D of 40 CFR Part 261 or (2) causes the LLRW to exhibit any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261. In addition, the following are included in the definition of hazardous waste for the purpose of this study: oils and sludges, and other wastes classified as hazardous by a RCRA-authorized state.

Your cooperation in completing this survey is greatly appreciated. To reiterate, the underlying purpose of performing this survey is to establish future guidance for managing mixed waste at EPA laboratories. Please complete the survey as accurately and thoroughly as possible within two (2) weeks after receipt.

A. General Information

- Facility Information
  Name:
  Address:

- Facility Category
  Type of Facility and Number of Staff

- NRC/Agreement State License Number:

- EPA Identification Number:

EPA Facility Classification	Total Quantity Generated (Kg/month)
Large quantity generator	
Small quantity generator	
Conditionally exempt small quantity generator	
No EPA classification:	

- Please list all applicable hazardous and radioactive wastes permits and the administering agency for your facility (federal, state, local):

  Hazardous:

  Radioactive:

- Name, title, and telephone number of person completing form:

  Name:
  Title:
  Tel. No.:

B. Low-Level Radioactive Waste (LLRW)

B-1. Generation Please describe each LLRW stream generated at your facility. Waste that is similar in nature or source (or both) should be grouped together (e.g., unconsolidated trash, laboratory counting procedures, cleaning of laboratory equipment, animal carcasses, spent sealed sources, etc.)

Do not include those wastes considered as mixed wastes in this section. (Mixed Waste will be detailed in Section C)

Please use the codes in Attachment B-1 to complete this section.

Total LLRW Generated: Calendar Year 92

Item #	LLW Stream Number	Major Radionuclides	NRC Class A,B, or C	LLW Generating Process	Cumulative Activity (mCi)	Biological Hazard	Source Material	Volume (ft^3)	Management Option	Disposal Facility	Cost ($/$ft^3$)
1											
2											
3											
4											
5											
6											
7											

Total LLRW Generated: Calendar Year 93

Item #	LLW Stream Number	Major Radionuclides	NRC Class A,B, or C	LLW Generating Process	Cumulative Activity (mCi)	Biological Hazard	Source Material	Volume (ft^3)	Management Option	Disposal Facility	Cost ($/$ft^3$)
1											
2											
3											
4											
5											
6											
7											

Total LLRW Generated: Calendar Year 94

Item #	LLW Stream Number	Major Radionuclides	NRC Class A,B, or C	LLW Generating Process	Cumulative Activity (mCi)	Biological Hazard	Source Material	Volume (ft^3)	Management Option	Disposal Facility	Cost ($/$ft^3$)
1											
2											
3											
4											
5											
6											
7											

B-2. Undisposable LLRW

Please give a brief reason for each Item # identified above in B-1 as undisposable (i.e. Management Option = 1) under current regulations or conditions (e.g., evaluating options, holding for deregulation, unable to treat, unable to ship, using as a shield, etc.).

Undisposable Waste: Calendar Year 92

Item #	Reason for Storage

Undisposable Waste: Calendar Year 93

Item #	Reason for Storage

Undisposable Waste: Calendar Year 94

Item #	Reason for Storage

C. Mixed Waste (MW)

C-1. Generation

Please describe each MW stream generated at your facility. Waste that is similar in nature or source (or both) should be grouped together (e.g., gel fixing/washing, HPLC scintillation counting, spent reagents, decontamination of lead shielding, pump seal oil, filter washes, etc.)

Please use the codes in Attachment B-2 to complete this section.

Total Mixed Waste Generated: Calendar Year 92

Item #	LLW Stream Number	Physical Description	MW Generating Process	Major Radionuclides	NRC Class A, B, or C	Cumulative Activity (mCi)	Biological Hazard	Source Material
1								
2								
3								
4								

Please also identify the following characteristics of the MW streams in the order that they were identified above.

Item #	Volume (ft^3)	Hazardous Component	RCRA Hazardous Waste Code	Storage	Management Option	Disposal Facility	Cost ($/$ft^3$)
1							
2							
3							
4							

Total Mixed Waste Generation: Calendar Year 93

Item #	LLW Stream Number	Physical Description	MW Generating Process	Major Radionuclides	NRC Class A, B, or C	Cumulative Activity (mCi)	Biological Hazard	Source Material
1								
2								
3								
4								

Please also identify the following characteristics of the MW streams in the order that they were identified above.

Item #	Volume (ft^3)	Hazardous Component	RCRA Hazardous Waste Code	Storage	Management Option	Disposal Facility	Cost ($/$ft^3$)
1							
2							
3							
4							

Total Mixed Waste Generation: Calendar Year 94

Item #	LLW Stream Number	Physical Description	MW Generating Process	Major Radionuclides	NRC Class A, B, or C	Cumulative Activity (mCi)	Biological Hazard	Source Material
1								
2								
3								
4								

Please also identify the following characteristics of the MW streams in the order that they were identified above.

Item #	Volume (ft^3)	Hazardous Component	RCRA Hazardous Waste Code	Storage	Management Option	Disposal Facility	Cost ($/$ft^3$)
1							
2							
3							
4							

C-2. Undisposable LLRW

Please give a brief reason for each Item # identified above in C-1 as undisposable (i.e. Management Option = 1) under current regulations or conditions (e.g., evaluating options, holding for deregulation, unable to treat, unable to ship, using as a shield, etc.).

Undisposable Waste: Calendar Year 92

Item #	Reason for Storage

Undisposable Waste: Calendar Year 93

Item #	Reason for Storage

Undisposable Waste: Calendar Year 94

Item #	Reason for Storage

Is there any other mixed waste that is not covered by this survey?

Additional Comments:

THANK YOU FOR YOUR ASSISTANCE IN COMPLETING THIS QUESTIONNAIRE.

ATTACHMENT B-1

Please use the guide to complete Section B.

LLW Stream No. - See Attachment B-3.

Major Radionuclides - Identify the different radionuclides in the waste.

NRC Class A, B, or C - Use 10 CFR 61.55 for determination.

LLW Generating Process - Indicate the process which produces the waste (e.g. laboratory counting procedures, equipment cleaning, etc.).

Cumulative Activity - Indicate the mCi amount for the waste.

Biological Hazard - If the LLRW is also considered an infectious agent, sharp, or animal carcass, indicate with a check (✓).

Source Material - If the LLRW also contains Uranium or Thorium ores indicate with a check (✓).

Volume (ft^3) - Indicate the volume for the waste. Note that 30- & 55-gallon drums are approximately 4.0 and 7.5 ft^3 respectively.

Management Option - Use the following codes for indicating the Management Option for the waste

1 = permanent onsite storage/undisposable
2 = storage for decay
3 = storage for accumulation (>90 days) and offsite treatment and/or disposal
4 = offsite treatment and/or disposal
5 = other

Disposal Facility - Indicate the final disposal facility (if any) for the waste (e.g., Barnwell, SEG, sewer discharge, etc.).

Cost ($/$ft^3$) - When possible, please indicate the cost for management of the waste including any handling, shipping, treatment, storage, or disposal fees.

ATTACHMENT B-2

Please use the guide to complete Section C.

LLW Stream No. - See Attachment B-3.

Physical Description - Indicate the nature of the waste (e.g., bulk/vials, liquid, solid, aqueous liquids, ash, uncompacted solid, etc.).

MW Generating Process - Indicate the process which produces the waste (e.g. liquid scintillation counting, gel fixing/washing, lead shielding decontamination, pump seal oil, equipment cleaning, etc.).

Major Radionuclides - Identify the different radionuclides in the waste.

NRC Class A, B, or C - Use 10 CFR 61.55 for determination.

Cumulative Activity - Indicate the mCi amount for the waste.

Biological Hazard - If the LLRW is also considered an infectious agent, sharp, or animal carcass, indicate with a check (✓).

Source Material - If the LLRW also contains Uranium or Thorium ores indicate with a check (✓).

Volume (ft^3) - Indicate the volume for the waste. Note that 30- & 55-gallon drums are approximately 4.0 and 7.5 ft^3 respectively.

Hazardous Component - Indicate the hazardous chemical or element in the MW (e.g., toluene, xylene, acetone, etc). Please refer to Attachment 4 for hazardous waste classification and sample lists.

RCRA Hazardous Waste Code - Refer to Attachment 4 for sample lists of RCRA hazardous waste codes.

Storage - Use the following code to indicate the type of storage:

1 = Storage for accumulation for less than the RCRA authorized storage time limit (usually 90 days)

2 = Storage for accumulation for longer than the RCRA authorized storage time limit (usually 90 days)

Management Option - Use the following codes for indicating the Management Option for the waste

1 = permanent onsite storage/undisposable
2 = storage for decay
3 = offsite treatment and/or offsite disposal
4 = onsite treatment and/or offsite disposal
5 = onsite treatment and/or onsite disposal
6 = other

Disposal Facility - Indicate the final disposal facility (if any) for the waste (e.g., Envirocare, DSSI, NSSI, Perma-Fix, etc.).

Cost ($/ft^3) - When possible, please indicate the cost for management of the waste including any handling, shipping, treatment, storage, or disposal fees.

ATTACHMENT B-3

Indicate the radioactive waste streams by entering their code numbers from the following list. Enter a 3-digit number for those categories which are not subcategorized, but enter a 4-digit number for a waste stream identity which is subcategorized (e.g., contaminated lead shielding would be indicated with 2233).

LLW Stream Numbers

LLW Stream No.	Waste Stream Name
201	Biological Waste (Non-infectious) 1. Animal carcasses containing ^{14}C and/or tritium 2. Animal carcasses containing radioisotopes other than ^{14}C or tritium 3. Other biological waste
202	Trash and or Solid Waste (not lead) - noncompacted
203	Trash and or Solid Waste (not lead) - compacted
204	Filter Media - Dewatered
205	Filter Media - Solidified
206	Filters, Mechanical
207	Gaseous Sources
208	Incinerator Ash or Residuals
209	Ion Exchange Resins - Dewatered
210	Ion Exchange Resins - Solidified
211	Irradiated Reactor or Pool Components
212	Liquids Aqueous - Absorbed
213	Liquids Aqueous - Solidified
214	Liquids Organic - (Solvents, Chlorinated Solvents, etc.)
215	Liquids Scintillation, containing ^{14}C and/or tritium - (fluids or vials)
216	Liquids Scintillation, containing radioisotopes other than ^{14}C and/or tritium - (fluids or vials)
217	Mineral Extraction Waste
218	Uranium Sludges
219	Radioactive Sealed Sources, Devices, or Gauges
220	Solidified Evaporator Bottoms/Concentrates/Sump Sludge
221	Vitrified Ash or Resins
222	Waste Oils (Seal Oils from pumps for example) 1. Solvent-contaminated waste oil 2. Waste oil free from solvent contamination
223	Lead-Containing Waste 1. Blankets 2. Sheeting

LLW Stream Numbers (contd.)

LLW Stream No.	Waste Stream Name
223	Lead-Containing Waste (contd.)
	3. Shielding
	4. Batteries
	5. Aqueous liquids
	6. Organic liquids
	7. Lead-contaminated equipment
	8. Lead-contaminated trash
	9. Other
224	Mercury-Containing Waste
	1. Elemental mercury
	2. Hydraulic oil
	3. Solids
	4. Liquids
	5. Other
225	Paint
	1. Water-based
	2. Oil-based
	3. Epoxy-based
	4. Lead-based
226	Other - (Specify)

ATTACHMENT B-4

Selected Industry and EPA Hazardous Waste Numbers

Section A. Listed Hazardous Waste

EPA details listed hazardous waste from nonspecific sources in 40 CFR 261 Subpart D: §261.3.

Mixture Rule

Any solid waste mixed with one or more listed hazardous waste is hazardous. This rule applies regardless of what percentage of the waste mixture is composed of listed hazardous waste. (Note that certain so called "dry waste" such as solvent and radionuclide-contaminated rags, may be hazardous waste via the mixture rule). The following are exceptions to this rule:

- Wastewater subject to regulation by the Clean Water Act mixed with low concentrations of a listed waste (unless the resultant mixture exhibits one of the characteristics);
- Mixtures of nonhazardous waste and listed waste that were listed for exhibiting a characteristic (if the resultant mixture does not exhibit any of the characteristics);
- Mixtures of nonhazardous waste and characteristic hazardous waste that no longer exhibit any of the characteristics;
- Certain concentrations of spent solvents and laboratory wastewater that are discharged in low concentrations and do not pose a threat to human health or the environment (see 10 CFR 20.2003 & 10 CFR 20.2005); and
- *De minimis* losses of discarded commercial chemical products or intermediaries used as raw materials in manufacturing or produced as byproducts.

Derived-From Rule

Any solid waste generated from the management of a listed hazardous waste (including any sludge, spill residue, ash, filter, emission control dust, or leachate but not including precipitation run-off) is a hazardous waste.

Listed Hazardous Wastes from Nonspecific Sources:

EPA HW No.	Hazardous Waste
F001	The following spent halogenated solvents used in degreasing: Tetracloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of 10 percent of more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.

EPA HW No.	Hazardous Waste
F002	The following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane, and 1,2,2-trichloroethane; all spent solvent mixtures/blends containing, before use, a total of 10 percent or more (by volume) of one or more of the above halogenated solvents or those listed in F001, F004, or F005; and still bottoms form the recovery of these spent solvents and spent solvent mixtures.
F003	The following spent halogenated solvents: Xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, pseudocumene, and methanol; all spent solvent mixtures/blends containing, before use, only the above spent nonhalogenated solvents; and all spent solvent mixtures/blends containing, before use, one or more of the above nonhalogenated solvents and a total of 10 percent or more (by volume) of one ore more of those solvents listed in F001, F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F004	The following spent halogenated solvents: Cresols and cresylic acid, and nitrobenzene; all spent solvent mixtures/blends containing, before use, a total of 10 percent or more (by volume) of one ore more of the above nonhalogenated solvents or those solvents listed in F001, F002, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F005	The following spent halogenated solvents: Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, trigylcerol, and 2-nitropropane; all spent solvent mixtures/blends containing, before use, a total of 10 percent or more (by volume) of one or more of the above nonhalogenated solvents or those solvents listed in F001, F002, or F004; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F020- F023	Dioxin waste
F026-F028	Dioxin waste

Section B. Characteristic Hazardous Wastes

A solid waste can also be considered hazardous, if it exhibits one or more of the following characteristics.

I. Ignitability

A waste is ignitable and is classified as D001 if it meets any of the following criteria:

1. It is a liquid (except for aqueous solutions containing less than 24 percent alcohol by volume) and has a flash point less than 140 ^{o}F;
2. It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes, and when ignited, burns so vigorously and persistently that it creates a hazard;
3. It is an ignitable compresses gas, as defined by the Department of Transportation; or

4. It is an oxidizer, as defined by the Department of Transportation

The following is a sample list of D001 waste:

Acetonitrile
Cis-2-pentene
Coal Tars
Ethanol
Formaldehyde
Formamide
Naphthalene
Organic Solvents
Tetrahydrofuran

II. Corrosivity

A waste is corrosive and is classified as D002 if it meets either of the following criteria:

1. It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter; or
2. It is a liquid and corrodes steel at a rate greater than 0.25 inches per year at specified conditions.

The following is a sample list of D002 waste.

Acids
Corrosive Liquids
Phenol
Phosphoric Acid
Sodium Hydroxide
Sulphuric Acid

III. Reactivity

A waste is reactive and is classified as D003, if it meets any of the following criteria:

1. It is normally unstable and readily undergoes violent change without detonating;
2. It reacts violently with water;
3. It forms potentially explosive mixtures with water;
4. When formed with water, it generates dangerous quantities of toxic fumes, gases, or vapors;
5. In the case of cyanide- or sulfide-bearing waste, it generates dangerous quantities of toxic fumes, gases, or vapors when exposed to pH conditions between 2 and 12.5;
6. It detonates or explodes when subjected to a strong initiating force or heated under confinement;
7. It readily detonates or decomposes explosively at standard temperature and pressure; or
8. It is defined by DOT as forbidden explosive, Class A explosive, or Class B explosive.

The following is a sample list of D003 waste.

Potassium Cyanide
Sodium Cyanide

IV. Toxicity

A waste exhibits the characteristics of toxicity if a representative sample of a liquid or the extract of a solid waste contains any of the following constituents at a level equal to or greater than the given value below. The test for toxicity is the Toxic Characteric Leaching Procedure (TCLP) as described in 40 CFR Part 261, Appendix II (SW-846, Method 1311).

Haz. No.		mg/l	Haz. No.		mg/l	Haz. No.		mg/l
D004	Arsenic	5.0	D027	1,4-Dichlorobenzene	7.5	D035	Methyl ethyl ketone	200.0
D005	Barium	100.0	D028	1,2-Dichloroethane	0.5	D036	Nitrobenzene	2.0
D018	Benzene	0.5	D029	1,1-Dichorethylene	0.7	D037	Pentachlorophenol	100.0
D006	Cadmium	1.0	D030	2,4-Dinitrotoluene	0.1	D038	Pyridine	5.0
D019	Carbon		D012	Endrin	0.02	D010	Selenium	1.0
	tetrachloride	0.5	D031	Heprachlor(and epoxide)	0.008	D011	Silver	5.0
D020	Chlorodane	0.03	D032	Hexachlorobenzene	0.1	D039	Tetrachloroethlylene	0.7
D021	Chlorobenzene	100.0	D033	Hexachloro-1,3-butadiene	0.5	D015	Toxaphene	0.5
D022	Chloroform	6.0	D034	Hexachloroethane	3.0	D040	Trichloroethylene	0.5
D007	Chromium	5.0	D008	Lead	5.0	D041	2,4,5-Trichlorophenol	400.0
D023	o-Cresol	200.0	D013	Lindane	0.4	D042	2,4,6-Trichlorophenol	0.2
D024	m-Cresol	200.0	D009	Mercury	0.2	D017	2,4,5-TP (Silvex)	1.0
D025	p-Cresol	200.0	D014	Methoxychlor	10.0	D043	Vinyl Chloride	0.2
D016	2,4-D	10.0						

APPENDIX C: COMMONLY GENERATED RADIONUCLIDES AT EPA LABORATORIES

Radio-nuclide	Type of Decay (abundance %)	Half-life	Major radiations, Energies (Mev), and Frequency per disintegration (%)
^{3}H	negative beta emission (100)	12.3 years	β^- : 0.019 max. No γ
^{14}C	negative beta emission (100)	5,730 years	β^- : 0.156 max. No γ
^{32}P	negative beta emission (100)	14.3 days	β^- : 1.17 max. No γ
^{35}S	negative beta emission (100)	87.9 days	β^- : 0.167 max. No γ
^{36}Cl	negative beta emission positive beta emission orbital electron capture	3×10^5 years	β^- : 0.709 β^+ : 0.12 No γ
^{45}Ca	negative beta emission	163 days	β^- : 0.258 max. No γ
^{51}Cr	gamma (9.8) X-ray electron capture	27.8 days	γ : 320.1
^{60}Co	negative beta emission (100)	5.3 years	β^- : 1.48 max (0.12%), 0.314 max (99+%) γ : 1.17 (100%), 1.33 (100%)
^{63}Ni	negative beta emission	92 years	β^- : 0.067
^{125}I	orbital electron capture	60 days	γ : 0.0352
^{137}Cs	negative beta emission	30.0 years	β^- : 1.18 max (7%), 0.514 max (93%) γ : 0.662 (85%), Ba X-rays e^- : 0.624, 0.656 (8%)
^{225}Ra	negative beta emission	14.8 days	β^- : 0.32 max. γ : 0.04
^{238}U	alpha particle decay, spontaneous fission	4.91×10^9 years	α : 4.20 (75%), 4.15 (25%) γ : Th X-rays e^- : 0.03, 0.043 Daughter radiations from ^{234}Th, ^{234m}Pa
^{241}Am	alpha particle decay	458 years	α : 5.482 (85%), 5.439 (13%), 5.386 (2%) γ : 0.06, 0.027-0.37

APPENDIX D: RESEARCH APPROACH

More than 50 research materials were reviewed to determine applicability to this study (see Section 6). The materials were collected from the academic, commercial, federal, state, and medical communities. The review of the literature suggests that the primary focus is dedicated to addressing mixed waste management at the laboratory level. This warranted the need for an entire section (Section 2) devoted to addressing an integrated laboratory-wide approach to mixed waste management.

Two primary search tools were consulted to produce the list of studies for this effort. The first source, the Victor Network, provided a list of the publications and journals available through the University of Maryland library system. This aided in identifying academic and other materials related to laboratory mixed waste management. A second source was the National Technical Information Service (NTIS) Bibliographic Database that provides a list of government publications for the years 1977-1995.

Based on the literature survey and contacts with the industry experts, it was discovered that there are a limited number of studies that focus exclusively on mixed waste generated from laboratories or research facilities (particularly on HPLC and LSC). This is especially the case for pollution prevention techniques, recycling options, and waste segregation strategies. A telephone survey of federal, commercial, and other laboratories was conducted to identify state-of-the-art waste management techniques and identify literature that would contribute to this study. Attachment D-1 lists the names and organizations of the 37 professionals contacted. Table D-1 below highlights the framework of this survey instrument. Additional materials were collected from EPA sources that had been accumulated for other research studies.

Table D-1: Framework for Phone Survey Administered to MW Research Staff

1) Clarification of Survey Responses

- General Description of Waste Generating Practice
- Clarification of Management Option
- Incomplete Information

2) Elicit Approaches/Strategies to Improve P2 Practices (MW Focus)

- Determine What is Successful (laboratory practices, analysis techniques)
- Identify Waste Minimization Goals
- Identify Publishable Research

3) Elicit Suggestions for Further Research/Recommendations

- Are There Significant Technology Data Gaps?

ATTACHMENT D-1: LIST OF CONTACTS

Contact	Organization
Dick Blauvelt	ASME Mixed Waste Committee Chairman, BDM Federal
Lou Todisco	NEN Products
Andy Francis	Oak Ridge National Laboratory
Jerry Klein	Oak Ridge National Laboratory
Bob Hilton	Conversion Systems, Incorporated
Nick Orlando	Nuclear Regulatory Commission
Jan Berry	Oak Ridge National Laboratory
Sam Suffrand	Oak Ridge National Laboratory
Eric Williams	Lockheed Idaho
Priscilla Bunton	DOE
Paul Longsworth	DOE
Stanley Wolfe	DOE
Esmeralda Party	Rockefeller University
John Moore	Oak Ridge National Laboratory
Kent Hancock	DOE
Karen Catlett	Oak Ridge National Laboratory
Cathy Stanton	Stanton Associates
William Mills	Health Physics Society
Cathy Asbell	Lockheed Idaho
Frank Masse	Massachusetts Institute of Technology
Susan Jahansooz	Lawrence Berkeley Laboratory
Edwin Becker	National Institutes of Health
Steve Hoeffner	Rust Environmental Services, Clemson Technical Center
Kevin Twitchell	Lockheed Idaho
Roger Scott	Lockheed Idaho
Bill Dornsife	State of PA Radiation Control Division of Environmental Protection, Chairman of NCRP, MW Subgroup
Stan Zigma	Sandia National Laboratories
Carol Creutz	Brookhaven National Laboratory
Emmitt Barkley	Howard Hughes Medical Center
Fred Petschauer	Brookhaven National Laboratory
Peter Reinhardt	University of Wisconsin - Madison
Don Carlson	University of Texas - Dallas
Allen Pasternak	Cal Rad
Susan Spencer	University of California - Berkeley
Trish Baisden	Lawrence Livermore Laboratory
Andrea Sutherland	Affymax Research Institute
Peter Ashbrook	University of Illinois at Urbana-Champaign

APPENDIX E: RESULTS OF ORNL SURVEY

Oak Ridge National Laboratory, *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, December 1992.

The report was jointly sponsored by the Nuclear Regulatory Commission (NRC) and EPA and attempts to provide a national profile on the volumes, characteristics, and treatability of commercially generated low-level mixed waste for 1990. The data and conclusions resulted from a national survey of commercial mixed waste generators which included academic, industrial, medical, and NRC/Agreement State-licensed government facilities, and nuclear utilities. A list of some of the findings include:

Generation

- Mixed waste comprised about 9 percent of the low-level radioactive waste generated in 1990.

- 140,000 ft^3 of mixed waste was generated in the United States in 1990 by commercial facilities.
  Of that:
  - 71% (100,000 ft^3) - LSC fluid
  - 18% - organic solvents (CFCs), corrosive organics, and waste oil
  - 3% - toxic metals
  - 8% - other

- The contribution from **government** facilities was approx. 19% (27,000 ft^3)
  Of that:
  - 77% - LSC fluid
  - 13 % - other organics

Storage

- 75,000 ft^3 of mixed waste was identified as being stored onsite in 1990.
  Of that, the largest percentage of mixed waste in storage was contaminated by:
  - Cadmium - 35%
  - LSC fluid - 17%

- The contribution by **government** to the total mixed waste in storage was approx. 4 percent (2800 ft^3), over half of which was contaminated by LSC fluid. Note however, that the amounts in storage do not necessarily equate to amounts that are undisposable or require disposal. Some mixed waste may merely be accumulating for treatment purposes.

Untreatable

- Survey indicated that over 4800 ft^3 of mixed waste was considered untreatable in 1990, approximately 31 percent (1,455 ft^3) of which came from the **government** category. The two primary chemicals found in the untreatable **government** mixed waste were LSC fluids (over 50 percent) and "other organic" compounds (27 percent).

Treatment/Disposal

- Approximately 67 percent (143,000 ft^3) of the mixed waste generated and in storage in 1990, including all of the LSC fluid, could be treated by thermal destruction techniques. This figure does not include the untreatable mixed waste being stored.

Demand/Capacity

- The national profile estimates that existing treatment facilities could have treated approximately 95 percent of the mixed waste generated during 1990. However, an important caveat to note is that the U.S. Department of Energy, which is not included in the survey produces a great deal of mixed waste (approx. 800,000 ft^3) compared to the amount identified in the survey. Thus, if the DOE began competing for treatment capacity with the other commercially generated mixed waste there is a potential for a significant shortfall in treatment facility capacity.

- Insufficient capacity currently exists, as of 1990, for mixed waste contaminated with CFCs, some LSC wastes, lead shielding, other waste contaminated with lead solids, and equipment and debris contaminated with mercury.

APPENDIX F: OVERVIEW OF OTHER MW/LLRW SURVEYS, DATABASES, AND STATE LOW-LEVEL RADIOACTIVE WASTE DISPOSAL EFFORTS

The literature search identified other surveys and databases that address different aspects of waste management and pollution prevention. In addition, there existed several documented state-level efforts notably New York, Pennsylvania, and Ohio, that examine approaches to dispose of low-level radioactive waste generated within their jurisdiction. Discussions with state policy makers and other researchers suggest that states are examining options for management of LLRW and MW in the longterm. This has palpable implications for the EPA research facilities that generate LLRW and MW. EPA facilities that generate these wastes need to keep apprised of the state specific issues relating to treatment and storage options. It is incumbent upon RSOs and other research staff to incorporate pollution prevention, storage, and disposal objectives within the context of these policies.

The New York State Energy Research and Development Authority, *Low-Level Radioactive Waste Storage Study: Vol. 1: Storage and Capability at Generator Sites*, September 1993.

The New York State Energy Research and Development Authority conducted a low-level radioactive waste (LLRW) storage study with three purposes: 1) to evaluate the present ability of generators of LLRW in New York State to store their waste at the facilities where it is generated, 2) to evaluate the ability of generators to expand existing capacity to allow storage onsite for a minimum of 10 years; and 3) to investigate the economic viability of establishing a separate centralized storage facility for Class A LLRW from medical and academic institutions. This piece does not discuss mixed waste disposal issues specifically, but reaches several valuable and interesting conclusions.

An in-state disposal facility along with other options designed to increase disposal capacity are being considered. Extended storage of LLRW is expected to be required for several years after access to the Barnwell facility is to be discontinued. Detailed questionnaires were administered by the New York Energy Research and Development Authority to 206 LLRW generating facilities and site visits were made to 166 facilities. These facilities included nuclear power plants, hospitals, medical research centers, clinical laboratories, universities, industries, and government facilities. Briefly, the results of the survey indicate that 142 facilities would have to store waste on site for extended periods totaling approximately 50,000 cubic feet of LLRW per year requiring storage. Clearly, it is necessary to reduce the volume of waste requiring storage or build enhanced storage capacity.

Although the underlying purpose of this survey was do address the pressing need for enhanced storage capacity for the generation of LLRW, several observations can be culled from this report. As was the case with the survey of EPA laboratories, cost information associated with storage and treatment was, at best, sporadically available. To thoroughly analyze the cost considerations associated with various waste management options, this information is critical to this analysis. Secondly, there existed significant variations between facilities in the philosophy of managing research, though the concerns expressed by these laboratories related to onsite storage were strikingly similar.

Community Partnership Plan, Commonwealth of Pennsylvania, Department of Environmental Protection.

The Commonwealth of Pennsylvania is currently evaluating sites for a LLRW waste disposal facility. The Commonwealth's Department of Environmental Protection is developing a Community Partnership Plan which is a voluntary process whereby local municipalities determine the feasibility of hosting the facility. The construction of the site is in response to the perceived tenuous acceptance of LLRW at the Barnwell disposal facility. Pennsylvania formed a "compact" with Delaware, Maryland, and West Virginia so that transportation and disposal of the low-level waste would be managed at regional level. When the Barnwell facility did not accept the waste (on an earlier) occasion from Pennsylvania generators, more than 120 temporary facilities across the state stored these waste.

The National Governors Association, *Issue Paper From the NGA FFCA Commercial Mixed Waste Subgroup*, 1995.

The National Governors Association (NGA) convened the Federal Facility Compliance Act (FFCA) Task Force in May 1994. A Commercial Mixed Waste Subgroup was recommended to be instituted to examine the feasibility of DOE acceptance of commercial mixed waste. In addition to the legal considerations, it was recommended that information detailing the volumes, waste types, and available commercial treatment options be investigated. If DOE facilities are permitted to accept this waste, the EPA facilities have greater flexibility in selecting options for waste disposal.

This article describes the correspondence between DOE and the NGA Task Force. Originally a Low-Level Waste Forum was established in 1986 to respond to state concerns regarding commercial mixed waste management. After FFCA was passed in 1992, DOE engaged in a cooperative agreement with NGA to facilitate implementation of the Act and concluded that the appropriate mechanism for addressing DOE acceptance of mixed waste was via the Forum. A report was prepared that determined the technical, regulatory, and legal considerations associated with DOE acceptance of commercial mixed waste would not result in significant additional requirements for DOE. Another important issue centered around the availability of information on commercial waste types and volumes.

Mixed Waste Treatment Study (Draft), Prepared for the Electric Power Research Institute, Research Project 3800-22, December 1995.

The lack of treatment/disposal capacity for mixed waste has resulted in most nuclear utilities having to store relatively small volumes of mixed waste onsite under the RCRA hazardous waste permitting requirements. Since most utilities do not have RCRA permits, the regulatory complexities associated with the management of mixed waste is a significant concern to generators. This Mixed Waste Treatment Study was designed to provide nuclear utilities with a comprehensive reference document regarding mixed waste treatment to facilitate the identification of treatment/disposal options to minimize or eliminate the need for permitted storage and, ultimately, reduce the cost of mixed waste management.

The approach and objectives of this study are analogous to the EPA work assignment. Initially, a survey of utilities was performed to identify those regulatory options being employed by utilities for the onsite management of mixed wastes. In addition, an overview of the types of waste, generating processes, available onsite and offsite treatment options, and an assessment of potential emerging technologies for treatment is outlined. A majority of the waste generating processes and management obstacles discussed in this study are not particularly germane to EPA facilities. A brief highlight of the hazards and treatment issues associated with liquid scintillation cocktails is provided. The two mixed waste treatment facilities identified as the applicable treatment providers are Perma-fix and DSSI.

The Mixed Waste Inventory Report, Idaho National Engineering Laboratory, Prepared for the U.S. Department of Energy, November 1995.

The MWIR-1995 database contains a detailed, nationwide compilation of information on DOE mixed waste streams and treatment systems. In addition, the 1995 version include data on nonmixed, transuranic (TRU) waste streams. The data set addresses "stored" streams which are defined as (a) streams currently in storage at both EM-30 and EM-40 sites and (b) streams that have yet to be generated but are anticipated within the next 5 years from sources other than environmental restoration or decontamination and decommissioning activities.

The database represents a comprehensive accounting framework that may serve as a model for other national surveys such as the *National Profile.* The processes that generate mixed waste at DOE facilities are fundamentally different than that of the EPA laboratories. The survey reveals that DOE facilities do in fact generate LSC cocktails, but these represent minute quantities relative to other waste streams.

The 1993 Massachusetts Low-Level Radioactive Waste Survey Report, The Massachusetts Low-Level Radioactive Waste Management Board, [data collection and analysis conducted by Richard B. Fairfull] 11/94.

This excerpt provides a summary of the total mixed LLRW produced in Massachusetts in 1993 and the concomitant management option. The second largest category 55,577 ft^3 of mixed waste generated was liquid scintillation fluid which was disposed of by incineration at out-of-state facilities. The onsite storage for decay management option represented only 406.9 ft^3 whereas the waste shipped for disposal accounted for 52,692 ft^3. This reinforces the finding that mixed waste streams generated at EPA laboratories are very similar to those in the commercial, medical, and federal communities.

Low-Level Radioactive Waste Management in North Carolina, Briefing prepared by the North Carolina Department of Environment, Health and Natural Resources, Division of Radiation Protection, 1994.

A summary document prepared by the North Carolina Department of Environment, Health, and Natural Resources, Division of Radiation Protection, highlighted the volumes and radioactivity levels of the mixed waste stored in North Carolina at the end of 1994. The survey results indicated that approximately 750 cubic feet of mixed waste containing 22 curies were being

stored at 12 facilities. The Academic category accounted for 60 perceny of the volume of the stored waste by only 8.6 percent of the radioactivity. Conversely, the Industrial category accounted for 29 percent of the volume and 91 percent of the radioactivity. It was concluded that although the survey results may underestimate the total amount of mixed waste being stored in North Carolina, these amounts are relatively small.