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Hazardous Waste Minimization Assessment: Fort Sam Houston, TX

by
Seshasayi Dharmavaram
Bernard A. Donahue

On November 8, 1984, the U.S. Congress signed into public law the Hazardous and Solid Waste Amendments (HSWA) act establishing a national policy on waste minimization. Regulations created to support the HSWA require hazardous waste generators to develop and follow a hazardous waste minimization program. Moreover, the Department of Defense has established a goal of 50 percent reduction in hazardous waste generation by 1992 (compared to 1985 generation data).

After surveying hazardous material procurement, hazardous waste generation, and current methods of treatment, storage, and disposal, researchers conducted feasibility and economic analyses of minimization options and prepared a hazardous waste minimization (HAZMIN) plan for Fort Sam Houston, TX.

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FOREWORD

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CONTENTS

SF 298	1
FOREWORD	3
LIST OF FIGURES AND TABLES	10
1 INTRODUCTION	15
Background	15
Objective	16
Approach	17
Scope	17
Mode of Technology Transfer	17
2 HAZARDOUS WASTE MINIMIZATION	18
Source Reduction	19
Better Operating Practices	19
Product/Material Substitution	19
Process Changes	20
Recycling Onsite/Offsite	20
Treatment	21
HAZMIN Assessment	22
3 FORT SAM HOUSTON	28
History/Geography	28
Tenants	29
Environmental Quality	29
Air Pollution Control	29
Water Pollution Control	30
Solid Waste Management	31
Hazardous Materials Management	31
Hazardous Waste Management	31
4 SOURCES OF WASTE GENERATION AND TYPES OF WASTES	33
Source Types	33
Motor Pools and Vehicle Maintenance Facilities (MPVM)	33
Hospitals, Clinics, and Laboratories (HCL)	35
Paint Shops (PS)	37
Photography, Printing, and Arts/Crafts Shops (PPAS)	38
Industrial Maintenance, Small Arms Shops (IMSS)	38
Aviation Maintenance Facilities (AMF)	39
Other Source Types	40
Wastes Selected for Technical/Economic Analysis	40
5 WASTE MINIMIZATION FOR MOTOR POOLS AND VEHICLE MAINTENANCE FACILITIES AND AVIATION MAINTENANCE FACILITIES	67
Source Reduction	67
All Wastes - Better Operating Practices	67
All Wastes - Better Operating Practices - Segregation	68
All Wastes - Better Operating Practices - Periodic Maintenance and Cleanup of Equipment	68
Solvent (PD680-I) - Material Substitution -PD680-II	68

CONTENTS (Cont'd)

	Page
Solvent (PD680-II) - Better Operating Practices	68
Solvent (PD680-II) - Better Operating Practices - Emissions Minimization	68
Solvent (PD680-II) - Process Change	69
Solvent (PD680-II) - Process Change - Testing	69
Solvent (PD680-II) - Process Change - Solvent Sinks (Equipment) Modification	69
Carburetor Cleaner - Production Substitution	69
Used Oil - Better Operating Practices - Selective Segregation	69
Used Oil - Process Change - Fast Lube Oil Change System (FLOCS)	70
Caustic Wastes - Product Substitution	70
Caustic Wastes - Process Change - Hot Tank (Equipment) Modifications	70
Aqueous or Caustic Wastes - Process Change - Dry Ovens	70
Aqueous Wastes - Process Change - Two-Stage Cleaning in Jet Spray Operations	71
Antifreeze Solution - Better Operating Practice - No Draining	71
Antifreeze Solution - Product Substitution	71
Antifreeze Solution - Process Change - Testing	71
Antifreeze Solution - Process Change Extend Life	72
Brake Shoes (Asbestos Waste) - Better Operating Practices	72
Recycling Onsite/Offsite	72
Solvent (PD680-II) - Onsite Recycling - Distillation	72
Solvent (PD680-II) - Offsite Recycling - Contract/Leased Recycling	72
Solvent Carburetor Cleaner - Offsite Recycling	73
Carburetor Cleaner - Offsite Recycling - Contract/Leased Recycling	73
Used Oil - Onsite Recycling - Gravity Separation/Blending	73
Used Oil - Offsite Recycling - Closed-Loop Contract	73
Used Oil - Offsite Recycling - Sale to Recyclers	73
Antifreeze Solutions - Onsite Recycling	74
Lead-Acid Batteries - Offsite Recycling	74
Aqueous or Caustic Wastes - Equipment Leasing	74
Dirty Rags/Uniforms - Onsite/Offsite Recycling - Laundry Service	74
Treatment	74
Used Oil - Onsite Pretreatment - Filtration	74
Used Oil - Onsite Pretreatment - Gravity Separation	75
Used Oil - Onsite Treatment - Blending/Burning	75
Aqueous Wastes - Onsite Pretreatment - Filtration	75
Aqueous Wastes - Onsite Treatment - Evaporation	76
Aqueous Wastes - Onsite Treatment - Waste Treatment	76
Carburetor Cleaner - Offsite Treatment	76
Antifreeze Solution - Offsite Treatment	76
Lead-Acid Battery Electrolyte - Treatment	76
NICAD Battery Electrolyte - Treatment	76
 6 WASTE MINIMIZATION FOR HOSPITALS, CLINICS, AND LABORATORIES . . .	 88
Regulations	89
Source Reduction - All Wastes	90
IW/PW/GW/Sharps - Better Operating Practices - Segregation	90
Source Reduction - Infectious and Pathological Wastes	90
IW/PW - Better Operating Practices - Segregation/Labeling	90
IW/PW - Better Operating Practices - Collection/Transportation	90
IW/PW - Better Operating Practices - Storage	90

CONTENTS (Cont'd)

	Page
Treatment - Infections and Pathological Wastes	90
IW/PW - Treatment/Better Operating Practices - Incineration	90
IW/PW - Treatment/Better Operating Practices - Autoclaves/Retorts	91
Source Reduction - Sharps	91
Source Reduction - Hazardous Wastes	91
HW - Better Operating Practices - Inventory	91
HW - Better Operating Practices - Proper Storage	91
HW (solvents) - Better Operating Practices - Segregation	92
HW (solvents) - Product Substitution	92
HW (solvents) - Process Change	92
LW - Better Operating Practices - Disposal	92
HW (mercury) - Better Operating Practices	93
HW (mercury) - Process Change	93
HW (formaldehyde) - Better Operating Practices	93
HW (formaldehyde) - Process Change	93
CW - Better Operating Practices - Collection/Disposal	93
CW - Better Operating Practices	93
CW - Product Substitution	94
RW - Product Substitution	94
RW - (²²⁶ Radium) - Product Substitution	94
Recycling Onsite/Offsite - Hazardous Wastes	94
HW (xylene, other solvents) - Recycle Onsite - Distillation	94
HW (solvents) - Offsite Recycling	95
HW (mercury) - Offsite Recycling	95
HW (formaldehyde) - Onsite Recycling - Reuse	95
HW (photographic chemicals) - Recycle Onsite/Offsite - Silver Recovery	95
Treatment - Infectious and Pathological Wastes	95
HW (solvents) - Onsite Treatment - Incineration	95
HW (solvents) - Offsite Treatment - Incineration	96
LW (acids/alkalis) - Treatment - Neutralization	96
 7 WASTE MINIMIZATION FOR PAINT SHOPS	 99
Source Reduction	100
Solvent-Based Paints - Product Substitution - Powder Coatings	100
Solvent-Based Paints - Product Substitution - Water-Based Formulations	100
Solvent-Based Paints - Product Substitution - Two-Component	
Catalyzed Coatings	101
Solvent-Based Paints - Product Substitution - Radiation-Curable Coatings	101
Paint Wastes - Better Operating Practices - Segregation	101
Solvent Wastes - Better Operating Practices - Adopt Good Manual	
Spraying Techniques	101
Solvent Wastes - Better Operating Practices - Avoid Adding Excess Thinner	102
Solvent Wastes - Better Operating Practices - Avoid Excessive Air	
Pressures for Atomization	102
Solvent Wastes - Better Operating Practices - Maintain Equipment Properly	102
Solvent Wastes - Better Operating Practices - Lay Out Equipment Properly	102
Solvent Wastes - Better Operating Practices - Isolate Solvent-Based	
Spray Units From Water-Based Spray Units	102

CONTENTS (Cont'd)

	Page
Solvent Wastes - Better Operating Practices - Close Floor Drains in Production Area	102
Solvent Wastes - Better Operating Practices - Purchase Proper Quantities of Paints	103
Solvent Wastes - Better Operating Practices - Segregate Wastes	103
Solvent Wastes - Better Operating Practices - Standardize Solvent Use	103
Solvent Wastes - Product Substitution - Use High-Solids Formulations	103
Solvent Wastes - Process Change - Choose Proper Coating Equipment	103
Solvent Wastes - Process Change - Replace Conventional Spray Units With Electrostatic Units	103
Solvent Wastes - Process Change - Replace Air-Spray Guns With Pressure Atomized Spray Guns	104
Aqueous Wastes - Process Change - Dry Paint Booths	104
Recycling Onsite/Offsite	104
Paint Wastes - Onsite Recycling - Recycle Paint Overspray/Sludge	104
Solvent Wastes - Onsite Recycling - Ultrafiltration, Distillation, or Evaporation	104
Solvent Wastes - Offsite Recycling - Closed-Loop Contract	105
Treatment	105
Solvent Waste - Onsite Pretreatment - Gravity Separation	105
Paint/Solvent/Aqueous Wastes - Offsite Treatment	105
 8 WASTE MINIMIZATION FOR PHOTOGRAPHY, PRINTING, AND ARTS/CRAFTS SHOPS	 107
Source Reduction - Photography and Printing Operations	108
All Wastes - Better Operating Practices - Proper Material Handling and Storage	108
Source Reduction - Photographic Operations	108
Photographic Chemicals - Better Operating Practices - Proper Chemical Storage	108
Photographic Films - Material Substitution - Nonsilver Films	108
Other Photographic Wastes - Material Substitution	109
Fixing Bath Solutions - Process Change - Extend Bath Life	109
Photographic Wastewater - Process Change - Reduction in Water Use	109
All Photographic Wastes - Process Change	110
Source Reduction - Printing Operations	110
Metal Etching/Plating Wastes - Process Change	110
Metal Etching and Plating Wastewater - Process Change - Reducing Water Use	110
Lithographic Plate Processing Chemicals - Better Operating Practices - Reduced Chemical Use	110
Lithographic Plate Processing Plates - Better Operating Practices - Proper Storage/Recycling	110
Lithographic Plate Processing Plates - Material Substitution	111
Web Press Wastes - Process Change - Break Detectors	111
Waste Inks/Cleaning Solvents/Rags - Better Operating Practices	111
Waste Inks - Better Operating Practices	111
Waste (Flexographic) Inks - Product Substitution - Water-Based Inks	111
Waste Inks - Product Substitution - UV Inks	112
Waste Inks - Product Substitution - EB Inks	112
Waste Inks - Product Substitution - Heat Reactive Inks (Web Presses)	112
Cleaning Solvents - Good Operating Practices - Pour Cleaning	112
Cleaning Solvents - Good Operating Practices	113

CONTENTS (Cont'd)

		Page
	Cleaning Solvents - Product Substitution - Nonhazardous Formulations	113
	Fountain Solutions - Product Substitution	113
	Waste Paper - Good Operating Practices - Reduce Usage	113
	Recycling Onsite/Offsite - Photographic Operations	113
	Spent Fixing Bath Solution - Onsite Recovery	113
	Photographic Films - Offsite Recycling - Silver Recovery	114
	Recycling Onsite/Offsite - Printing Operations	114
	Metal Etching and Plating Wastewater/Sludge - Onsite/Offsite	
	Recycling - Material Recovery	114
	Used Metal Wastes - Offsite Recycling	114
	Waste Inks - Onsite Recycling	114
	Waste Inks - Offsite Recycling	114
	Cleaning Solvents - Onsite Recycling - Distillation	114
	Waste Paper - Offsite Recycling	115
	Treatment - Printing Operations	115
 9	WASTE MINIMIZATION FOR INDUSTRIAL MAINTENANCE,	
	SMALL ARTS/CRAFTS SHOPS	118
	Treatment - Alkaline Cleaning	119
	Source Reduction - Dry Media Blasting	119
	Dry Wastes - Product Substitution - Plastic Media Blasting	119
	Dry Wastes - Process Change - Plastic Media Blasting	120
	Source Reduction - Cutting and Threading	120
	Cooling/Cutting Oils - Better Operating Practices - Material Conservation	120
	Cooling/Cutting Oils - Better Operating Practices - Proper	
	Concentration Maintenance	120
	Cooling/Cutting Oils - Better Operating Practices - Proper Storage	120
	Cooling/Cutting Oils - Better Operating Practices - Operator	
	Handling/Segregation	120
	Cooling/Cutting Oils - Better Operating Practices - Chemical Purchase	121
	Cooling/Cutting Oils - Better Operating Practices - Metal Chips Removal	121
	Cooling/Cutting Oils - Proper Substitution	121
	Cooling/Cutting Oils - Process Change - Equipment Modifications	121
	Cooling/Cutting Oils - Process Change - Process Controls	121
	Cooling/Cutting Oils - Process Change - Control Bacterial Growth	121
	Treatment - Cutting and Threading	122
	Cooling/Cutting Oils - Onsite Treatment	122
	Cooling/Cutting Oils - Offsite Treatment	122
 10	WASTE MINIMIZATION FOR OTHER SOURCE TYPES	124
	Heating and Cooling Plants	124
	Used Oils Burning	124
	Laundry and Drycleaning Facilities	125
	Woodworking and Preserving	125
	Pesticide Users	126
	Open Burning/Open Detonation	126
	Firefighting and Training	127
	Underground Storage Tanks (USTs)	127

CONTENTS (Cont'd)

	Page
11 WASTE MINIMIZATION FOR MISCELLANEOUS WASTES	142
Polychlorinated Biphenyls	142
PCBs in Transformers	142
PCB Waste Management	143
USACERL's PCB Transformer System	143
Onsite Mobile Treatment Units	143
Ordnance	143
Contaminated Soil	144
Empty Containers	144
Returning Drums to Suppliers	144
Contracting With a Reconditioner	144
Contracting With a Scrap Dealer or Disposal in a Landfill	145
12 ECONOMIC ANALYSES FOR HAZARDOUS WASTE MINIMIZATION	147
Used Oil	147
Cleaning Solvent Waste	150
Battery Acid	152
Antifreeze Solution	154
Paint Thinner Waste	155
Aqueous Paint Sludge Waste	158
13 SUMMARY AND RECOMMENDATIONS	171
Summary	171
Recommendations	172
Plan Implementation	172
METRIC CONVERSION TABLE	174
REFERENCES	175
APPENDIX A: FORT SAM HOUSTON - HAZMIN PLAN	181
APPENDIX B: HAZMIN PROTOCOL AND SURVEY FORMS	198
APPENDIX C: FORT SAM HOUSTON - LIST OF TENANTS	216
LIST OF ABBREVIATIONS AND ACRONYMS	218
DISTRIBUTION	

FIGURES

Number		Page
1	Waste Minimization Hierarchy	23
2	Waste Minimization Techniques	24
3	Hazardous Waste Minimization Program Development Procedure	26
4	Hazardous Waste Minimization Assessment and Feasibility Analysis Procedure	27
5	Comparison of the Net Present Values for Minimization of Used Oil Wastes	166
6	Comparison of the Net Present Values for Cleaning Solvent Waste Minimization Options	167
7	Comparison of the Net Present Values of Options for Minimizing Battery Acid Waste	168
8	Comparison of the Net Present Value of an Option for Minimizing Waste Antifreeze Solution	169
9	Comparison of the Net Present Values of Options for Minimizing Paint Thinner Waste	170

TABLES

1	List of Waste Exchanges	25
2	Hazardous Waste Generation at FORSCOM Installations	42
3	List of Sources Ranked In Order of Importance	43
4	Motor Pools and Vehicle Maintenance (MPVM) Facilities	44
5	Quantities of Hazardous Wastes Generated at MPVM Facilities	45
6	Quantities of Hazardous/Nonhazardous Materials Used at MPVM Facilities	46
7	Hospitals, Clinics, and Laboratories (HCL)	47
8	Quantities of Hazardous Wastes Generated at HCL	48
9	Quantities of Hazardous/Nonhazardous Materials Used at HCL	51
10	Paint Shops (PS)	54
11	Quantities of Hazardous Wastes Generated at PS	54
12	Quantities of Hazardous/Nonhazardous Materials Used at PS	55

TABLES (Cont'd)

Number		Page
13	Photography, Printing, Arts/Crafts Shops (PPAS)	56
14	Quantities of Hazardous Wastes Generated at PPAS	56
15	Quantities of Hazardous/Nonhazardous Materials Used at PPAS	57
16	Industrial Maintenance, Small Arms Shops (IMSS)	58
17	Quantities of Hazardous Wastes Generated at IMSS	58
18	Quantities of Hazardous/Nonhazardous Materials Used at IMSS	59
19	Aviation Maintenance Facilities (AMF)	59
20	Quantities of Hazardous Wastes Generated at AMF	60
21	Quantities of Hazardous/Nonhazardous Materials Used at AMF	60
22	Other Waste Sources	61
23	Quantities of Hazardous Wastes Generated by Other Waste Sources	61
24	Quantities of Hazardous/Nonhazardous Materials Used by Other Sources	62
25	Waste Generation Summary	63
26	Total Waste Generation Rates By Waste Categories	66
27	Typical MPVM and AMF Operations With Materials Used and Wastes Generated	77
28	Waste Classification for MPVM and AMF	78
29	Partial Listing of Waste Recyclers, Haulers, Equipment Leasing Companies, and Equipment Manufacturers	79
30	Equipment Leasing Costs	83
31	Parts Cleaning Equipment Purchase Costs	84
32	Test Criteria for Used Cleaning Solvent (PD680-II)	84
33	Solvent Recovery Equipment	85
34	Aqueous Waste Volume Reduction Equipment Suppliers	87
35	Waste Classification for HCL	97

TABLES (Cont'd)

Number		Page
36	Properties of Radionuclides Used in Hospitals	98
37	Waste Classification for Paint Removal, Painting, and Brush Cleaning	106
38	Typical PPAS Operations With Materials Used and Wastes Generated	116
39	Waste Classification for PPAS	117
40	Waste Classification for IMSS	123
41	Used Oil Fuel Specification	128
42	Amounts of Typical Hazardous Wastes Generated from Drycleaning Operations	129
43	Drycleaning and Laundry Operations and Wastes Classification	130
44	Wastes Classification: Woodworking and Preserving Operations	131
45	Waste Classification: Pesticides	132
46	Ingredients Contained in Propellants, Explosives, and Pyrotechnics (PEP)	141
47	Common Elements Found in PEP and OB/OD Soil Residue	141
48	PCB Replacement/Treatment/Disposal Services	146
49	PCB Transformer Retrofilling Services	146
50	Savings to Investment Ratios and Discounted Payback Periods for a Fast Lubricating Oil Change System	162
51	Savings to Investment Ratios and Discounted Payback Periods for a Fast Lubricating Oil Change System for 1000 Vehicles	163
52	Purchase Cost of Distillation Stills (in 1989 Dollars)	163
53	Total Life Cycle Costs of Cleaning Solvent Waste Options at Varied Generation Rates	164
54	Comparison of Options for Cleaning Solvent Waste at Various Generation Rates	164
55	Total Life Cycle Costs of Options for Paint Thinner Waste at Varied Generation Rates	164
56	Comparison of Options for Paint Thinner Waste at Various Generation Rates	165

TABLES (Cont'd)

Number		Page
57	Comparison of the Life Cycle Costs and SIR and DPP Calculations for Small and Medium-sized Operations of Wet and Dry Paint Booths	165
A1	Fort Sam Houston Waste Generation Summary	193
A2	Total Waste Generation Rates by Waste Categories	196
A3	Calculation of the Overall Waste Reduction Factors	197

HAZARDOUS WASTE MINIMIZATION ASSESSMENT: FORT SAM HOUSTON, TX

1 INTRODUCTION

Background

Waste minimization is the process of reducing the net outflow of hazardous solid, liquid, and gaseous effluents from a given source or generating process. It involves reducing air emissions, contamination of surface and ground water, and land disposal by means of source reduction, recycling processes, and treatment leading to complete destruction. Transferring pollutants from one medium to another (e.g., from water to air) by treatment processes is not waste minimization.

On November 8, 1984, the U.S. Congress signed into public law¹ the Hazardous and Solid Waste Amendments (HSWA) act establishing a national policy on waste minimization. HSWA required the U.S. Environmental Protection Agency (USEPA) to issue regulations that began the process of implementing the 1984 amendments to the Resource Conservation and Recovery Act (RCRA).² Among the Federal regulations is a requirement that every generator of hazardous wastes (HW) producing in excess of 2205 pounds (lb)³ per month certify, when hazardous wastes are manifested (listed on a tracking document), that a hazardous waste minimization program is in operation.³ Generators are required to submit biennial reports to the USEPA that describe efforts taken to reduce the volume and toxicity of waste generated during the year. Federal regulations issued in October 1986 clarify the status of small quantity (220 to 2205 lb/month) generators (SQG) of hazardous waste.⁴ SQGs are required to make a "good faith" effort to minimize hazardous waste generation and implement the best available treatment, storage, or disposal alternative economically feasible.

The more restrictive regulations, high treatment/disposal expenses, and increased liability costs prompted private industry and several government agencies to critically examine means that will lead to prevention of pollution as opposed to end-of-pipe treatment methods. Waste minimization is economically beneficial to Army installations. Some of the cost savings realized by minimizing wastes result from: reduced transportation and disposal costs for offsite disposal; reduced compliance costs for permits, monitoring, and enforcement; reduced onsite treatment costs; reduced onsite storage and handling costs; lower risk of spills, accidents, and emergencies; lower long term liability and insurance costs; reduced raw materials costs; reduced waste generation fees; reduced effluent costs and assessments from local sewage treatment plants; reduced production costs through better management and efficiency; and reduced operation and maintenance costs.

In fiscal year (FY) 1987, the Army directly paid (through a centrally funded process) the Defense Logistics Agency (DLA) \$17.5 million for disposal of only 15 percent of the total wastes generated

¹ Public Law 98-616, *Hazardous and Solid Waste Amendments* (1984).

² Public Law 94-480, *Resource Conservation and Recovery Act* (1976).

³ Regardless of the units of measure used in source documents, all measurements have been converted to English units. Metric conversions are on p 174.

⁴ 40 CFR 261, *Identification and Listing of Hazardous Waste* (1985), and 40 CFR 262, *Standards Applicable to Generators of Hazardous Wastes* (1985).

⁵ Federal Register, Vol 51, No. 190 (October 1986), pp 35190-35194.

by Army installations.⁵ The DLA, through its Defense Reutilization and Marketing Offices (DRMOs) located in several regions, was responsible for disposal of most categories of hazardous waste generated by the installations. The installations do not have a separate funding account for waste disposal and therefore do not realize the responsibility for waste generation and the cost of disposal. Beginning in FY 1990, the accounting process for waste disposal will be decentralized to provide a strong economic incentive to reduce waste generation.⁶ The installations will have to pay the waste disposal costs from their operation and maintenance budget.

In December 1985, the Joint Logistics Commanders (JLC) established the following Department of Defense (DOD) policy:⁷

The generation of hazardous waste (HW) at Department of Defense activities is a short- and long-term liability in terms of cost, environmental damage, and mission performance. A HW minimization program shall be developed by each service and shall contain the basic concepts in this directive.

Recognizing the liabilities of improper disposal and the advantages of waste minimization, JLC set a DOD-wide goal of 50 percent reduction in hazardous waste generation by 1992, based on the baseline generation in 1985. The Department of the Army is following this DOD goal and has established a policy⁸ applicable to all Active Army, Reserve, and National Guard installations.

Army installations are like small cities with a variety of activities that generate pollution within their boundaries. Unlike civilian cities, where there are many SQGs, each installation as a whole (and its Commander) is a generator held responsible for complying with regulations and reducing pollution from all the activities within its boundaries. Environmental protection must be made a primary concern of every employee on an installation. Everyone must make an effort to protect our air, water, and land from industrial and chemical contaminants. Pollution prevention pays not only in terms of complying with regulations, saving in disposal/treatment costs, reducing liability and improving public image, but also in maintaining the good health and welfare of all people.

Each installation is responsible for implementing a hazardous waste minimization (HAZMIN) plan and each employee, military and civilian, is responsible for following the plan. To comply with both the letter and the spirit of the law, the U.S. Army Forces Command (FORSCOM) contracted the U.S. Army Construction Engineering Research Laboratory (USACERL) to prepare HAZMIN plans for five FORSCOM installations. This report contains the HAZMIN plan for Fort Sam Houston, TX.

Objective

The objective of this research was to develop a hazardous waste minimization plan for Fort Sam Houston, TX to include the actions necessary to accomplish reduction in volume and toxicity of hazardous wastes generated.

⁵ V.J. Ciccone and Associates, Inc., *Program Status Report: Department of the Army Hazardous Waste Minimization* (U.S. Army Environmental Office, August 1988), p 43.

⁶ Office of the Assistant Chief of Engineers, "Hazardous Waste Disposal Funding," DAEN-ZCP-B Memorandum (Department of the Army, 28 October 1988).

⁷ Joint Logistics Commanders, "Hazardous Waste Minimization Program," Memorandum to the Deputy Secretary of Defense (12 December 1985).

⁸ *Hazardous Waste Minimization (HAZMIN) Policy* (Department of the Army, 1989).

Approach

The following approach was used to develop the plan:

1. Prepare a study strategy that included development of a protocol for conducting a HW inspection/survey. The inspection/survey protocol was developed from literature reviews and previous HW surveys performed by the U.S. Army Environmental Hygiene Agency (USAEHA), and USACERL.
2. Conduct a survey of all possible waste generated at Fort Sam Houston from 4 through 9 December 1988, 7 through 9 February 1989, and 22 through 24 March 1989.
3. Compile data on hazardous materials procurement by different users on the installation.
4. Compile data on hazardous waste generation for each possible generator on the installation.
5. Compile information on each waste stream including: waste characterization; waste source; baseline generation; current method of treatment, storage, and disposal and the associated costs; and past/present minimization efforts and associated costs.
6. Prioritize waste streams by criteria such as: composition, quantity, degree of hazard, method and cost of disposal, compliance status, liability, and potential to minimize.
7. Identify and prioritize minimization options for major waste streams.
8. Conduct feasibility and economic analyses of minimization options.
9. Prepare the final plan.

Scope

Although an attempt was made to quantify all the hazardous materials procured by and hazardous wastes generated at Fort Sam Houston, a study of the mass balance of chemicals entering and wastes leaving the installation (which allows development of strategies for waste minimization) could not be completed because of lack of data.

Some of the tables prepared for this report contain blanks. The blanks do not represent zero waste generation, but rather that the data was not available. Fort Sam Houston should make every effort to locate the data and update the tables. Proper inventory control will generate data for future use.

Mode of Technology Transfer

The HAZMIN plan (Appendix A) will be presented to Fort Sam Houston for implementation. The recommendations that have been made should be incorporated in the installation policies and regulations.

2 HAZARDOUS WASTE MINIMIZATION

The HSWA requires generators of hazardous wastes to certify that they have a waste minimization program. Every waste shipment manifest (or tracking document) is accompanied by the following declaration, in compliance with Section 3002(b) of HSWA:

The generator of the hazardous waste has a program in place to reduce the volume and toxicity of such waste to the degree determined by the generator to be economically practicable; . . .

HSWA Section 3002(a) requires the generators of hazardous wastes to submit a biennial report, including their efforts to reduce the volume and toxicity of wastes generated. HSWA Section 3005(h) requires facilities that treat, store, or dispose of hazardous wastes to submit annual reports accompanied by similar declarations on waste minimization.

The HSWA also established a national land disposal restriction program by developing a schedule for banning all hazardous wastes from land disposal by May 1990. In November 1986, USEPA issued the first set of restrictions regarding land disposal of hazardous wastes.⁹ These restrictions prohibited land disposal of untreated and concentrated spent solvents. Deadlines for banning land disposal were extended for other solvent wastes because it was felt that sufficient nationwide capacity for treatment did not then exist. It may well be that in a few years commercial land disposal will be available only to hazardous waste residues from treatment processes. In addition, generators must realize that they may be held liable for environmental contamination. Therefore, alternatives to land disposal are necessary.

Minimization includes any reduction in hazardous waste generation and any activities that result in either a reduction in the total volume or quantity of hazardous wastes, or a reduction in the toxicity of hazardous wastes produced, or both, as long as the activities are consistent with the national goal minimizing present and future threats to the environment.¹⁰ By this definition, treatment options such as incineration are considered HAZMIN techniques. HAZMIN, therefore, can be achieved by:

1. **Source Reduction:** reducing or eliminating waste generation at the source, usually within a process or by an action taken to reduce the amount of waste leaving a process,
2. **Recycling Onsite/Offsite:** using a waste as an effective substitute for a commercial product, or as an ingredient or feedstock in a process. Recycling also implies reclaiming useful constituent fractions from a waste or removing contaminants, allowing the waste to be reused, or
3. **Treatment:** eliminating the hazardous characteristics of a waste to make it nonhazardous to human health and the environment.

The hierarchy that should be used in a waste minimization process is shown in Figure 1.* The small amount of residue (e.g., ash) from the process will require "ultimate" disposal (e.g., landfill burial). Various waste minimization techniques, discussed in detail below, are shown in Figure 2. These techniques can be divided into three HAZMIN categories. Maximum waste reduction is usually achieved by using the best combination of suitable techniques from all three categories.

⁹ Federal Register, Vol 51, No. 190.

¹⁰ *Minimization of Hazardous Waste. Executive Summary and Fact Sheet*, EPA/530/SW-86/033A (U.S. Environmental Protection Agency [EPA], Office of Solid Waste, 1986).

* Figures and tables are located at the end of each chapter.

Source Reduction

Source reduction is at the top of the hierarchy and is the "ideal" solution to the problem of hazardous wastes. All wastes have some potential to be minimized by using better operating practices, product/material substitution, and process changes. Source reduction eliminates the need for storage, transportation, treatment, and residue disposal, and the associated liabilities.

Better Operating Practices

Better operating practices include the simplest source reduction measures such as reducing spillage and leaks, inventory control, employee education/training and control, and better materials/wastes handling practices (e.g., segregation). Experience has shown that education and training programs in safety and hazardous materials/wastes management can be very effective. One approach to good housekeeping is to automate or computerize continuous processes, thereby decreasing human involvement and errors. Waste segregation is an extremely important housekeeping practice that should be incorporated into the work standard. For example, mixing a minute quantity of hazardous waste with a large quantity of nonhazardous waste generates a large quantity of hazardous waste that has to be reported and properly disposed of. Therefore, wastes should never be mixed (e.g., solvents and oils, trash and solvents/oils, gasoline and solvents, etc.). Also, the purity of the waste determines its recyclability (discussed below). Combining dissimilar wastes reduces the chance of recovering either one of them. By using waste segregation and improved handling, most generators could considerably reduce the quantities of wastes generated.

Inventory control is perhaps the most critical and effective better operating practice for HAZMIN. It is a low-cost and easily implementable method that is popularly used in many industries.¹¹ The quantities of wastes generated can be minimized by reducing the amount of excess material in stock and the amount used in any process or operation. Controlling the purchase of raw materials is the first step in inventory control. Standard operating procedures that allow local or Federal supply system purchase of only approved materials should be established. New materials must be approved before purchase. A tracking system should be established to ensure that all the materials purchased are used properly. Such a materials "manifest" system is a tool that is useful not only in minimizing waste generation but also in complying with the Community "Right-To-Know" law.¹²

Product/Material Substitution

Product/material substitution is a major category of source reduction. Most hazardous wastes are so categorized because they result from processes that use hazardous materials as input or in an intermediate step. Product substitutions are necessary to minimize the environmental impacts of some products (e.g., pesticides such as DDT, 2,4,5-T etc.) and associated wastes. Use of nonhazardous or less hazardous products as substitutes is therefore recommended. An example of product substitution is replacing cadmium plated products with zinc or aluminum plated products in metal finishing operations. Material substitution can also be viewed as a change in a process that involves using nonhazardous or less hazardous input or raw material, or a material with few impurities. Less hazardous materials with fewer impurities can reduce the likelihood of generating high volumes of hazardous wastes. Some examples of material substitution are:¹³ replacing chlorinated solvents (e.g., trichloroethylene [TCE],

¹¹ G.E. Hunt and R.N. Schechter, "Minimization of Hazardous-Waste Generation," in *Standard Handbook of Hazardous Waste Treatment and Disposal*, H.M. Freeman Ed. (McGraw Hill, New York, NY, 1989), pp 5.3-5.27; D. Huisingh, *Profits of Pollution Prevention: A Compendium of North Carolina Case Studies* (North Carolina Board of Science and Technology, Raleigh, NC, 1985).

¹² Public Law 99-499 Title III, *Superfund Amendments and Reauthorization Act* (1986).

¹³ *Alternative Technology for Recycling and Treatment of Hazardous Wastes*, Third Biennial Report (California Department of Health Services, Alternative Technology and Policy Development Section, 1986).

1,1,1-trichloroethane, etc.) with hot caustic solutions or detergents in degreasing operations; using noncadmium pigments in ink manufacture; and replacing cyanide formulations with noncyanide formulations in cadmium electroplating baths.

One major form of product/material substitution is "aqueous" substitution; the use of water-based materials as inputs or products in a process. Many aqueous alternatives have been developed by the chemical industries. Some examples of aqueous substitution are:¹⁴ replacing organic liquids (e.g., TCE, Stoddard solvent, xylene, toluene, etc.) with water-based products (e.g., Citrikleen, Histoclear, etc.) in metal cleaning and degreasing operations; replacing petroleum-based fluids with water-based fluids in metalworking and machining operations; substituting solvent-based ink with water-based ink in the printing processes; and using a water-based developing system instead of a solvent-based system in the manufacture of printed circuit boards.

Process Changes

Some generators will have to consider either improvements in the manufacturing process or even major changes in the technological processes to achieve waste reduction. Process change is a category of source reduction and includes source control. Source control implies examination and reevaluation of the processes that generate hazardous waste. Process optimization and increased efficiency were terms commonly used in source control projects to obtain the best quality product. Not much attention was paid to the waste. The concept of source control, therefore, is not new. Optimizing a process or increasing its efficiency also reduces the quantities of wastes generated. Process change or source control can further be divided into: process/equipment modifications, improved controls, and energy/water conservation.

Process/equipment modifications will require that operating/manufacturing processes and equipment used for waste minimization be redesigned. Some examples of process modifications are:¹⁵ using dry plastic media blasting instead of wet chemical stripping (with methylene chloride, hot caustics, etc.) to remove paint from metallic substrates, replacing concurrent rinsing with countercurrent rinsing in metal plating and surface finishing operations, and retrofitting the existing chrome-plating processes with equipment that reduces the discharge of rinsewater to almost zero.

Improved controls could also be included under "better operating practices." It implies proper control of processes or equipment to reduce emissions and waste generation. Conserving energy/water by controlling the heat input and reducing the amount of rinse/process water used can reduce emissions, solid wastes, and wastewater.

Recycling Onsite/Offsite

After all source reduction techniques have been examined for a particular waste stream, recycling options, both onsite and offsite, should be considered. Three types of onsite recycling operations are available:¹⁶ (1) reuse of waste in the same process (e.g., continuous recycling of rinsewaters in plating/finishing operations, recycling of tetrachloroethylene in dry cleaning operations), (2) use of the waste in a different process (e.g., using waste battery acid as a neutralizing agent in an industrial wastewater treatment plant), and (3) processing the waste to produce a reusable product (e.g., distilling solvents, burning used oil for heat content, etc.). Offsite recycling includes methods used to process the waste to produce a usable product (e.g., re-refining waste oil, reclaiming lead from lead-acid

¹⁴ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

¹⁵ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

¹⁶ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

batteries, recovering silver from fixing bath solutions, incinerating hazardous wastes for heat content, etc.).

Recycling of hazardous wastes is encouraged by the Federal and State governments. Hazardous waste generators must explore all recycling opportunities for wastes whether or not the generation is reduced. Industrial recyclers are available for a number of wastes. Recyclable wastes include:¹⁷ unused commercial chemical products, halogenated solvents, oxygenated solvents, hydrocarbon solvents, petroleum products (including oils and hydraulic fluids), pickling liquor, unspent acids and alkalis, and selected empty containers. Some offsite programs recycle batteries, mercury, and drums. Offsite recycling is also a major part of the program called "solvent leasing." In this program, a generator will lease process equipment. The equipment owner provides clean solvent and is responsible for removing and recycling used solvent.

An offsite recycling method that needs to be evaluated by DLA and DRMOs is the use of waste exchanges to recycle wastes. Waste exchanges are operations that engage or assist in transferring wastes and information concerning wastes. They help generators develop effective waste minimization programs and comply with legislative and regulatory requirements. A list of waste exchanges operating in North America is provided in Table 1. Some of these organizations are waste information "clearinghouses" and others are waste material exchanges. The information exchanges are usually nonprofit organizations that provide information about the availability and demand of waste materials. Material exchanges act as agents or brokers, and usually take the waste materials, process them, and market them for profit.

Treatment

Treatment of hazardous wastes should be the last minimization choice; after source reduction and recycling, but before "ultimate" disposal. Treatment alternatives must be considered only if source reduction and recycling are not feasible or economically practical. A treatment process: (1) destroys or detoxifies a hazardous waste to a material safe for disposal, (2) concentrates or reduces the volume of wastes for safer handling and disposal, or (3) immobilizes the hazardous components to keep them from the environment. Generators of large amounts of hazardous wastes usually treat the wastes onsite; generators of small amounts of hazardous wastes use offsite treatment facilities. With the increased availability of commercially packaged treatment units, generators may opt to treat wastes onsite. A hazardous residue requiring "ultimate" disposal may still be generated. Treatment processes include neutralization, filtration, evaporation, incineration, and precipitation. Acids, bases, and plating wastes are some of the waste streams that can be treated readily.

Four broad categories of treatment technologies (physical, chemical, biological, and thermal) are applicable to all waste streams. Physical treatment techniques, generally involving phase separation (e.g., solids from liquids), include:¹⁸ separation techniques such as centrifugation, clarification, coagulation, decantation, encapsulation, filtration, flocculation, flotation, foaming, sedimentation, thickening, and ultrafiltration; and specific component removal techniques such as adsorption, blending, catalysis, crystallization, dialysis, distillation, electrodialysis, evaporation, magnetic separation, leaching, ion exchange, liquid-liquid extraction, reverse osmosis, stripping, and sand filtration. Some of the physical treatment techniques can be readily used as pretreatment steps (e.g., filtration, sedimentation, etc.) before onsite recycling of wastes and also as a part of better housekeeping practices.

¹⁷ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

¹⁸ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

Chemical treatment techniques that use the differences in chemical properties of substances include:¹⁹ mound adsorption, fixation, oxidation, precipitation, reduction, chlorination, chlorinolysis, cyanide destruction, degradation, detoxification, ion exchange, neutralization, ozonation, and photolysis. Biological treatment techniques include:²⁰ activated sludge digestion, aerobic processes, composting, trickling filtration, and waste stabilization. Biological treatment processes rely on microorganisms (bacteria, fungi, etc.) to decompose and/or bioaccumulate the contaminants in wastes.

As a HAZMIN technique, treatment, unlike source reduction or recycling, has legal (or RCRA) implications. A permit has to be obtained for treatment of hazardous wastes. Only elementary neutralization (e.g., laboratory acids/bases neutralization) and "enclosed" wastewater and other treatment units are exempt from permitting requirements.²¹

HAZMIN Assessment

The HAZMIN assessment procedure and development of the plan (Appendix A) was based on the methods described in *EPA (Environmental Protection Agency) Manual for Waste Minimization Opportunity Assessments*,²² and other references.²³ The assessment protocol and survey forms are attached in Appendix B.

Development of a successful HAZMIN program contains four critical phases: planning and organization, assessment, feasibility analysis, and implementation (see Figure 3). Figure 4 indicates the two phases that USACERL was involved in. The U.S. Army Forces Command (FORSCOM) did the initial planning and organization for Fort Sam Houston.

The first task in the assessment phase is to gather all the available information pertaining to hazardous materials procurement, waste generation, and operating procedures. Second, the waste streams are prioritized and selected for assessment. Team members are selected and a survey agenda is organized. The next step is the actual survey that includes: interviewing supervisors, foremen, and operators; observing housekeeping practices; inquiring about standard operating procedures; and gathering information about levels of administrative controls. Waste minimization options are then evaluated. The most promising options are selected for detailed evaluation.

In the feasibility analysis phase, the technical and economic feasibility of selected minimization options is evaluated. This phase includes the installation information (Chapter 3) and data gathered (Chapter 4), waste minimization techniques for the various types of sources and wastes (Chapters 5 to 11), and economic analysis of minimization options for select waste streams (Chapter 12).

Fort Sam Houston should implement the HAZMIN plan according to methodology presented in Chapter 13. Successful implementation of the plan will require command support and commitment. Continuance of the HAZMIN program in the future will require constant evaluation of the goals, reassessment of generators, and developing newer/better procedures for minimizing wastes.

¹⁹ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

²⁰ *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

²¹ 40 CFR 260, *Hazardous Waste Management System: General* (1985).

²² *EPA (Environmental Protection Agency) Manual for Waste Minimization Opportunity Assessments*, EPA/600/2-88-025 (USEPA, Hazardous Waste Engineering Research Laboratory, 1988).

²³ R.H. Hemstreet, "How to Conduct your Waste Minimization Audit," in *Waste Minimization Manual* (Government Institutes, Inc., Rockville, MD, 1987), pp 61-75; M.E. Resch, "Hazardous Waste Minimization Audits using a Two-Tiered Approach," *Environmental Progress*, Vol 7 (1988), pp 162-166; M. Drabkin, C. Fromm, and H. M. Freeman, "Development of Options for Minimizing Hazardous Waste Generation," *Environmental Progress*, Vol 7 (1988), pp 167-173.

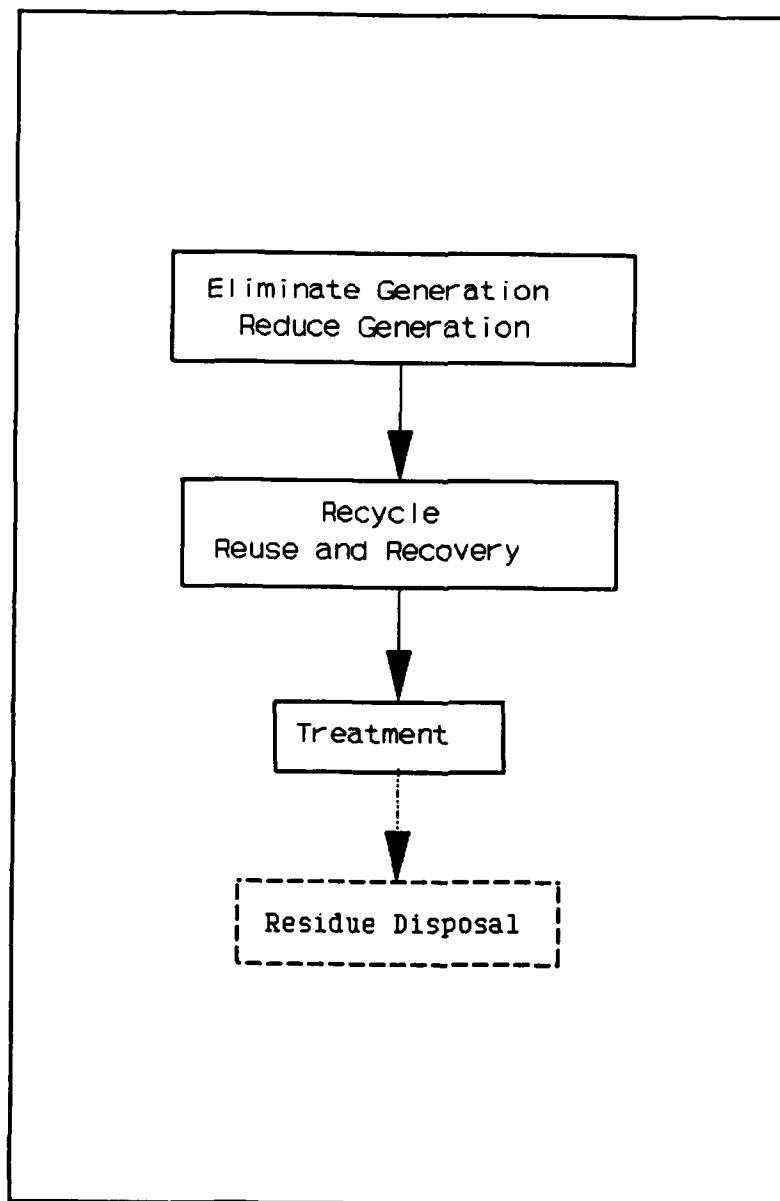


Figure 1. Waste minimization hierarchy.

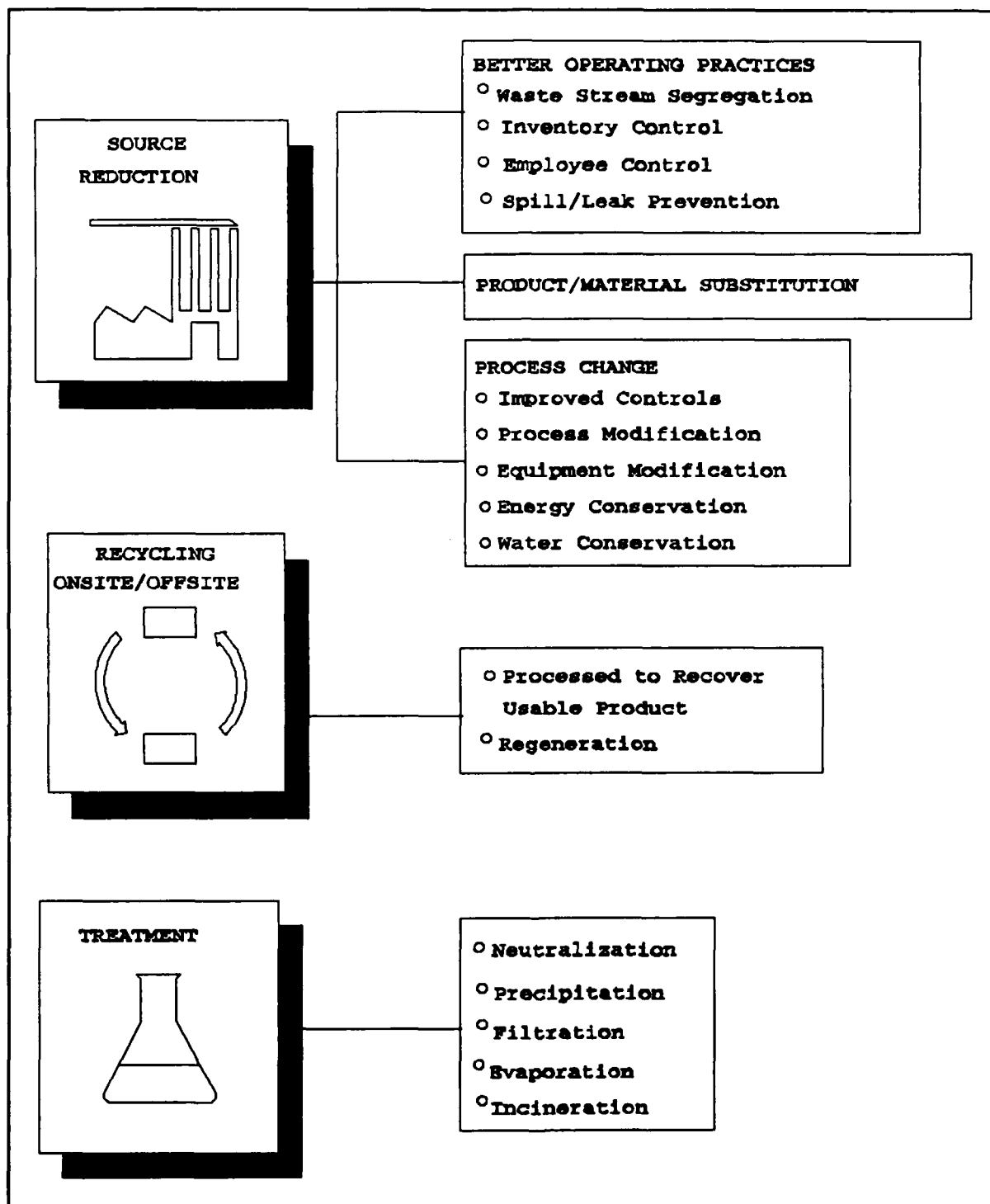


Figure 2. Waste minimization techniques.

Table 1
List of Waste Exchanges*

Alberta Waste Materials Exchange
4th Floor Terrace Plaza
4445 Calgary Trail South
Edmonton, Alberta
CANADA T6H 5R7
(403) 450-5461

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

Canadian Inventory Exchange*
900 Blondin
Ste-Adele, Quebec
CANADA J0R 1L0
(514) 229-6511

Canadian Waste Materials Exchange
Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario
CANADA L5K 1B3
(416) 822-4111

Enkam Research Corporation*
P.O. Box 590
Albany, NY 12202
(518) 436-9684

Georgia Waste Exchange*
c/o America Resource Recovery
P.O. Box 7178, Station A
Marietta, GA 30065
(404) 363-3022

Great Lakes Regional Waste Exchange
470 Market Street, S.W.
Suite 100-A
Grand Rapids, MI 49503
(616) 451-8992

Indiana Waste Exchange
P.O. Box 1220
Indianapolis, IN 46206
(317) 634-2142

Industrial Materials Exchange Service
2200 Churchill Road
IUSEPA/SLPC-24
Springfield, IL 62706
(217) 782-0450

Industrial Waste Information Exchange
New Jersey Chamber of Commerce
5 Commerce Street
Newark, NJ 07102
(201) 623-7070

Manitoba Waste Exchange
c/o Biomass Energy Institute, Inc.,
1329 Niakwa Road
Winnipeg, Manitoba
CANADA R2J 3T4
(204) 257-3891

Montana Industrial Waste Exchange
Montana Chamber of Commerce
P.O. Box 1730
Helena, MT 59624
(406) 442-2405

Northeast Industrial Waste Exchange
90 Presidential Plaza, Suite 122
Syracuse, NY 13202
(315) 422-2405

Resource Recovery of America**
P.O. Box 75283
Tampa, FL 33675-0283
(813) 248-9000

South Waste Exchange
Urban Institute
UNCC Station
Charlotte, NC 28223
(704) 547-2307

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

Tennessee Waste Exchange
Tennessee Manufacturers and Taxpayers
Association
226 Capitol Blvd., Suite 800
Nashville, TN 37219
(615) 256-5141

Wastelink, Division of Tenecon
Associates*
P.O. Box 12
Cincinnati, OH 45174
(513) 248-0012

Western Waste Exchange
ASU Center for Environmental Studies
Krause Hall
Tempe, AZ 85287
(602) 965-1858

Zero Waste Systems**
2928 Poplar Street
Oakland, CA 94608
(415) 893-8261

*For-profit information exchange
**Material waste exchange.

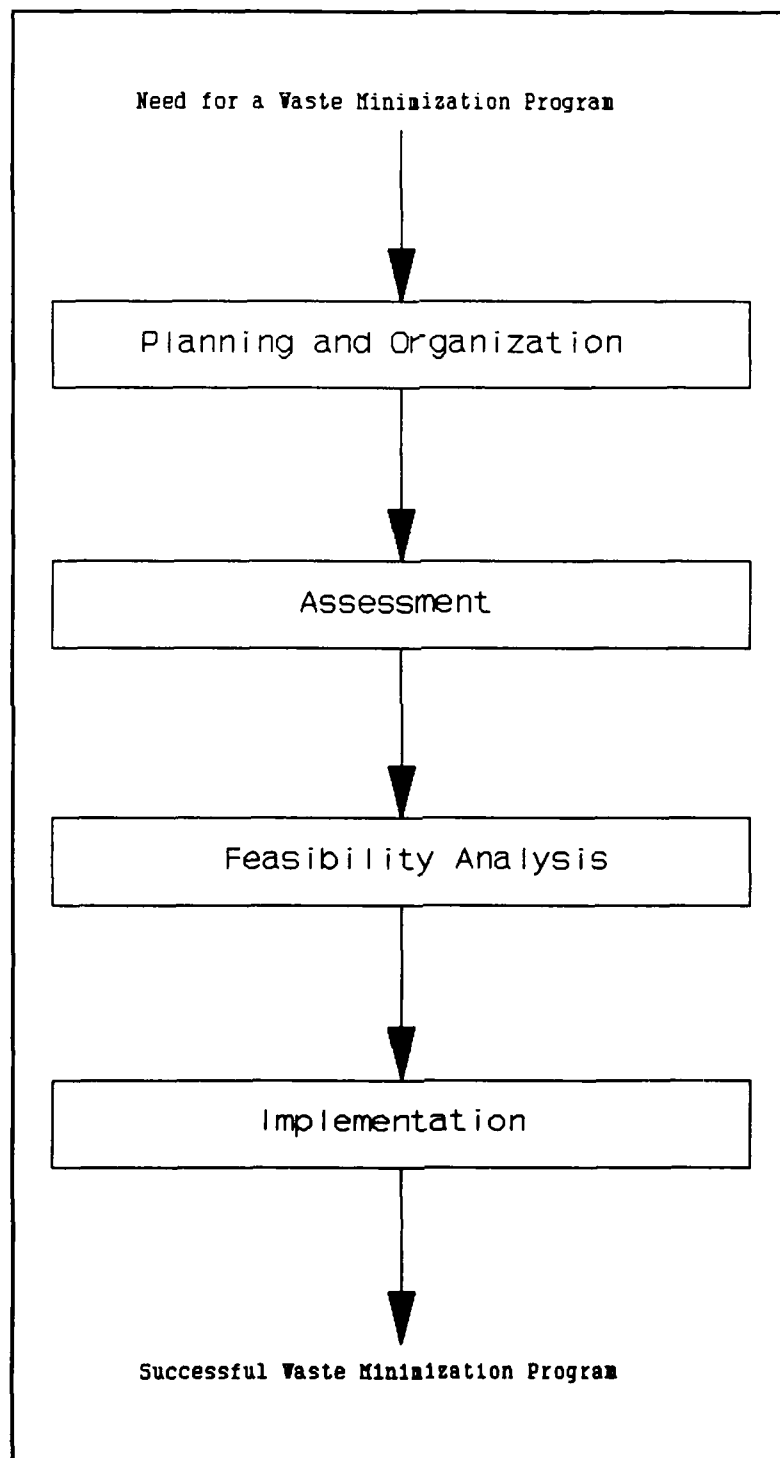


Figure 3. Hazardous waste minimization program development procedure.

ASSESSMENT

- **Prioritize and Select Assessment Targets**
- **Select and Interview Personnel**
- **Collect HM Procurement and HW Generation Data**
- **Survey Site and Review Data**
- **Prioritize Waste Streams and Generate Options**
- **Screen and Select Options for Further Evaluation**

FEASIBILITY ANALYSIS

- **Technical Evaluation**
- **Economic Evaluation**
- **Select Options for Implementation**

Figure 4. Hazardous waste minimization assessment and feasibility analysis procedure.

3 FORT SAM HOUSTON

History/Geography

Federal troops have been in the city of San Antonio, Texas, since 1850 when the Alamo was reconstructed. The Alamo was used as a quartermaster depot for support of troops stationed west of San Antonio. Construction of Fort Sam Houston as a permanent Army post began in 1870 on the 93 acres donated by the city over a period of 5 years. In December of 1879, the first building (the Quadrangle) was built and occupied. The post, then known as the Post of San Antonio, was not only a quartermaster depot, but also a border patrol station and a fort against Indian attack. It was named Fort Sam Houston in 1890 after General Sam Houston, the former Commander-In-Chief of the Army of the Republic of Texas.

After 1898, Fort Sam Houston was a training and outfitting station for troops being sent to the Spanish-American War, and then a quartermaster depot for troops being sent to the Philippines. Since the turn of the century more buildings were erected and the mission was expanded to include an Infantry Post, a Cavalry Post, an Artillery Post, a hospital, and a chapel. In the 20th century the mission of Fort Sam Houston has included mobilization, training, and development. By 1937, additional construction of barracks, general depot, quarters, and the Brooke Army Medical Center (BAMC), extended the installation to 3265 acres.

Fort Sam Houston was the main training center in the country by the beginning of World War II. With the Japanese attack on Pearl Harbor, the fort was put under wartime status and as many as 11 armies were organized and mobilized from there. During the same time, the headquarters of the Fourth U.S. Army (spread over Texas, Louisiana, Oklahoma, and New Mexico), was moved to the Quadrangle from the Presidio of Monterey, California. The Fourth U.S. Army was eventually deactivated in 1971. During the Korean Conflict, many of the troops were inducted at Fort Sam Houston and many of the wounded were treated at the large medical facility.

In 1971, the headquarters of the Fifth U.S. Army was moved to Fort Sam Houston from Fort Sheridan, Illinois. Currently, the Fifth U.S. Army covers an eight-state area of the central and southcentral United States for reserve activities. The command of Fort Sam Houston, however, was transferred to FORSCOM headquartered at Fort McPherson, GA.

Following a major reorganization of the Army medical departments in 1973, a Health Services Command (HSC) was established with headquarters in Fort Sam Houston. An Academy of Health Sciences (AHS) was also formed to include medical training and field service. BAMC is regarded as the world's largest military medical center. HSC is in charge of AHS and BAMC is currently run by the U.S. Air Force. Because of the many medical activities on Fort Sam Houston, it is unique and distinct from other FORSCOM installations.

Fort Sam Houston is located in south central Texas, 2.5 miles northeast of San Antonio. It is kidney-shaped; approximately 4.25 miles long and 1.5 miles wide. The surrounding land is urban, residential, and commercial, with some suburban agricultural properties located northeast of the installation.

Fort Sam Houston contains a number of archeologically and historically significant areas; the Quadrangle, the Clock Tower, the Pershing House, the Eisenhower House, and Memorial Chapel have been included in the National Register of Historical Places. About 540 acres of the southwest sections of Fort Sam Houston have been dedicated as a National Historical Landmark and include a number of residential and troop-type buildings. The original Quartermaster Depot is also located there. Some of the most famous Army personalities served at Fort Sam Houston including General Eisenhower,

General Pershing, General MacArthur, and President Theodore Roosevelt. The first plane used on a military mission was prepared and flown from Fort Sam Houston. This led to formation of the U.S. Air Force.

Tenants

The mission of Headquarters, Fifth U.S. Army and Fort Sam Houston is to command, operate, and administer use of available resources. In addition, it also provides supervision, training, guidance, intelligence support, legal assistance, financial management, administrative, and logistical support, and training areas for all troop units, activities, tenants, and supported U.S. Army Reserve Commands and Units. Medical activities have their own logistical support, for medical supplies and field maintenance, under the BAMC. Among the major tenants at Fort Sam Houston are:

1. Health Services Command (HSC)
2. Brooke Army Medical Center (BAMC)
3. Academy of Health Sciences (AHS)
4. U.S. Army Fifth Recruiting Brigade (SW)

Other tenants are listed in Appendix C.

Environmental Quality

This section discusses the status of environmental quality as affected by the number of pollution sources located at Fort Sam Houston. The information has been extracted from *Environmental Assessment - Fort Sam Houston, Texas*,²⁴ and other assessments.²⁵

Air Pollution Control

Fort Sam Houston and its subinstallations are located in the Metropolitan San Antonio Intrastate Air Quality Control Region (AQCR) Number 217. In 1982, the USEPA classified the AQCR to be in compliance with the National Ambient Air Quality Standard (NAAQS) for sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and total suspended particulates. The Texas Air Quality Control Board (TACB) has adopted the NAAQS and monitors the air quality at Fort Sam Houston with seven air surveillance monitors and one continuous monitor located on the post. The city of San Antonio and Fort Sam Houston in particular are in compliance with the NAAQS.

The major source of air pollutants at Fort Sam Houston is the post incineration facility which incinerates "red bag" (infectious, sharps, general, etc.) wastes generated by BAMC and other medical activities. Although there are a number of incineration units at the central facility, only one unit (460 pounds per hour) is operated at any time. There are no secondary controls for emissions from the incinerators; minimal quantities of air pollutants are generated. One problem is that the plastic from the red bags melts and prevents proper distribution of flame and heat, causing the incinerators to break down frequently.

²⁴ *Environmental Assessment - Fort Sam Houston, Texas*, Draft Report (Department of the Army, Headquarters Forces Command, March 1988).

²⁵ B.N. McMaster, et al., *Installation Assessments of Fort Sam Houston, Tex., and Subinstallations: Camp Bullis, Canyon Lake Recreation Area*, DRXTH-ES-IA-81314 (Prepared for the Commander, Fort Sam Houston, Texas, and the U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD, 1982).

A smaller laboratory incinerator (50 pounds per hour), located at Building 2630 was originally designed to burn infectious hospital wastes but is currently unused. A third incinerator, located near the Quadrangle, is used for burning paper (classified documents) and is operating in compliance with standards.

A number of heating plants and small water heaters in buildings are also located at Fort Sam Houston. The large boilers are located at the main post laundry, BAMC, AHS, FUSA Headquarters, troop dining facilities, and the Beach Pavilion. All of them use natural gas as a fuel and hence very small quantities of air pollutants are released to the atmosphere. Open burning and detonation is not conducted. Munitions are burned at Camp Bullis approximately 10 times a year and coordinated with TACB authorities.

Particulate emissions from the main carpentry shop are controlled with a large cyclone separator. The quantities of dust generated from three other small shops were not considered significant enough to warrant installation of control equipment.

A number of mobile sources of air emissions (administrative/tactical/recreation vehicles) exist at Fort Sam Houston. However, servicing on a regular basis, improving fuel efficiency, and maintaining emission control equipment have minimized the air emissions.

Water Pollution Control

The water supplied throughout Fort Sam Houston is moderately hard, but good quality. Several samples from the different wells throughout the fort and San Antonio are tested regularly. Samples are also submitted to a regional laboratory and the analysis provided to the Texas Department of Health.

All the wastewater generated at Fort Sam Houston is discharged to the city of San Antonio's sewerage system. Wastewaters from the eastern part of the installation, including the National Cemetery and the independent school district, are discharged into the city regional collection system and treated at a central facility. The western part of the installation discharges wastewaters into the sewers linked to the Rilling Road Sewage Treatment Plant.

At Camp Bullis, a permitted wastewater treatment plant is operated by Fort Sam Houston's Directorate of Engineering and Housing. The wastewater is collected from the cantonment area and rifle ranges and processed through a grit chamber and manually cleaned bar screens, a primary settling tank, oxidation ponds, a chlorination system, a sludge digester, sludge drying beds, and a tertiary filter. This treatment plant did not perform very efficiently because of high loadings experienced on weekends. Some of the conclusions of previous surveys were that:

The tertiary filters as added to the lagoon system are not effective in reducing biochemical oxygen demands (BOD) and total suspended solids (TSS) to permit limitations.

Wastewater flow (volume) and TSS concentrations at final discharge exceed TDWR permit limitations.

The condition of the treatment plant components and the size of the lagoons required to handle existing or anticipated flow makes it uneconomical to repair or upgrade.

Of all the alternative solutions to the sewage treatment problem at Camp Bullis, land application is considered optimum until the long term solution of a regional sewage treatment plant can be accomplished. The land disposal system has been established and has corrected

the system inadequacies to an acceptable level, meeting the interim NPDES land disposal criteria.

Solid Waste Management

Fort Sam Houston generates an average of 50,000 pounds of solid refuse daily. Most of the refuse comes from family housing, hospital, and administration activities and consists primarily of paper, cardboard, and food wastes.

Domestic garbage, consisting of mixed food waste, paper, and metals, is collected and transported to public landfill sites offpost. At one time, solid waste was disposed of in landfills located in the eastern part of the fort. There are a number of abandoned landfills that were all closed by 1979.

Hazardous Materials Management

A number of insecticides are used at Fort Sam Houston in the pest management program including: Diazanone (o,o-Diethyl o-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphoro-thioate, malathion, chlordane, dursban (chlorpyrifos), phostoxin (aluminum phosphide) and synergized pyrethrins. Herbicides used include Ammate-X (ammonium sulfamate) and Tandex (Karbutilate). Buildings 4168 and 1874 are used to store pesticides and formulate them for use.

Fort Sam Houston has implemented a Pest Control Standard Operating Procedure that contains specific procedures for pest management, mixing and using pesticides, and disposal of containers. Most of the control and actual application is performed by DEH employees according to specified standards.

Small amounts of explosive ordnance are stored in protective bunkers separated from areas used for storing other hazardous materials. Petroleum, oil, and lubricants (POL) products are stored in several temporary and permanent storage areas throughout the fort. A number of underground and above ground storage tanks are used to store fuels (diesel, gasoline, aviation gasoline, etc.). A program for testing for leaks in all underground storage tanks has been completed.

A Spill Prevention Control and Countermeasures (SPCC) and an Installation Spill Contingency Plan (ISCP) have been developed. These plans provide prevention and control measures to minimize the potential for accidental spills of hazardous and toxic materials. They also provide assurance of quick response by cleanup teams in case of accidental spills. Segments of SPCC and ISCP are incorporated in the Installation Hazardous Waste Management Plan. All the plans have been distributed among the various directorates and major commands on post.

Hazardous Waste Management

Fort Sam Houston has developed and implemented a Hazardous Waste Management Plan.²⁶ Some of the topics discussed in the plan include responsibilities; turn-in procedures; a hazardous materials inventory; training; a waste analysis plan; a tracking system; and hazardous waste storage, packaging, labeling, and shipment. A number of installation agencies are represented on a Hazardous Waste Management Board (HWMB) by personnel responsible for proper management of hazardous wastes.

²⁶ *Installation Hazardous Waste Management Plan* (Prepared by the Hazardous Waste Program Manager, Directorate of Engineering and Housing, Fort Sam Houston, Texas, 1988) 26 pp.

The HWMB discusses and makes decisions on all matters pertaining to hazardous waste management and addresses issues such as waste minimization, used solvent elimination, and materials currently in use or being considered for use.

All the waste generating activities are required to appoint hazardous waste managers, maintain logbooks of waste generation, and an accurate inventory of materials purchased, provide analysis of wastes, and compile monthly reports. The hazardous materials inventory is reviewed periodically by the HWMB. Specific turn-in procedures are followed in accordance with instructions provided in the *Defense Utilization and Disposal Manual*.

In compliance with federal regulations, Fort Sam Houston has proposed a training program for all personnel handling, collecting, storing, and transporting hazardous wastes. The personnel are trained to a level consistent with their duties and responsibilities. Analysis of wastes is the responsibility of the hazardous waste program manager who assists the unit managers in collecting representative samples of wastes.

An effective hazardous waste tracking program has been established at Fort Sam Houston. As a result the installation is capable of determining when, what type, and how much waste has been turned in to the interim storage facility, when it was transported offsite, the shipping manifest document number, and the destination of the shipment.

All the wastes that are turned in for disposal are stored at a conforming storage facility. They are ultimately transported to the Defense Reutilization and Marketing Office (DRMO) located on Kelly Air Force Base, San Antonio. The waste management contractors then ship the wastes to authorized Treatment, Storage, and Disposal Facilities (TSDFs).

4 SOURCES OF WASTE GENERATION AND TYPES OF WASTES

FORSCOM installations are generally administrative, hospital/medical, or active troop installations. Various quantities of hazardous wastes are generated at these installations depending on their respective missions. For comparison Table 2 shows the quantities of waste generated at 22 installations.²⁷

Fort Sam Houston is reported to have generated 38.3, 36.8, 21.8 metric tons in 1985, 1986, and 1987, respectively, as reported in their annual Defense Environmental Status Report. These are the wastes that were turned in to the DRMO for proper disposal; the numbers do not reflect the actual quantities of wastes generated. The data presented in this chapter were obtained from a survey of the various generators (between 4 and 9 December 1988), monthly generation reports required by the environmental office, and offsite shipping manifests. Analysis of the data indicates that the average annual waste generation rate is 215,542 pounds per year, not including 180 lead-acid and 1980 lithium batteries, and PCB-contaminated equipment.

Source Types

Many different source types generate hazardous wastes. It is necessary to understand each of the source types and the wastes generated before attempting to minimize the total quantities generated.

Fort Sam Houston is mainly a hospital/medical installation with few tenants. The total quantity of waste generated, compared to other FORSCOM installations, is still quite small. Since Fort Sam Houston generates no major waste streams, but small quantities of many different types of wastes, each waste generator was evaluated. The data was used to develop the HAZMIN plan. The first step in the feasibility and technical analysis was to identify and prioritize all the generators on the installation. Next, each generator was considered in order of decreasing importance for characterization of waste streams generated. The most important waste streams were then studied to determine the minimization options and their technical feasibility.

Three different criteria were used to determine the ranking of the different types of sources. The first is the number of such sources on an installation, which can vary depending on the installation's mission. The second is the numbers and quantities of waste streams generated at each type of source, which is generally known or can be estimated. And the third is the minimization potential (including provision for cost of managing wastes) for the wastes for each type of source, which is important in developing a feasible waste minimization plan. Based on the above criteria, each source type was scored on a scale of 1 to 5. The ranking of sources, shown in Table 3, is in decreasing order of the total scores. Each source type is discussed in the same order below.

Motor Pools and Vehicle Maintenance Facilities (MPVM)

FORSCOM installations typically have a variety of motor pools and vehicle maintenance facilities for tactical and nontactical vehicles. Nontactical vehicle motor pools are used to service and maintain all the administrative vehicles (e.g., cars, vans, trucks, etc.), engineering maintenance vehicles (e.g., trucks, bulldozers, forklifts, etc.), and grounds maintenance vehicles (e.g., tractors, mowers, etc.) on the installation. Servicing and maintenance of tactical vehicles is performed at various troop and

²⁷ V.J. Ciccone & Associates, Inc., p C-4.

tactical vehicle motor pools. Tactical vehicles can be divided into track-laying vehicles (e.g., self-propelled howitzers, guns, mortars, armored personnel carriers, etc.) and wheeled vehicles (e.g., cargo trucks, ambulances, truck tractors, wreckers, etc.). Fort Sam Houston has a number of motor pools and vehicle maintenance facilities as shown in Table 4.

Various levels of services are performed on the vehicles at each of the motor pools and vehicle maintenance facilities. Included in the services are: periodic maintenance (e.g., fluids change, tuneup, etc.), transmission maintenance, engine repair, brake servicing, battery repair/servicing, front-end alignment, and unique repairs (as required, for different tactical vehicles). The typical repair operations that use hazardous materials and generate hazardous wastes are: oil and grease removal, engine parts and equipment cleaning, solution replacement, and paint stripping and painting (discussed later under *Paint Shops*). Among the equipment commonly used at motor pools and vehicle maintenance facilities are: solvent sinks (parts cleaning), hot tanks (for engine and radiator cleaning), and spray equipment.

Some general categories of hazardous materials used at motor pools and vehicle maintenance facilities are: batteries, oils, petroleum distillates, mineral spirits, varsol, halogenated solvents, aromatic hydrocarbons, oxygenated hydrocarbons, mixtures, acids, and alkalis. A variety of nonhazardous materials (e.g., sorbent, rags, etc.) are used in conjunction with these hazardous materials and also generate hazardous wastes.

Each motor pool generates different quantities of wastes, as listed in Table 5. The blanks in Table 5 (and similar tables throughout this report) do not represent zero waste generation, but rather that the data were not available. Fort Sam Houston should make every effort to locate the data and update the tables. Proper inventory control will generate data for future use. For comparison, the quantities of hazardous and nonhazardous materials that lead to the generation of wastes are listed in Table 6. The Directorate of Logistics (DOL) nontactical vehicle maintenance shop (MPVM #1) uses Safety-Kleen owned vats containing parts and immersion-cleaning solvents that are changed every 6 weeks. Two hundred and fifty-five administrative and 33 satellite vehicles in the Transportation Motor Pool (TMP) are serviced at MPVM #1 for "A" and "B" (high-level) maintenance. An area bermed with sand is used to store waste oil drums. A waste consisting of mixed fuels is generated because of poor operating practices or accidental occurrences such as pumping diesel into an engine containing gasoline. Safestep™ is the adsorbent used to clean up spills on the ground in the various shops. The adsorbent is disposed of in a dumpster as a solid waste.

The DOL tactical vehicle maintenance shop (MPVM #2) repairs 1/4- to 22 1/2-ton wheeled tactical vehicles. About 8500 to 10,000 different repair jobs are handled by MPVM #2. The immersion solvent, supplied in a vat by Safety-Kleen and used to clean carburetors or remove carbon deposits from parts, consists primarily of methylene chloride, O-dichlorobenzene, and cresylic acid. It is changed every 6 weeks. MPVM #2 has a tank containing a caustic solution for cleaning radiators. Spent battery electrolyte (sulfuric acid) from unsealed lead-acid batteries is drained into a tank and neutralized with sodium bicarbonate. No tests are performed on the effluent to determine its lead content. Sealed lead-acid batteries are stored in a storage area and turned in to DRMO.

The DEH vehicle maintenance shop (MPVM #3) maintains approximately 250 vehicles and maintenance equipment. Safety-Kleen equipment is used for parts cleaning and carbon removal; the solvents are replaced every 4 weeks. Sulfuric acid is drained from lead-acid batteries and neutralized onsite with sodium bicarbonate. Empty casings from the drained batteries are turned in to DRMO. Ninety-five percent of the batteries used at MPVM #3 are maintenance-free (sealed). All the drains from MPVM #3 are connected to an oil/water separator, which has not been cleaned or maintained since construction. MPVM #3 also has a dry painting booth used for painting vehicles. No lead-based chemical agent resistant coating (CARC) is used. The dry filters containing paint residue are disposed of as solid waste. Another DEH shop with functions similar to a vehicle/equipment maintenance facility is the grounds section (MPVM #4). About 400 different pieces of grounds,

garden, and lawn maintenance equipment such as lawn mowers, concrete saws, and compressors are repaired there.

The largest quantity of waste oil (16,800 pounds per year [lb/yr]) is generated at the Directorate of Personnel and Community Affairs (DPCA) auto craft shop (MPVM #5), because the facility is used by residents to change lubricating oil in privately-owned vehicles. A couple of Safety-Kleen parts cleaning tanks are available for cleaning parts from minor repair operations. The golf course maintenance shop (MPVM #6) services 39 vehicles (including golf carts, lawn mowers, etc.). They used to have their own recycler for waste oils, however, recycling was discontinued and they were asked to use DRMO's services. Equipment batteries are turned in with the rest of the installation's used batteries at the DOL storage area (Building 4189).

The 485th Medical Detachment motor pool (MPVM #7) repairs and maintains ambulances and other hospital vehicles. Similar maintenance activities occur at the 507th Medical Company motor pool (MPVM #10). The U.S. Army Reserve Equipment Concentration Site (USARECS) vehicle maintenance facility (MPVM #9) services 610 vehicles located onsite and 1500 vehicles from other reserve centers in the region. The serviced vehicles come in many different sizes, including trailers. Instead of using an organic solvent (e.g., PD680-II) for parts cleaning, an aqueous solution (Citrikleen) that can be drained into the sewer system is used at MPVM #9. A part of the AHS motor pool (MPVM #11) at Camp Bullis is maintained by DOL personnel. They maintain a parts cleaning tank and replace the solvent (PD680-II) periodically. MPVM #11 also has a large Safety-Kleen parts cleaning tank.

The Texas Army National Guard vehicle maintenance facility (MPVM #12) services 208 different vehicles including buses, trucks, jeeps, and about 89 generators. The spent antifreeze is not collected, but is allowed to drain into the sewer. About 300 gallons per year (gal/yr) of parts cleaning solvent is purchased locally; used solvent is turned in to DRMO. A considerable quantity (110 gal/yr) of contaminated fuel (gasoline and diesel) is also generated.

The Army and Air Force Exchange Service (AAFES) Post Exchange (PX) gas station (MPVM #13) has both parts and carbon removal equipment supplied by Safety-Kleen. The solvents are changed every 3 weeks. About 10 to 12 oil changes are performed daily at MPVM #13. A contractor has been retained to pick up the used oil. The spent lead-acid batteries are not turned in to DRMO, but are recycled wet using a local recycling firm (TexPak) at a value of \$2.85 each. At Camp Bullis MPVM #14 uses government-owned dip tanks for parts degreasing and carbon removal from carburetors. About 1965 lb/yr of PD680-II is generated. About 155 gal/mo of a mixture of transmission fluid, brake fluid, and petroleum naphtha (90 percent) is sent to the AHS Combat Casualty Care Course (C4) to burn animals for training of medical personnel. Students at C4 are trained to save burn and fire victims.

All the MPVMs combined generate about 70 tons of waste, not including the solvents changed periodically by Safety-Kleen. The DOL shops (MPVM #1, #2) are the largest, followed by DEH (MPVM #3), DPCA Auto Crafts Shop (MPVM #5), AAFES PX gas station (MPVM #13), USARECS Maintenance Facility (MPVM #9), and all the rest. About 25,000 lb/yr of solvents are managed through a Safety-Kleen contract. Used lubricating oil is the largest quantity (78,000 lb/yr) waste generated, followed by spent antifreeze solution (13,000 lb/yr), spent sulfuric acid (9500 lb/yr), transmission/hydraulic fluid (7500 lb/yr), contaminated fuel (7000 lb/yr), and others (30,000 lb/yr).

Hospitals, Clinics, and Laboratories (HCL)

A typical FORSCOM installation has at least one hospital (or medical center), providing full medical and dental services for active duty and retired military personnel and dependents on the installation. Each hospital has many clinics supporting different medical departments (anesthesiology, dermatology, internal medicine, obstetrics and gynecology, pathology, radiology, surgery, urology, etc.).

Each department has laboratories that use hazardous materials and generate hazardous wastes. In addition to hospitals for treating patients, there may be other teaching facilities and laboratories for training personnel belonging to the medical department activity (MEDDAC) section of the military services. Other dental and veterinary clinics and facilities are located on the installation.

The preventive medicine department of the hospital is primarily responsible for the safety and security of medical staff and patients that may be exposed to hazardous materials/wastes and emissions. Many hazardous chemicals and radioactive materials are used in hospitals, clinics, and laboratories. The wastes include: chemical waste, infectious solid waste, noninfectitious waste, pharmaceutical waste, and radioactive waste.

Table 7 lists all the HCLs at Fort Sam Houston. There are seven main complexes: BAMC - Main Hospital (Bldg. 1000); BAMC - Beach Pavilion Complex (Bldg. 2376); BAMC - Medical Laboratory (Bldg. 2630); ISR - Burn Center (Bldg. 2653); Medical Field Service School (Bldg. 2841); BAMC - Troop Medical Clinic, Dental Clinic (Bldg. 1279); and BAMC - U.S. Area Dental Laboratory (Bldg. 2059). The wastes generated and corresponding materials consumed are presented in Tables 8 and 9, respectively. Most of the wastes generated were allowed to go down the drain. As shown in Table 8, only a limited amount of information (i.e., wastes turned in for disposal to DRMO or reported on monthly generation reports) is available on waste generation. More detailed information is available on raw materials consumption. A "worst-case" scenario would be to assume that the amount of wastes generated is equal to the amount of raw materials consumed. In actual practice, some of the material is consumed in laboratory use, some lost due to volatility/evaporation, and the remaining accounts for generation of solid or liquid ("hazardous") waste. Some of the hazardous wastes are expired shelf-life items.

Medical infectious waste (in "red" bags) is the largest quantity (679 tons per year) waste generated by all the BAMC laboratories and services combined and the Regional Veterinary Laboratory Services (HCL #19). Among the laboratory hazardous waste generators, only the BAMC's Department of Clinical Investigation (HCL #16) reported generation of a variety of solvent wastes. About 1300 lb/yr xylene wastes are reported by the Department of Pathology and Area Laboratory Services' Histology Laboratory (HCL #1) and Department of Medicine's Dermatology Service (HCL #13). However, consumption of xylene is reported as only 120 lb/yr. The ISR - Laboratory Division's Radiology section reports generation of 968 lb/yr of toluene; the consumption rate is unknown. About 4900 lb/yr of formalin is generated by the Department of Pathology's Morgue (HCL #2). HCL #1 generates 200 lb/yr of mercury wastes.

A small distillation still is operated at HCL #1 to recover xylene from waste xylene. It is also used for recycling ethyl alcohol. All the infectious waste (primarily pathological - body parts, microbiological wastes, bulk blood, sharps, and isolation trash) from BAMC is incinerated at the Main Post Incinerator. Other infectious waste, also incinerated, comes from the veterinary hospital and consists of plastic syringes, small dead animals, expired chemicals, and trash. BAMC and the veterinary hospital generate about 370 bags and 3 "red" bags per day, respectively. Each incinerator can process about 17 bags per load or 200 bags per day. The incinerators have no secondary controls for emissions. The plastic from the red bags melts and prevents proper distribution of flame and heat, causing the incinerators to break down frequently (once a month). The cost of incineration is reported to be about \$0.40 per pound, or \$540,000 per year.

Examination of material usage rates, in Table 9 indicates that photographic fixer is consumed in a large quantity (20,000 lb/yr), followed by isopropyl alcohol (19,000 lb/yr), methanol (14,500 lb/yr), photographic developer (11,500 lb/yr), ethyl alcohol (11,000 lb/yr), acetone (1900 lb/yr), acetic anhydride (1400 lb/yr), and others (3300 lb/yr). The photographic fixer and developer is used mainly at BAMC - Department of Pathology and Area Laboratory Services' photographic laboratory (HCL #5), BAMC - Department of Radiology's Diagnostic Service (HCL #18), and AHS - Dental Sciences

Division Special Branch (HCL #22). A large quantity of isopropyl alcohol is used by BAMC-pharmacy services (HCL #15) and AHS - Medical and Surgical Division's Anatomical Physiology Branch (HCL #31). BAMC - Department of Pathology - Chemistry Section's STAT laboratory (HCL #7) is the largest user of methanol, followed by HCL #1 and the AHS - Laboratory Sciences Division's Microbiology Branch (HCL #24). No use information was available from the Institute for Surgical Research (ISR).

Paint Shops (PS)

A FORSCOM installation has painting operations ranging from spray painting with cans to painting of large vehicles. DEH paint shops, typically, have the responsibility of painting buildings, preparing signs, painting the fleet of grounds maintenance and other vehicles. DOL paint shops have large paint booths for painting tactical and nontactical vehicles. The only hazardous waste generated by spray painting with cans, which is commonplace throughout the installation, is the empty cans with wet/dried paint residue. Paint thinners used in large painting operations result in generation of large quantities of hazardous waste.

Table 10 lists the facilities that perform painting operations at Fort Sam Houston. The wastes generated are presented in Table 11, with the corresponding material use in Table 12. The most complete waste generation information is available only from the DOL Maintenance Division's Allied Trades Section (PS#1). About 865 lb/yr of heavy duty lacquer thinner (supplied by Safety Kleen), composed of acetone, methyl ethyl ketone, and xylene, is used at the shop. This thinner is applied with a special safety gun and equipment cleaner to clean painting equipment (e.g., spray guns). PS #1 has a water-wall paint booth that is used for repainting vehicles. CARC, enamels, and lacquer paints are all used as surface coatings. Three different types of thinners, corresponding to the coatings, are used at PS #1. The paint booth filters are steam cleaned and reused. The dried sludge that accumulates on the bottom of the wells is scraped and disposed of as solid waste.

PS #1 stores: enamel alkyd camouflage (petroleum distillate, lead compounds); lacquer cellulose nitrate (lead); epoxy and additives (xylene, epoxy resins); dope and lacquer thinner (ignitable solvents); synthetic thinner; ethylene glycol monobutyl ether; paint remover (methylene chloride, methanol); synthol enamel clear finish (lead); acrylic enamel zincrom primer (zinc chromate, xylene, toluene, lead); universal retarder (toluene); primer surfacer (toluene, xylene); acrylic lacquer thinner (toluene); boiled linseed oil; acetone reducer; acrylic lacquer (ketone, alcohol, toluene); varnish (petroleum distillate, lead); dual-etch (phosphoric acid, butyl cellosolve); spray paint cans; and CARC.

The DEH Sign Shop (PS #2) makes reflective signs. Most of the painting is accomplished using a hand brush or a spray can. However, they use a large quantity (8300 lb/yr) of petroleum naphtha supplied by Safety Kleen. The solvent is replaced every 3 weeks. The DEH Paint Shop (PS #3) has a water-wall paint booth that is used for painting large parts or components of equipment. PS #3 also has the responsibility of painting buildings at Fort Sam Houston. A lacquer thinner, containing toluene, ketones, glycol ethers, esters, methanol, etc., is used to clean equipment and brushes. A paint remover containing methylene chloride (SKIMTM) is used to strip paint from components. The mixture of the stripper and water is not disposed of as hazardous waste, but is allowed to drain into the sewer. The sludge from the bottom of the water-wall booth is flushed with water and allowed to drain into the sewer. Most of the solid accumulated on the sides is scraped off and disposed of as solid waste. About 16 booth filters are disposed of every 30 days in a solid waste container.

Although the DPTMSEC Training Support Center (PS #5) uses a number of chemicals, no waste generation information was available. PS #5 accounts for 10 percent of the total material consumption of 5.5 tons. Seventy-five percent of the weight of materials is petroleum naphtha used at PS #2. The same substance also accounts for 75 percent of the total waste (5.8 tons) reported as

generated. Including the thinner supplied by Safety Kleen, 2500 lb/yr of thinner is generated by PS #1; the other paint shops use about 220 lb/yr.

Photography, Printing, and Arts/Crafts Shops (PPAS)

FORSCOM installations have photography and print shops that conduct a wide range of printing operations including standard forms, brochures, pamphlets, newsletters, and circulars. The shops perform image and plate processing. Image processing is a method of preparing artwork that includes typesetting and photoprocessing. The photographic process produces a negative with the light portions of the photographed object filled with large deposits of silver. Among the steps involved in a photographic process are: developing, fixing, washing, and reducing/intensifying. Wastes produced by the photographic processes include: chemical wastes, bath dumps, and wastewaters containing photoprocessing chemicals, silver, etc.

The printing process requires an image carrier (manual, mechanical, electrostatic, or photomechanical) that takes the ink from a roller and transfers it to a rubber blanket. The image is then transferred from the rubber blanket to a paper. Waste produced from the printing process include: waste inks, trash, used plates, used ink containers, damaged or worn rubber blankets, waste press oils (lubricating oils), cleanup solvents, and rags.

Table 13 lists the PPAS at Fort Sam Houston. About 8 tons of waste per year is reported as generated. Quantities of wastes generated by the different shops is shown in Table 14. For comparison, the material use is shown in Table 15. The total material consumption is reported as 23 tons per year. Of the wastes generated, the photographic fixer and developer solutions are generated in largest quantity (11,200 lb/yr), accounting for 70 percent of the total. These waste streams are generated by DPTM - Training and Audiovisual Support Center (TASC) Photographic/Printing Section (PPAS #1), Graphics Section (PPAS #2), and DMA - Topography/Hydrology Center (PPAS #5). After use, the solutions from the baths developing black and white photographs are sent for silver recovery. The color processing solutions are drained in the sewer. Spent Blankrola™ solvent is next in quantity generated (2900 lb/yr), followed by perchloroethylene (1300 lb/yr), and others (800 lb/yr). Most of these wastes are generated by the DOIM - Printing and Publication Branch (PPAS #4).

Of the 23 tons/yr of materials reported as used, nearly 40 percent (22,000 lb/yr) corresponds to the photographic fixer and developer solutions purchased by PPAS #5 and JMMC's Photographic Branch (PPAS #7). PPAS #2 is reported to be the largest user of materials; however, most of the 22,000 lb/yr consumed is nonhazardous anhydrous ammonia.

Industrial Maintenance, Small Arms Shops (IMSS)

The DOL and Directorate of Engineering and Housing (DEH) are usually responsible for the major industrial maintenance, small arms shops, etc., on a FORSCOM installation. The DOL and DEH industrial operations shops repair and maintain office machines, furniture, small arms, nuclear weapons, etc. Tenant units may have their own industrial operations shops conducting maintenance and repair on a small scale.

Industrial shops typically use vapor degreasers for degreasing operations; caustic dip tanks for cleaning iron and aluminum parts; battery recharging and neutralization tanks for battery repair/replacement; painting and paint-stripping equipment (See *Paint Shops* section); and phosphoric/chromic acid tanks for small arms refinishing. These operations use hazardous materials and generate hazardous wastes. A list of IMSS generators is shown in Table 16. Table 17 shows a list of generation rates from the industrial shops.

Many different kinds of hazardous materials are used at these shops, including halogenated solvents (trichloroethylene, 1,1,1-trichloroethane, etc.), paint thinners (xylene, toluene, etc.), corrosive chemicals (alkalis, phosphoric acid, chromic acid, etc.), and radioactive materials. Material use rates are listed in Table 18.

About 3.9 tons of waste are generated annually. Of the five generators, the DOL Maintenance Division's Specialty Equipment and Small Arms Shop (IMSS #3) is the largest (3340 lb/yr). It has two solvent vats, maintained by Safety Kleen, with the petroleum distillate being changed every 6 weeks. IMSS #3 conducts minor repairs on small arms up to 50-caliber weapons. No vapor degreasing operations are currently in use. However, an annual generation of 465 lb/yr of 1,1,1-trichloroethane waste is reported. A Universal Equipment Abrasive Blasting Machine is used for sand blasting, occasionally (2 hr/yr). The blasting sand is Texblast™ used at a rate of 100 lb/yr. The waste sand is mixed with sand and used to cleanup spills.

Among the IMSS, the DEH Metal Shop (IMSS #1) is the other shop that has a solvent tank operated by Safety Kleen. A total of 2880 lb/yr of petroleum naphtha is changed from the tanks at IMSS #1 and IMSS #3. The DEH Plumbing Section (IMSS #2) and IMSS #3 together generate 3700 lb/yr of spent cleaning solvent.

The material use information shows that BAMC-DOL Maintenance Branch (IMSS # 4, #5) uses 15,000 lb/yr of a total of 9 tons per year reported for all IMSS. Most of this amount (14,000 lb/yr) is paint used in painting vehicles, equipment, etc. The remaining amount (1000 lb/yr) corresponds to petroleum naphtha, alcohol, dichlorotetrafluoroethane, cutting/hydraulic oils, etc.

Aviation Maintenance Facilities (AMF)

Most FORSCOM installations have aviation maintenance facilities for maintaining different sizes of helicopters and airplanes. Various levels of services are performed on the aircraft, including: periodic maintenance (e.g., fluids change, tuneup, etc.), engine repair, brake servicing, battery repair/servicing, and unique repairs (if required, for different aircraft). The typical repair operations that use hazardous materials and generate hazardous wastes are: oil and grease removal, engine parts and equipment cleaning, solution replacement, and paint stripping and painting (discussed under *Paint Shops*). The equipment commonly used at these facilities includes: solvent sinks (parts cleaning), hot tanks (for engine cleaning), and spraying equipment.

Some general categories of hazardous materials used are: batteries, oils, petroleum distillates, mineral spirits, varsol, halogenated solvents, aromatic hydrocarbons, oxygenated hydrocarbons, mixtures, acids, and alkalis. A variety of nonhazardous materials (e.g., sorbent, rags, etc.) are used in conjunction with these materials and also generate hazardous wastes.

Table 19 lists all the AMFs located at Fort Sam Houston. Tables 20 and 21 present the available waste generation and material use rates, respectively. No information was available regarding the use and consumption of materials. Of the total of 5.6 tons generated per year, spent cleaning solvent is generated at the rate of 5500 lb/yr, contaminated aviation fuel (JP-4) at 5000 lb/yr, and turbine and hydraulic oils at 600 lb/yr.

The DOL Maintenance Division's Aircraft Section (AMF #1) services 9 helicopters. The turbine oil, containing wear metals, is accumulated in 55-gal drums and disposed of every other year. A considerable amount of contaminated fuel is generated. When the fuel is drained from the helicopters, the water vapor in the atmosphere condenses and contaminates it.

Other Source Types

Other source types at a typical FORSCOM installation include: heating and cooling plants, laundry and drycleaning facilities, sanitary landfills, wastewater treatment plant, troop unit industrial wastewater treatment plant, fire departments, hazardous waste storage facilities, POL storage yards, golf courses, grounds maintenance/garden shops, entomology shops, electrical maintenance shops, storage warehouses, water treatment plants, and other miscellaneous sources unique to each installation.

Fort Sam Houston has a number of power production and heating/cooling plants (HCP) that use hazardous materials and generate potentially hazardous wastes. The DEH Utility Division's Mechanical Branch, Air Condition and Refrigeration Section, and Heating and Boiler Plant are the primary generators. All of them have Safety Kleen equipment and use 2880 lb/yr of petroleum naphtha. About 2500 lb/yr of waste oil is generated by the Power Production Unit. Boiler blowdown is periodically generated by all the boilers. The generation rate (10 gal/day) was known only for the Heating and Boiler Plant, which is also known to use 250 lb/yr of corrosive and caustic chemicals. Other boilers are located at the Main Post Laundry (Building 330), BAMC (Building 1000), Troop Dining Facility (Building 1377), and Beach Pavilion (Building 2376).

The DEH Utility Division is also responsible for electrical repair and maintenance. They have three shops: Electrical Motor Repair, Interior Electrical Maintenance, and Exterior Electrical Maintenance. The Electrical Motor Repair shop is the only generator of concern. A large quantity (6625 lb/yr) of cleaning solvent is used while repairing electrical motors. The cleaning solvent and equipment are supplied by Safety Kleen. The exterior electrical shop maintains all transformers (about 1000) located on Fort Sam Houston. Analysis of PCB in transformer oil is accomplished at a laboratory located at Brooks Air Force Base. A number of transformers containing PCBs have been found and turned in to DRMO for proper disposal. All the transformers must be tested. An inventory and proper procedure for disposition/disposal must be established.

A number of miscellaneous generators unique to Fort Sam Houston, not discussed previously, are listed in Table 22. Tables 23 and 24 list the waste generation and material use rates, respectively. As seen in Table 23, generation rates for most of the generators are unknown. About 1980 lithium batteries are generated each year by the AHS - Joint Medical Readiness Training Center (C-4 Task Force), the AHS - Academy Brigade Supply Branch, and 507th Medical Company. Not including the lithium batteries, the total quantity of materials used by all the generators is about 16 tons per year, with the C-4 Task Force being the largest consumer.

The control and management of pesticides at Fort Sam Houston is the responsibility of DEH. All the pesticides are stored at Building 4168 and DEH personnel mix and apply them to lawns, gardens, and buildings throughout the installation. A number of fertilizers (750 lb/yr) and herbicides (1500 lb/yr) are also stored and used at the Harry Wurzbach Golf Course.

Drycleaning of clothes has not been occurring since 1986. Clothes are only laundered at the Main Post Laundry; drycleaning is performed by a contractor in San Antonio.

Wastes Selected for Technical/Economic Analysis

Table 25 summarizes the data presented in the previous section that were obtained during the HAZMIN survey, monthly generation reports, offsite shipping manifests, and periodic reports submitted to the USEPA, and the Texas Water Commission. Table 26 presents the waste generation rates according to waste categories and source types. PCB-contaminated equipment has not been included in the above summaries. The totals do not also reflect the weights of the batteries turned in for disposal.

Motor pools generate the largest quantity of wastes (137,978 lb/yr) consisting primarily of used oil (85,205 lb/yr), cleaning solvent (21,330 lb/yr), corrosives (12,873 lb/yr), and spent antifreeze (12,975). The next largest generators are the heating and cooling plants (23,965 lb/yr). However, 76 percent of their waste (18,250 lb/yr) is boiler blowdown, which seems to have been overestimated. Occasional discharge of blowdown may not adversely affect the wastewater quality. It may still be within the NPDES limits but this can only be determined by proper testing. Photography, printing, and arts/crafts shops are the next largest generators (13,338 lb/yr) followed by paint shops (11,360 lb/yr), hospitals, clinics, and laboratories (7500 lb/yr), electrical maintenance (6579 lb/yr), and waste storage facility (300 lb/yr). The waste storage facility is not the actual generator of PCB-contaminated soil. However, the contaminated soils collected from locations throughout the post are collected at the waste storage facility.

In terms of total wastes, used oil is the largest quantity (88,303 lb/yr) waste stream. It is followed by nonhalogenated solvents (53,887 lb/yr), corrosives (31,123 lb/yr), spent antifreeze (12,975 lb/yr), halogenated degreasing solvents (5968 lb/yr), paint thinners (2403 lb/yr), contaminated fuels (2095 lb/yr), waste paint-related materials (1234 lb/yr), alcohols (32 lb/yr), and miscellaneous wastes (17,089 lb/yr).

The wastes selected for technical and economic analysis are used oils, cleaning solvents (petroleum naphtha - 42,728 lb/yr, PD-680-II - 11,839 lb/yr, etc.), spent antifreeze, battery acid (9513 lb/yr), paint thinner (1971 lb/yr), and aqueous paint sludge.

Table 2
Hazardous Waste Generation at FORSCOM Installations*

Installation	Quantity of Waste Generated (metric tons)			Quantity of Waste Generated Onsite (metric tons)			Quantity of Waste Generated Offsite (metric tons)		
	1985	1986	1987	1985	1986	1987	1985	1986	1987
A.P. Hill	n/a	0.6	810.7	n/a	0.6	810.7	0.0	0.0	0.0
Bragg	94.5	246.9	258.2	94.5	236.3	242.3	0.0	10.6	15.9
Buchanan	-	-	-	-	-	-	-	-	-
Campbell	181.1	42.3	83.7	181.1	42.3	83.7	0.0	0.0	0.0
Carson	37.5	29.1	28.9	37.5	29.1	28.9	0.0	0.0	0.0
Devens	1142.6	359.4	412.4	1142.6	359.4	412.4	0.0	0.0	0.0
Drum	18.4	89.0	0.7	18.4	89.0	0.7	0.0	0.0	0.0
Hood	46.5	238.5	129.8	46.5	223.0	129.6	0.0	15.5	0.3
Irwin	2090.4	1019.6	1224.1	2090.4	1019.6	1224.1	0.0	0.0	0.0
Lewis	n/a	214.3	668.3	n/a	187.3	649.3	n/a	27.0	19.0
McCoy	62.6	35.1	64.0	23.9	23.5	26.2	38.7	11.6	37.8
McPherson	0.1	2.4	n/a	0.1	2.4	n/a	0.0	0.0	n/a
Meade	n/a	3.1	3.5	n/a	3.1	3.5	n/a	0.0	0.0
Ord	190.9	293.9	n/a	190.9	290.8	n/a	0.0	3.1	n/a
Polk	0.1	20.7	11.5	0.1	20.7	11.5	0.0	0.0	0.0
Presidio, SF	-	-	-	-	-	-	-	-	-
Richardson	21.1	16.4	4.8	21.1	16.4	4.8	0.0	0.0	0.0
Riley	18.6	18.6	18.6	18.6	18.6	18.6	0.0	0.0	0.0
Sam Houston	34.7	33.4	19.8	34.7	32.7	18.5	0.0	0.7	1.3
Sheridan	4.9	4.9	4.9	4.9	4.9	4.9	0.0	0.0	0.0
Stewart Hunter	7.7	302.4	445.8	7.7	302.4	445.8	0.0	0.0	0.0
Wainright	27.2	16.9	63.6	19.4	16.1	29.3	7.8	0.7	34.3
Total	3978.9	2987.5	4253.3	3932.4	2918.2	4144.8	46.5	69.2	108.6

*Source: V.J. Ciccone and Associates, Inc., p C-4.

Table 3
List of Sources Ranked in Order of Importance

Rank	Source Types	Number	Number and Quantities of Waste Streams	Minimization Potential	Total
I	Motor pools and vehicle maintenance facilities	5	5	5	15
II	Hospitals, clinics, and laboratories	5	5	4	14
III	Paint shops	4	4	5	13
IV	Photography, printing	3	5	4	12
V	Industrial maintenance, small arms shops, etc.	3	4	4	11
VI	Aviation maintenance facilities	2	4	4	10
VII	Heating/cooling plants	2	3	2	7
VIII	Electrical maintenance shops	3	1	1	5
IX	Laundry/drycleaning facilities	1	1	1	3
X	Sanitary landfills	1	1	1	3
XI	Wastewater treatment facilities	1	1	1	3
XII	Troop units	1	1	1	3
XIII	Fire departments	1	1	1	3
XIV	Hazardous waste storage facilities	1	1	1	3
XV	POL storage yards	1	1	1	3
XVI	Golf courses	1	1	1	3
XVII	Grounds maintenance and garden shops	1	1	1	3
XVIII	Entomology shops	1	1	1	3
XIX	Other storage warehouses	1	1	1	3
XX	Water treatment plants	1	1	0	2
XXI	Miscellaneous	1	1	0	2

Table 4

Motor Pools and Vehicle Maintenance (MPVM) Facilities

1. DOL - Maint. Div. - Nontactical Veh. Maint. - Buildings 2427, 2429
2. DOL - Maint. Div. - Tactical Veh. Maint. - Buildings 2511, 2512
3. DEH - B&G Div. - Motor Pool - Buildings 4208, 4209
4. DEH - B&G Div. - B&G Branch - Building 3882
5. DPCA - Community Rec. Div. - Auto Craft Shop - Building 2410
6. DPCA - Community Rec. Div. - Golf Course Veh. Maint. - Building 1874
7. 485th Medical Detachment Motor Pool - Building 2378
8. USNR, USMCR Veh. Maintenance - Building 3621
9. USAR CESC #2 Veh. Maintenance - Building 1520, 1521
10. 507th Medical Company Motor Pool - Building 3540
11. AHS Motor Pool - Camp Bullis - Building 6105
12. Texas Army National Guard Motor Pool - Building 3501
13. AAFES, PX Service Station - Building 2610
14. Camp Bullis Motor Pool - Building 6034

Table 5

Quantities of Hazardous Wastes Generated at MPVM Facilities*

Wastes	MPVM #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spent cleaning solvent (or Petroleum Naphtha)		6240**	960	1850	960	1850	540	40		960		1620	460	1620	1965
Spent Immers. Cleaning Comp.		540	540	2350				98					2310	540	
Waste Motor Oil		16,200	10,200	9240	14	16,800	1155	770	1260	3850			3500	14,700	
Spent Antifreeze Sol.				1980	5800		720				3875				
Dead Batteries				5250			910***	210		+			++		
Spent Batt. Electrolyte (Sulfuric Acid)				9338	175										
Waste Trans. Fluid		770		578		770	175	25				4620		+++	
Waste Hyd. Fluid				578											
Contaminated Fuel		1540	3465					35		1540			770		
Caustic Radiator Sol.				3360											
Waste Paint Thinner						25									
Waste PRM (Acetone, MEK, Xylene)					302										
Spent Sorbent SAFESTEP															

* Quantities are reported in pounds per year.

** A blank in this and similar tables does not mean zero generation. Where data is unavailable, Fort Sam Houston should make every effort to locate the data and update the tables. Proper inventory control will generate data for future use in helping meet HAZMIN goals.

*** From 24 golf carts and 2 lawn mowers.

+ Wet turn-in.

++ Wet turn-in to TexPak.

+++ Mixed with waste motor oil.

Table 6

Quantities of Hazardous/Nonhazardous Materials Used at MPVM Facilities*

Materials	MPVM #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Petroleum Naphtha		6240	960	1850	960	1850	540	40			1620		1620	960	1960
Immersion Cleaner		540	540	2350				98					540		
Motor Oil							1260				6300				
Antifreeze						9									
Batteries				5250			910	210							
Battery Electrolyte															
Transmission Fluid							500								
Hydraulic Fluid															
Diesel/Mogas															
Radiator Solution															
Paint Thinner															
Paint															
Sorbent (SAFESTEP)															

*Quantities are reported in pounds per year.

Table 7

Hospitals, Clinics, and Laboratories (HCL)

-
1. BAMC - Dept. of Pathology - Histology; Building 2376
 2. BAMC - Dept. of Pathology - Morgue; Building 2376
 3. BAMC - Dept. of Pathology - Cytology; Building 2376
 4. BAMC - Dept. of Pathology - Microbiology; Building 2630
 5. BAMC - Dept. of Pathology - Photo. Lab.; Building 2376
 6. BAMC - Dept. of Pathology - Gen. Chem.; Building 2630
 7. BAMC - Dept. of Pathology - STAT. Lab.; Buildings 2376, 1000
 8. BAMC - Dept. of Pathology - Toxicology; Building 2630
 9. BAMC - Dept. of Pathology - Immunoassay; Building 2630
 10. BAMC - Dept. of Pathology - Immunobiology; Building 2630
 11. BAMC - Dept. of Pathology - STAT Chem./Hematology; Building 2376
 12. BAMC - Dept. of Pathology - Blood Bank; Buildings 1000, 2376
 13. BAMC - Dept. of Medicine - Dermatology; Building 2376
 14. BAMC - Dept. of Medicine - Pulmonary Disease; Building 2376
 15. BAMC - Pharmacy; Building 1000
 16. BAMC - Dept. of Clinical Investigation; Building 2376
 17. BAMC - Preventive Medicine - Environmental Health; Building 1000
 18. BAMC - Dept. of Radiology - Diagnostic Svc.; Building 2376
 19. BAMC - Regional Vet. Lab.; Building 2630
 20. AHS - Dental Sciences Div. - Hygiene Branch
 21. AHS - Dental Sciences Div. - Dental Lab.
 22. AHS - Dental Sciences Div. - Dental Spec. Branch
 23. AHS - Laboratory Sciences Div. - Clinical Lab.; Building 2841
 24. AHS - Laboratory Sciences Div. - Microbiology Br.; Building 2841
 25. AHS - Laboratory Sciences Div. - Clinical Microscopy; Building 2841
 26. AHS - Laboratory Sciences Div. - Chemistry Br.; Building 2841
 27. AHS - Preventive Medicine Div. - Entomology Lab.; Building 2841
 28. AHS - Preventive Medicine Div. - Environ. Qual. Lab.; Building 2841
 29. AHS - Preventive Medicine Div. - Med. Zool. Br.; Building 3393
 30. AHS - Medical Surgical Div. - Pharmacy Br.; Building 2841
 31. AHS - Medical Surgical Div. - Anatomical Physiology Br.; Building 2841
 32. AHS - Veterinary Sciences Div.; Building 2840
 33. AHS - X-Ray Branch; Building 2841
 34. ISR - Laboratory Division - Microbiology Section; Building 2653
 35. ISR - Laboratory Division - Biochemistry; Building 2653
 36. ISR - Laboratory Division - Pathology Section; Building 2653
 37. ISR - Laboratory Division - Internal Medicine Br.; Building 2653
 38. ISR - Laboratory Division - Veterinary Pathology; Building 2653
 39. ISR - Laboratory Division - Radiology Section; Building 2653

Table 8

11

Quantities are reported in pounds per year.

Table 8 (Cont'd)

Wastes	HCL#	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Acetone															
Acetonitrile				25											
Ethyl alcohol				25											
Methanol			8												
Phenol															
Carbon Disulf.			1												
MEK			2												
Toluene															
Xylene															
Chloroform															
Carbon Tetra.															
TCA															
TCE															
Methylene Chlor.															
Acetic Ac.															
Hydrochl. Ac.															
Nitric Ac.															
Sulfuric Ac.															
Phosphoric Ac.															
Other Acids															
Ammon. Hydrox.															
Potass. Hydrox.															
Sod. Hydrox.															
H ₂ O ₂															
Photo. Fixer															
Photo. Dev.															
Mercury															
Merc. Chloride															
Merc. Iodide															
Merc. Nitrate															
Merc. Nitrite															
Merc. Sulfate															
Merc. Cyanide															
Potass. Cyanide			3												
Sod. Cyanide															
Sod. Nitrate															
Sod. Nitrite															
Potass. Nitrate															
Potass. Permangan.															
Lead Acetate															
Formalin															
Formaldehyde															
Med. Infect.															
(Red Bags)															
Pathological															

30

Table 8 (Cont'd)

Wastes	HCL#	29	30	31	32	33	34	35	36	37	38	39
Acetone												
Acetonitrile												
Ethyl alcoh.												
Methanol												
Phenol												
Carbon Disulf.												
MEK												
Toluene												
Xylene												
Chloroform												
Carbon Tetra.												
TCA												
TCE												
Methylene Chlor.												
Acetic Ac.												
Hydrochl. Ac.												
Nitric Ac.												
Sulfuric Ac.												
Phosphoric Ac.												
Other Acids												
Amm. Hydrox.												
Potass. Hydrox.												
Sod. Hydrox.												
H ₂ O ₂												
Photo. Fixer												
Photo. Dev.												
Mercury												
Merc. Chloride												
Merc. Iodide												
Merc. Nitrate												
Merc. Nitrite												
Merc. Sulfate												
Merc. Cyanide												
Potass. Cyanide												
Sod. Cyanide												
Sod. Nitrate												
Sod. Nitrite												
Potass. Nitrate												
Potass. Permang.												
Lead Acetate												
Formalin												
Formaldehyde												
Med. Infect.												
(Red Bags)												
Pathological												

968

Table 9

Quantities of Hazardous/Nonhazardous Materials Used at HCL*

Materials	HCL #	1	2	3	4	5	6	7	8	9	10	11	12	13
Acetone				1	14		11				3			
Acetonitrile														
Ethyl Alcoh.	9833						19						1	
Isoprop. Alc.								13	13					25
Butanol														
Methanol					2		12	12000	23		1			
Phenol				1	11									
Benzene														
Carbon Disulf.														
MEK														
Toluene	1			0										
Xylene	5				57									
Chloroform					0	2			44					
Carbon. Tetra.														
TCA														
TCE														
Methylene Chlor.							14		39					
Acetic Acid		4			1	1	1	25	1331	6				
Hydrochl. Ac.	6				6		22	35			19			
Nitric Ac.							30	4	8					
Sulfuric Ac.		3						12	3	3		18		
Phosphoric Ac.								5	5					
Other Acids								6**	500***					
Amm. Hydrox.	7					5	14		1					
Potass. Hydrox.							1							
Sod. Hydrox.		8				17		3		1		8		
H ₂ O ₂							20***						500***	
Photo. Fixer							495							
Photo. Dev.														
Mercury														
Merc. Chloride				2			2							
Merc. Iodide														
Merc. Nitrate														
Merc. Nitrite														
Merc. Sulfate														
Merc. Cyanide														
Potass. Cyanide														
Sod. Cyanide							2							
Sod. Nitrate														
Sod. Nitrite								2						
Potass. Nitrate	1													
Potass. Permang.	1						2							
Lead Acetate														
Ammonium Fl.							30***							
Ferric Chloride							1						2	
Formalin														
Formaldehyde				100***	15**				6**					
Ethyl Ether						12**								
Ethyl Acetate							48		5					
Amyl Acetate							26							
Sod. Acetate							1							
Potass. Iodide														
Petrol. Ether							6**							
Iodine														
Hexane														

*Quantities are reported in pounds per year except where indicated.

**Liters per year.

***Milliliters per year.

Table 9 (Cont'd)

HCL#	14	15	16	17	18	19	20	21	22	23	24	25	26
Materials													
Acetone			17			822					985		
Acetonitrile			40				130						
Ethyl Alcoh.						165					1180		
Isoprop. Alc.		3429	17			34					164		
Butanol			2			59							
Methanol			156			818					1634		
Phenol		1									1		
Benzene			20			1							
Carbon Disulf.			3										
MEK													
Toluene			90			2							
Xylene			19					2			28		
Chloroform							124						
Carbon. Tetra.													
TCA													
TCE													
Methylene Chlor.													
Acetic Acid			2				23						
Hydrochl. Ac.													80
Nitric Ac.													
Sulfuric Ac.							90					2	
Phosphoric Ac.													23
Other Acids													
Amm. Hydrox.						12							
Potass. Hydrox.											47		
Sod. Hydrox.						4					3		1
H ₂ O ₂						100"							
Photo. Fixer				2385'					116"				
Photo. Dev.					1402'					116"			
Mercury			1										
Merc. Chloride													
Merc. Iodide											1		
Merc. Nitrate													
Merc. Nitrite													
Merc. Sulfate													
Merc. Cyanide													
Potass. Cyanide										23"			
Sod. Cyanide													
Sod. Nitrate													
Sod. Nitrite													
Potass. Nitrate													
Potass. Permang.						8							
Lead Acetate													
Ammonium Fl.													
Ferric Chloride													
Formalin													
Formaldehyde			2"								12"		
Ethyl Ether							388"						
Ethyl Acetate						56							
Amyl Acetate													
Sod. Acetate													
Potass. Iodide													
Petrol. Ether						388"							
Iodine													
Hexane			2"			39"							

'Gallons per year.

Table 9 (Cont'd)

HCL#	27	28	29	30	31	32	33	34	35	36	37	38	39
Materials													
Acetone													
Acetonitrile													
Ethyl Alcoh.													
Isoprop. Alc.					15000								
Butanol		2											
Methanol		409											
Phenol					51								
Benzene													
Carbon Disulf.													
MEK		2											
Toluene													
Xylene		9											
Chloroform			4										
Carbon. Tetra.													
TCA													
TCE		1											
Methylene Chlor.													
Acetic Acid			11										
Hydrochl. Ac.		13											
Nitric Ac.													
Sulfuric Ac.	75												
Phosphoric Ac.		2											
Other Acids													
Amm. Hydrox.													
Potass. Hydrox.													
Sod. Hydrox.													
H ₂ O ₂													
Photo. Fixer													
Photo. Dev.													
Mercury													
Merc. Chloride													
Merc. Iodide													
Merc. Nitrate													
Merc. Nitrite													
Merc. Sulfate													
Merc. Cyanide													
Potass. Cyanide													
Sod. Cyanide													
Sod. Nitrate													
Sod. Nitrite													
Potass. Nitrate													
Potass. Permang.													
Lead Acetate													
Ammonium Fl.													
Ferric Chloride													
Formalin													
Formaldehyde													
Ethyl Ether													
Ethyl Acetate			19										
Amyl Acetate		2											
Sod. Acetate													
Potass. Iodide													
Petrol. Ether													
Iodine													
Hexane													

Table 10
Paint Shops (PS)

1. DOL - Maintenance Division - Allied Trades Section; Buildings 2509, 2510
2. DEH - B&G Division-Sign Shop; Building 4197
3. DEH - Utility Division - AC/Refrigeration Section; Building 4197
4. DEH - B&G Division Motor Pool; Building 4208
5. DPTMSEC - TASC - Devices Section; Building 4001

Table 11
Quantities of Hazardous Wastes Generated at PS*

Wastes	PS #	1	2	3	4	5
Acetone						
Clean. Solv. NOS						
Contam. Petrol. Nap.				8316		
Contam. TCE						
Contam. Xylene						
Contam. MEK						
Old, Unused Paint		36				
Spent Paint Filters				192**		
Spent Paint Remover						
Spent Paint Thinner		240				
Spent Laq. Thinner						
Spent Synthetic Thinner						
Spent Thinner-Dope						
Spent Turpentine						
Waste PRM		865				
(Acetone, MEK, Xylene)						
Waste Paint Sludge		39***				

*Quantities are reported in pounds per year except where indicated.

**Filters per year.

***Gallons per year.

Table 12

Quantities of Hazardous/Nonhazardous Materials Used at PS

Materials	PS #	1	2	3	4	5
Acetone						8 lb
Clean. Solv. NOS						46 lb
Petrol. Nap.		8316 lb				
TCE						
Xylene						
Toluene						
MEK						
Paint, Enamel						
Paint, Latex						
Paint, CARC						
Paint Filters				192 filters		
Paint Remover						1 gal
Paint Thinner			50 gal		1 gal	
Laq. Thinner			75 gal		60 gal	
Synthetic Thinner			2 gal		20 gal	
Thinner Dope		75 gal			60 gal	
Turpentine			1 gal			4 gal
Metal Cleaner NOS						2 gal

Table 13

Photography, Printing, Arts/Crafts Shops (PPAS)

1. DPTMSEC - Training and Support Center - Photo, Print Section; Buildings 2010, 2016
2. DPTMSEC - Training and Support Center - Graphics Section; Building 1450
3. DPCA - Comm. Rec. Div. - Photo Craft Shop; Building 1222
4. DOIM - Admin. Serv. Div. - Print, Pub. Br.; Building 230
5. DMA - Topo/Hydro Center; Building 4011
6. U.S. Army COE Lab; Building 1196
7. JMMC Photo. Branch; Building 2001

Table 14

Quantities of Hazardous Wastes Generated at PPAS

Wastes	PPAS #	1	2	3	4	5	6	7
Spent Petro. Nap.								
Spent Clean. Solv. NOS		285 lb						
Spent TCE								
Spent Methyl. Chloride							155 lb	
Contam. Perchloro.					1270 lb			
Contam. Photo. Fix.		115 gal	60 gal			360 gal		
Contam. Photo. Dev.		175 gal	60 gal			630 gal		
Waste Inks								
Old, Unused Paint								
Spent Paint Thinner								
Waste Adhesive								
Non-Spec. Ammonia Developer								
Empty HM Containers								
Spent Electrostatic Soln.				45 gal				
Spent Electrostatic Dev.					68 lb			
Spent Bestine Solvt.								
Waste Ammonium Hydroxide								
Spent Deglazing Solvent								
Spent Blankrola					2888 lb			

Table 15

Quantities of Hazardous/Nonhazardous Materials Used at PPAS

Materials	PPAS #	1	2	3	4	5	6	7
Petro. Nap.					2885 lb			
Clean. Solv. NOS								
TCE						785 lb	465 lb	
Methylene Chloride							195	
Perchloroethylene								
Photo. Fixer					450 gal		730 gal	
Photo. Developer						650 gal		900 gal
Inks								
Paints			22 gal					
Adhesives			135 gal					
Paint Thinner		60 gal						
Anhyd. Ammonia			3000 gal					
Ammonia Developer			120 gal					
Electrostatic Sol.					350 gal			
(Potass. Ferrocyan.)								
Electrostatic Developer					68 gal			
Bestine Solvent			35 gal					
Ammonium Hydroxide		8 gal						
Deglazing Solvent					192 gal			
Methyl Chloroform								
Blankrola								

Table 16
Industrial Maintenance, Small Arms Shops (IMSS)

1. DEH - B&G Div. - Metal Shop; Building 4197
2. DEH - Utility Div. - Plumbing Sec.; Building 4197
3. DOL - Maint. Div. - Spec. Equip. Small Arms Repair; Building 371
4. BAMC - DOL - Maint. Br. - Med. Aids Fabr.; Building 2629
5. BAMC - DOL - Maint. Br. - Maint. & Repair Svc.; Building 2620
6. SARPMA - Logistics Div. - Carpentry Shop; Building 4197

Table 17
Quantities of Hazardous Wastes Generated at IMSS*

Wastes	IMSS #	1	2	3	4	5	6
Spent Petro. Nap.		960		1920			
Spent MEK							
Spent TCA			465				
Spent Methyl. Chlor.							
Spent Clean. Solv. NOS			2772	925			
Spent PD-680-II							770
Cutting oil							
Waste Hyd. Oil							
Dead Batteries							
Spent Electrolyte							
Spent Anti-Freeze Sol.							
Old, Unused Paint							
Empty Paint Cont.							
Old, Unused Adhesives							
Spent Paint Thinner							
Spent 102 Thinner							
Old, Unused PVC Cement							
Empty PVC Cement/Solv. Containers							
Spent Abrasive Blast Media			30				

*Quantities are reported in pounds per year.

Table 18

Quantities of Hazardous/Nonhazardous Materials Used at IMSS

Materials	IMSS #	1	2	3	4	5	6
Petroleum Naphtha		960 lb		1920 lb			
Alcohol						53 lb	
MEK							
Dichlorotetrafluoroethane					70 lb		
TCE							
Methylene Chloride							
Cleaning Solvent NOS							
Cutting Oil						4 lb	
Hydr. Oil						28 lb	
Antifreeze							
Batteries							
Paint					1400 gal		
Varnish					2 gal		
Adhesive Brush					12 gal		
Adhesives, Spray					120 gal		
Paint Thinner							
Lacquer Thinner							
Thinner Dope							
PVC Cement		3 gal					
PVC Solvent		3 gal					
Abrasive Blasting Sand		100 lb					

Table 19

Aviation Maintenance Facilities (AMF)

1. DOL - Maintenance Div. - Acft. Maint. Sec. Hangar, Building 3520
2. 507th Medical Detachment - Acft. Maint. Hangar 2; Building 3510
3. Texas Army National Guard - Aviation Maintenance

Table 20

Quantities of Hazardous Wastes Generated at AMF*

Wastes	AMF #	1	2	3
Spent Petro. Nap.				
Spent Solv. NOS		5082	465	
Spent Cleaning Compound				
Av. Fuel (JP-4)		3360	1680	
Contam. Fuel (Diesel/Mogas)				
Old, Unused Paint				
Spent Paint Thinner				
Spent Paint Remover				
Waste Turbine Oil		210		
Waste Hydr. Oil (FRH)		420		
Waste Deicer				
Dead Batteries				
Contam. Sorbent				

*Quantities are reported in pounds per year.

Table 21

Quantities of Hazardous/Nonhazardous Materials Used at AMF

Materials	AMF #	1	2	3
Cleaning Solv. (Petro. Nap.)				
MEK				
Cleaning Comp. (Methylene Chlor.)				
Av. Fuel (JP-4)				
Other Fuel (diesel/mogas)				
Paint				
Paint Thinner				
Paint Remover				
Turbine Oil				
Hydraulic Oil				
Deicer				
Batteries				
Sorbent				

Table 22
Other Waste Sources

-
1. AHS - Joint Med. Readiness Tr. Cntr. - C4 Task Force; Building 370
 2. AHS - Health Sciences Div.; Building 911
 3. AHS - Academy Brgde. - Supply Br.; Building 902
 4. DPCA - Comm. Rec. Div. - Woodcraft Shop; Building 371
 5. BAMC - Phys. Med. & Rehab. - Occ. Therapy Sec.; Building 2392
 6. DPTMSEC - Museum Div. - Fort Sam Houston Museum; Building 123
 7. 507th Medical Company

Table 23
Quantities of Hazardous Wastes Generated by Other Waste Sources

Wastes	MISC #	1	2	3	4	5	6	7
Spent Perchloroethylene								
Spent Petro. Nap.								
Spent Clean. Cmpd.								
Contam. Xylene								
Contam. Kerosene								
Spent Turpentine								
Unused, Old Paint								
Empty Paint Cont.								
Spent Paint Thinner								
Contam. Thinner Dope								
Waste Lube Oil								
Waste Antifreeze Soln.								
Contam. Diesel								
Contam. MOGAS								
Spent Veh. Batt.								
Spent Lith. Batt.		280		800				900
Waste Hydraulic Fluid								

Table 24

Quantities of Hazardous/Nonhazardous Materials Used by Other Sources

Materials	MISC #	1	2	3	4	5	6	7
Perchloroethylene					770			
Petro. Nap								
Acetone							2	
Alcohol			2					
TCE							4	
Clean. Compound (Methy. Chlor.)			2					
Xylene			1					
Toluene							2	
Kerosene								
Turpentine							84	
Paint		55	2					
Paint Thinner					168		14	
Thinner Dope		14						
Varnish		14						
Lube Oil		315	9					
Antifreeze		55						
Diesel	22050	7						
Mogas	7350	420						
Veh. Batteries		2						
Lithium Batt.		280		800				900
Hydraul. Fl.			2					
Rifle Cleaner		56						
Bleach		168						

Table 25
Waste Generation Summary

Waste Generating Operations or Conditions	Waste Category*	lb/yr	lb/yr/unit	Waste Stream Unit
Motor Pools and Vehicle Maintenance Facilities	1	12,873	9513	Sulfuric Acid
			3360	Caustic Radiator Wash
	2	12,975	15,975	Ethylene Glycol
	3	21,330	18,560	Petroleum Naphtha
			2310	PD-680-II
			460	MEK
	4	4068	4068	Methylene Chloride
	6	85,205	77,689	Motor Oil
			6938	Transmission Oil
			578	Hydraulic Oil
	7	1050		Diesel
				Mogas
Aviation Maintenance Facilities	8	302	302	Paint Related Material
	9	175	175	Paint Thinner
	10	180 veh. bat.	180 veh. bat.	Dead Batteries (vehicle)
	3	5547	5547	Degreasing Solvent
	6	630	210	Turbine Oil
			420	Hydraulic Oil
	7	660	660	JP-4

*Waste Category 1. Spent acids or bases (corrosives); 2. Spent antifreeze solution; 3. Spent degreasing solvents (nonhalogenated); 4. Spent degreasing solvents (halogenated); 5. Used alcohols; 6. Used oils; 7. Contaminated fuels; 8. Waste paint related material; 9. Spent thinners; 10. Miscellaneous wastes—smaller volumes.

Table 25 (Cont'd)

Waste Generating Operations or Conditions	Waste Category	lb/yr	lb/yr/unit	Waste Stream Units
Photography, Print, and Reproduction Facilities	3	285	285	Cleaning Solvent
	4	1425	155	Methylene Chloride
			1270	Perchloroethylene
	10	11,628	4280	Photo Fixer
			6920	Photo Developer
			360	Electrostatic Solution
			68	Electrostatic Developer
Vehicle Painting Facilities and Maintenance Paint Shops	3	8316	8316	Petroleum Naphtha
	8	932	360	Old, Unused Paint
			192	Spent Paint Filters
			380	Waste Paint Sludge
	9	2112	2112	Paint Thinner
Industrial Maintenance, Small Arms Repair, and Special Equipment Shops	3	6577	2880	Petroleum Naphtha
			3697	Spent Degreasing Solvent
	4	465	465	1, 1, 1-Trichloroethane
Power Production, Heating/Cooling Facilities	10	30	30	Abrasive Blasting Media
	1	18,250	18,250	Caustic Boiler Blowdown
	3	2880	2880	Petroleum Naphtha
	6	2450	2450	Lubrication Oils
	7	385	385	Contaminated Diesel

Table 25 (Cont'd)

Waste Generating Operations or Conditions	Waste Category	lb/yr	lb/yr/unit	Waste Stream Unit
Electrical Maintenance/Electric Motor Repair Facilities	3	6625	6625	Petroleum Naphtha
	9	116	116	Varnish Thinner
	6	18	18	Turbine Oil
Hospitals, Clinics, and Laboratories	3	2327	25	Acetylene
			1331	Xylene
			968	Toluene
			1	Carbon Disulfide
			2	MEK
	4	10	8	Carbon Tetrachloride
			2	1, 1, 1-Trichloroethane
	5	32	25	Ethyl Alcohol
			8	Methanol
	10	5131	3	Potassium Cyanide
			4910	Formalin
			218	Mercury
Hazardous Waste Storage Facility	10	300	300	PCB Contaminated Soil
Miscellaneous	10	1980	1980	Lithium Batteries

Table 26

Total Waste Generation Rates By Waste Categories*

Generator	Total	1	2	3	4	5	6	7	8	9	10
Motor Pool	137,978	12,873	12,975	21,330	4068		85,205	1050	302	175	180 veh. bat.
Aviation Maintenance	6837			5547			630	660			
Photography	13,338			285	1425						11,628
Paint Shops	11,360			8316					932	2112	
Industrial Maintenance	7072			6577	465						30
Heating Cooling	23,965	18,250		2880			2450	385			
Electrical Maintenance	6759			6625						116	
Hospitals	7500			2327	10	32					5131
Waste Storage Facility	300										300
Miscellaneous	1980 Li bat.										1980 Li bat.
Total	215,109	31,123	12,975	53,887	5968	32	88,303	2095	1234	2403	17,089

*Waste categories are the same as those in Table 25.

5 WASTE MINIMIZATION FOR MOTOR POOLS AND VEHICLE MAINTENANCE FACILITIES AND AVIATION MAINTENANCE FACILITIES

The typical maintenance and repair operations conducted in a vehicle or aviation maintenance facility are: oil and grease removal; engine, parts, and equipment cleaning; rust removal; and solution replacement. Table 27 lists the operations, the corresponding materials used, and the wastes generated. Table 28 lists the process descriptions and the corresponding waste descriptions according to hazardous waste codes and Department of Transportation (DOT) classifications. These waste descriptions are used when shipping the wastes offsite. Most of the wastes generated at MPVM are: parts cleaning solutions and miscellaneous detergent solutions, oil and grease from engine cleaning, spent automotive fluids, and lead-acid batteries. AMF generated most of the above wastes (except automotive fluids and lead-acid batteries) and nickel-cadmium batteries. Paint removal and painting operations may also occur at both MPVM and AMF. The minimization of wastes from such activities is discussed in Chapter 7.

Some of the equipment used, primarily in parts cleaning operations, are solvent sinks, hot tanks, and jet spray washers. Proper operation of this equipment minimizes material use and waste generation. The solvent in the sinks is recirculated continuously from a tank to the parts wash tray. The solvent (e.g., PD680-II) is replaced periodically. Hot tanks contain aqueous detergent or caustic solutions for immersion cleaning. These tanks are equipped with air or mechanical agitation devices and electrical heating devices to heat the solution to 356 °F. The jet spray washers consist of nozzles that emit rotating water jets to clean parts immersed in an aqueous wash solution. The contaminated liquid and sludge from both the hot tanks and jet sprays are removed periodically.

Tables 4, 5, and 6 in Chapter 4 list all the MPVM, waste generated, and materials used at Fort Sam Houston. The corresponding tables for AMF are 19, 20, and 21. Most of the minimization options discussed below have been obtained from *Waste Audit Study - Automotive Repairs*,²⁸ and other references.²⁹ These minimization options would be applicable to all the MPVM at Fort Sam Houston.

Source Reduction

All Wastes - Better Operating Practices

Better housekeeping practices are necessary to minimize the quantity and toxicity of wastes or emissions generated. Some of the methods include: closing the lids of containers (e.g., solvent sinks) containing volatile substances (e.g., Stoddard solvent); conveniently locating cleaning equipment near service bays; increasing employee awareness of proper waste handling and disposal procedures; labeling hazardous waste containers properly; segregating wastes in separate containers; and separating trash/solids before waste collection for recycling or treatment.³⁰ Draining wastes to a sewer is not a good practice and may be illegal in many states. Inadvertent losses (spills) can also be minimized by using good housekeeping practices.

²⁸ W.M. Toy, *Waste Audit Study - Automotive Repairs* (Prepared for the California Department of Health Services, Sacramento, CA, 1987).

²⁹ *Hazardous Waste Reduction Checklist - Automotive Repair Shops* (California Department of Health Services, Toxic Substances Control Division, 1988); *Hazardous Waste Reduction Assessment Handbook - Automotive Repair Shops* (California Department of Health Services, Toxic Substances Control Division, 1988).

³⁰ W.M. Toy, pp 27-28.

All Wastes - Better Operating Practices - Segregation

Segregation of waste streams is a very good practice that minimizes hazardous waste generation and also increases the recyclability of wastes. It is extremely important not to mix solvents and oils. Mixing results in a liquid with very little recycle value and increases the costs of disposal.³¹ Minimizing the quantity of contaminants in solvents improves the purity of reclaimed solvent (in onsite recycling) and its market value (in offsite recycling). Used oils, after being drained from engines, are known to be contaminated with parts cleaning solvent, carburetor cleaner, fuels, rags, water, trash, etc.³² These contaminants may make the used oil a hazardous waste due to ignitability, corrosivity, or toxicity, thereby reducing the possibility of energy recovery by burning it in boilers or reducing its market value (for offsite reclamation).

All Wastes - Better Operating Practices - Periodic Maintenance and Cleanup of Equipment

All the equipment, including solvent sinks, hot tanks, and spray washers, must be properly maintained. The tank bottoms must be cleaned frequently to reduce sludge accumulation and contamination of replacement solutions.

Solvent (PD680-I) - Material Substitution - PD680-II

Petroleum distillate Type I (PD680-I) is a flammable substance with a flash point of 102 °F, which is below the USEPA's flammability hazard limit of 140 °F. It must be substituted with petroleum distillate Type II (PD680-II) that has a flash point of 140 °F or above. Changes must be made in the local and centralized procurement processes to prevent users from obtaining PD680-I. When ordering solvent, the user must specify that substitution is not acceptable.

Solvent (PD680-II) - Better Operating Practices

A parts cleaning solvent, such as PD680-II, must not be used to clean floors or hands. It is expensive and must be dedicated to the intended purpose of parts cleaning only. Immersion and removal of parts from the solvent sinks must be done slowly to minimize splashes and rapid evaporation of solvent.

Solvent (PD680-II) - Better Operating Practices - Emissions Minimization

Among the good housekeeping practices, efforts to reduce air emissions are probably the most significant in terms of reducing hazardous wastes released to the environment. Using covers on solvent sinks (or cold cleaning tanks) can result in a 24 to 50 percent reduction in solvent losses.³³ Several standard methods are available for minimizing emissions from immersion cleaning, wipe cleaning, and spray cleaning operations.³⁴

³¹ R.H. Salvanes Associates, *Used Oil and Solvent Recycling Guide*, Final Report (Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1985), pp 1-38.

³² L.C. Chicoine, G.L. Gerdes, and B.A. Donahue, *Reuse of Waste Oil at Army Installations*, Technical Report N-135/ADA123097 (USACERL, September, 1982).

³³ ICF Associates, Inc., *Guide to Solvent Waste Reduction Alternatives: Final Report* (Prepared for the California Department of Health Services, October 1986), pp 4-11 through 4-13.

³⁴ ASTM Standard D3640-80, "Standard Guidelines for Emission Control in Solvent Metal-Cleaning Systems," *Annual Book of American Society of Testing and Materials Standards*, Vol 15.05 (American Society of Testing and Materials [ASTM], 1988).

Solvent (PD680-II) - Process Change

If dip tanks or dunk buckets full of solvent are used for parts cleaning, the process must be modified. Solvent sinks clean parts more effectively and are easy to use. Spillage and evaporation is less from solvent sinks than from dip tanks or buckets. Equipment leasing services (see Table 29) lease solvent sinks. The equipment, raw materials, maintenance, and waste removal are part of the contract and are included in the service price (see Table 30). Testing of solvents (discussed below) before changing must be included in the contract.

If a leasing service is not desirable economically, a solvent sink must be purchased and the waste solvent recycled. Table 31 lists the sizes and the approximate costs of solvent parts washers. Local vendors must be contacted for exact information.

Solvent (PD680-II) - Process Change - Testing

Solvents are normally replaced periodically, based on the operator's perception of "dirtiness." Simple tests to estimate the "solvation power" of the spent solvent can be used to extend the life of the solvent before disposal. The physicochemical tests most useful for used solvent testing are: absorbence, specific gravity, viscosity, and electrical conductivity.³⁵ Testing instruments (optical probe colorimeter, electronic specific gravity meter, Ostwald viscometer, and electrical conductivity meter) are commercially available. By obtaining a measure of these properties, the usefulness of the solvent can be determined based on Table 32. If the total score (sum of the ratings for all the properties) is less than 6, the solvent is not "spent." If the score is greater than 6, the solvent should be recycled. The criteria provided in Table 32 are only recommendations; they must be revised based on site-specific use and testing. Using solvent testing will reduce raw material and waste disposal costs and minimize the wastes generated.

Solvent (PD680-II) - Process Change - Solvent Sinks (Equipment) Modifications

Solvent losses can be minimized by adding drip trays and lids to existing solvent sinks. About 25 to 40 percent of the solvent is lost because of spillage and about 20 percent because of evaporation.³⁶ Racks or baskets may be designed and fitted to the solvent sinks to drain parts after cleaning. Minimizing solvent losses results in cost savings for the raw material and waste handling/disposal.

Carburetor Cleaner - Product Substitution

Carburetor cleaners typically contain methylene chloride (< 47 percent), 1,1,1-trichloroethane (< 5 percent), cresylic acid (< 27 percent), and wetting agents. The automobile industry has reformulated them to exclude the use of 1,1,1-trichloroethane.³⁷ Substitute cleaners must be used.

Used Oil - Better Operating Practices - Selective Segregation

Segregation of used oils and related products is not a source reduction alternative in the strictest sense of the term, yet selective segregation of used oil products may ultimately reduce the large volumes of hazardous wastes³⁸ that could be produced by mixing used oils with radiator drainings (containing oxylates, phenols, ketones, and acids) and used solvents. Product segregation is initially

³⁵ B.A. Donahue, et al., *Used Solvent Testing and Reclamation, Volume I: Cold-Cleaning Solvents*, Technical Report N-89/03/ADA204731, Vol I (USACERL, December 1988).

³⁶ W.M. Toy, pp A-1 - A-23.

³⁷ W.M. Toy, p 20.

³⁸ D.W. Brinkman, M.L. Whisman, and C.J. Thompson, *Management of Used Lubricating Oil at Department of Defense Installations: A Guide*, NIPER B06711-2 (National Institute for Petroleum and Energy Research, 1986), p 26.

cost-intensive, but many factors favor selective segregation of used oils. These factors include but are not limited to: the increasing costs of hazardous waste disposal, particularly for mixed waste disposal; the fact that the British thermal unit (Btu) value of used oil for burning as a fuel is lowered by the presence of solvents; and under USEPA regulations, hazardous wastes cannot be burned except in boilers with air pollution controls and secondary burners. These factors effectively prohibit blending used oil with boiler fuel if the used oil is listed as a hazardous waste.

Used Oil - Process Change - Fast Lube Oil Change System (FLOCS)

The Fast Lube Oil Change System (FLOCS) is a quick and efficient method of draining crankcase oil from vehicles. The model 30A FLOCS oil evacuation unit is designed to evacuate oil from crankcases under a vacuum. The engines must be fitted with quick-connect couplings to provide easy access to the oil drain, eliminating the need for lifts or pits. Because the oil is evacuated under vacuum pressure, sludge buildup in the oil pans is reduced. Spills are virtually eliminated and a substantial savings in time, labor costs, and equipment can be realized. All FLOCS units are designed to accommodate manual draining of the oil pan when necessary.

A single FLOCS unit was tested at Peterson Air Force Base (AFB), CO, from February 1982 to April 1983 to determine if FLOCS offered sufficient advantages over the normal lube oil change methods to warrant its adoption in the Air Force. Savings during 1 year of operation totaled \$1176.00 for 25 vehicles. A total savings of \$7526.40 was expected based on a conservative 8-year life expectancy for the unit. A payback of 1.6 years was projected. The economic success of the FLOCS unit, along with the elimination of spills that could result in accidents to shop personnel, prompted recommendations that the FLOCS evacuation unit be adopted for Air Force use.³⁹

Caustic Wastes - Product Substitution

Caustic cleaning compounds are used in hot tanks and jet spray washers. Substitution of detergent compounds minimizes the amount of hazardous (corrosive) wastes produced. Caustic compounds are necessary for cleaning engines made of iron or iron alloys. With the rapid change to manufacturing engine blocks of aluminum, the use of detergent solutions for cleaning is also increasing.

Caustic Wastes - Process Change - Hot Tank (Equipment) Modifications

A major waste from hot tank operations is the tank bottom sludge containing heavy metals, oil, grease, etc. A typical practice is to dislodge the sludge from the bottom of the tank and dump it into a sump. Installing a collection tray with an overflow to the sump will allow for proper capture and disposal of the sludge. Hot tanks must also be equipped with drip trays and pans for collecting solution that drips off the parts after cleaning. The solution in the trays or pans must then be emptied back into the hot tank.

Aqueous or Caustic Wastes - Process Change - Dry Ovens

Hot tanks or spray washers are typically used for engines/parts washing. If the parts are small enough, ovens could be used to burn off the grease, oil, and particles. The dry ash can then be removed from the parts using shot blasters (preferably with plastic beads) and disposed of in a landfill. The ash must be tested for toxicity before assigning a disposal method. Testing the oven stack

³⁹ *Management/Equipment Evaluation Program, Report H82-1B (1st Space Support Group, U.S. Air Force, Peterson Air Force Base, CO, 1983).*

emissions for air pollutants may be required. However, using a dry oven will eliminate hazardous (corrosive and toxic) wastes that contain caustics, heavy metals, and oily dirt.

Aqueous Wastes - Process Change - Two-Stage Cleaning in Jet Spray Operations

Most of the parts covered with oil, grease, and heavy dirt residues are cleaned using jet spray operations. If many parts need to be cleaned, a two-stage cleaning operation might provide cleaner parts in a shorter time. Two washers can be connected in series with the first removing most of the heavier residue and the second providing the final rinse. The cleaning solution from the second tank is transferred to the first tank (countercurrent processing).

Antifreeze Solution - Better Operating Practice - No Draining

Current practice is to dispose of spent antifreeze solution from radiators by emptying it directly into either a municipal or installation sanitary sewer system. Although the solution contains primarily ethylene glycol (which is poisonous), it is biodegradable and is neither carcinogenic nor mutagenic. Therefore, disposal in a sewer system should not present a problem.⁴⁰ However, the U.S. Army Mobility Equipment Research and Development Command has documented the presence of phenols, ketones, acids, oxylates, and aldehydes in radiator drainings formed during the use of ethylene glycol as a coolant.⁴¹ Antifreeze wastes are considered hazardous wastes in some states (e.g., California) because ethylene glycol's oral human lethal dose (LD₅₀) is 1400 mg/kg, which is far below the state toxicity limit of 5000 mg/kg. As other state and local regulations lower the levels of phenols permitted in drinking water and sewage treatment plant effluents, antifreeze waste may have to be disposed of as a hazardous waste.

Antifreeze Solution - Product Substitution

Biological treatment of the ethylene glycol waste stream is difficult and the chlorination processes (commonly used in a waste treatment plant) generate other toxic chlorinated hydrocarbons. Substituting propylene glycol for ethylene glycol in antifreeze formulas will reduce the toxicity of the waste stream. Propylene glycol is a nontoxic compound commonly used as a food additive.⁴²

Antifreeze Solution - Process Change - Testing

Testing the antifreeze solution, which may currently be drained into the sanitary sewers, before draining and disposal can help minimize the amount of wastes generated. Standard methodologies available for testing engine coolants in cars and light trucks⁴³ may be adapted for other types of vehicles. Electrochemical tests based on the measurement of galvanic currents have proven useful for measuring the levels of corrosion inhibitors and corrosivity of the antifreeze solution in a radiator (or any other heat transfer device).⁴⁴ Such test methods allow continuous monitoring of the solution to

⁴⁰ Union Carbide Corporation, *Ecological Aspects of UCAR Deicing Fluids and Ethylene Glycol* (Prepared for the Hazardous Materials Technical Center, Rockville, MD, 1984).

⁴¹ J.H. Conley and R.G. Jamison, *Reclaiming Used Antifreeze*, Report 2168/ADA027100 (U.S. Army Mobility Equipment Research and Development Command [USAMERDC], Fort Belvoir, VA, 1976).

⁴² F.E. Mark and W. Jetten, "Propylene Glycol, A New Base Fluid for Automotive Coolants," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (American Society of Testing and Materials [ASTM], 1986), pp 61-77.

⁴³ ASTM Standard D2847-85, "Standard Practice for Testing Engine Coolants in Car and Light Truck Service," *Annual Book of American Society of Testing and Materials Standards*, Vol 15.05 (ASTM, 1988).

⁴⁴ R.L. Chance, M.S. Walker, and L.C. Rowe, "Evaluation of Engine Coolants by Electrochemical Methods," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (ASTM, 1986), pp 99-102; C. Fiaud, et al., "Testing of Engine Coolant Inhibitors by an Electrochemical Method in the Laboratory and in Vehicles," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (ASTM, 1986), pp 162-175.

determine the exact time of change (rather than change on a periodic basis, such as 6 months, or when the mechanic thinks it is "dirty").

Antifreeze Solution - Process Change - Extend Life

A Military Specification, MIL-A-53009,⁴⁵ developed by the U.S. Army Research and Development Center, Fort Belvoir, VA, allows the use of antifreeze (MIL-A-46153⁴⁶) whose inhibitor system has reached a marginal condition.⁴⁷ The military additive can extend the life of the antifreeze by more than 1 year. It was originally developed for use if new antifreeze was in short supply. During 1987 and 1988, ethylene glycol was in short supply because of the unavailability of ethylene (base stock) and the retail price doubled. In addition to environmental incentives, economic incentives to minimize the quantities of ethylene glycol wastes generated also exist.

Brake Shoes (Asbestos Waste) - Better Operating Practices

Asbestos dust, released when replacing brake shoes, is a hazardous waste. Friable (crushed under hand pressure) asbestos must be carefully collected and handled as a hazardous waste. Some equipment leasing companies may also provide asbestos collection services.

Recycling Onsite/Offsite

Solvent (PD680-II) - Onsite Recycling - Distillation

If large quantities of solvents are used (i.e., over 4000 gal/yr) they can be recycled onsite using distillation stills. These units offer a quick investment payback (i.e., less than 3 years).⁴⁸ In the distillation process, the solvent is boiled and the vapors are condensed and collected in a separate container. Substances with a higher boiling point than the solvent (e.g., oils, metal residues, etc.) remain in the bottom of the still. A smaller amount of contaminants will result in a higher purity for the reclaimed solvent. Therefore, it is very important to segregate solvent wastes from oils and other contaminants in the service bays. Table 33 lists some of the major suppliers of solvent distillation equipment. Detailed comparisons of the economics of distillation and solvent management options discussed in this chapter are available elsewhere.⁴⁹

Solvent (PD680-II) - Offsite Recycling - Contract/Leased Recycling

Solvent sinks for parts cleaning can be owned or leased. In a lease arrangement, the contractor (e.g., Safety Kleen) replaces fresh solvent periodically (specified in the contract) and takes the spent solvent for recycling. Wastes can thus be better contained and the solvent recycled rather than disposed of. Contract recycling has been accepted as a good practice by the automobile industry.⁵⁰ Table 29 lists some of the equipment leasing and service companies.

⁴⁵ Military Specification MIL-A-53009, *Additive, Antifreeze Extender, Liquid Cooling System* (Department of Defense [DOD], 6 August 1982).

⁴⁶ Military Specification MIL-A-46153, *Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package* (DOD, 31 July 1979).

⁴⁷ J.H. Conley and R.G. Jamison, "Additive Package for Used Antifreeze," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (ASTM, 1986), pp 78-85.

⁴⁸ R.H. Salvesan Associates, pp 35-36.

⁴⁹ B.A. Donahue and M.B. Carmer, *Solvent "Cradle-To-Grave" Management Guidelines for Use at Army Installations*, Technical Report N-168/ADA137063 (USACERL, December 1983); *Economic Analysis of Solvent Management Options*, Technical Note 86-1 (Department of the Army, May 1986).

⁵⁰ W.M. Toy, pp 29-30.

Solvent and Carburetor Cleaner - Offsite Recycling

Solvent and carburetor cleaner wastes can also be sent to a solvent contractor/recycler for offsite recycling. A number of companies (Table 29) provide this service.

Carburetor Cleaner - Offsite Recycling - Contract/Leased Recycling

Some companies distill spent carburetor cleaners and return the cleaner to the user. Equipment similar to solvent sinks is available for lease or purchase. The contract fees include the cost of periodic pickup and disposal of sink bottoms. Companies that provide equipment leasing services for carburetor cleaners are listed in Table 29.

Used Oil - Onsite Recycling - Gravity Separation/Blending

A state-of-the-art RACOR™ oil-to-fuel blending system that will help avoid the problem of disposing of used oils has been developed. The RACOR system is typically used in conjunction with a fuel reservoir or tank. The system blends waste diesel crankcase oil with diesel fuel. It also filters/recycles and transfers diesel fuel from the fuel holding tank. The system comes with a waste holding tank and oil injection system. Used oil from the system's holding tank is blended into diesel fuel (not to exceed 5 percent) and cycled through a three-stage filter to remove water and solid contaminants, resulting in a fuel that is 99.5 percent free of emulsified water and solid particulates. Use of a closed-loop system such as the RACOR system may satisfy all technical requirements and military specifications for oil/fuel blends³¹ and should be tested.

Used Oil - Offsite Recycling - Closed-Loop Contract

A closed-loop re-refining contract stipulates that the re-refiner agrees to process the used oil furnished by the generator, returning it to original quality for a contracted price per gallon. The re-refiner does not take ownership of the used oil but merely assumes custody of the oil until it is returned to the generator.

Among the possible disadvantages of a closed-loop contract is that installations may wish to offer used oil, solvents, and synthetic lubricants as a package. Of more immediate and important concern is that before re-refined oil can be used in government vehicles and engines, it requires approval for the Qualified Products List. Approval is a costly procedure but ensures that the product meets specifications. With estimates of \$50,000 for an engine sequence test (1982 dollars) to qualify used oil to meet Army requirements,³² many re-refiners are reluctant to enter into a contractual agreement unless the cost of such tests can be included in the closed-loop contract.³³ More recent studies have placed the cost of such a qualification procedure at \$75,000.³⁴

Used Oil - Offsite Recycling - Sale to Recyclers

Sale of used lubricating oils may be the most economical answer for an installation. Although burning and closed-loop recycling agreements offer increased economic rewards, constraints may limit the options available to an installation and make selling used oil the only feasible alternative. The cost of selling or disposing of used oil includes sampling and testing the oil, storage before the sale, 55-

³¹ D.W. Brinkman, W.F. Marshall, and M.L. Whisman, *Waste Minimization Through Enhanced Waste Oil Management*, NIPER B06803-1 (National Institute for Petroleum and Energy Research, 1987); T.C. Bowen, Personal Communication, U.S. Army, Belvoir R&D Center, Materials, Fuels, and Lubricants Laboratory, Fort Belvoir, VA, 1987.

³² Mil-L-46152, *Lubricating Oil, Internal Combustion Engine, Administrative Service, Metric* (DOD, 1 August 1988).

³³ L.C. Chicoine, G.L. Gerdes, and B.A. Donahue, pp 16-19.

³⁴ D.W. Brinkman, M.L. Whisman, and C.J. Thompson, p S-3.

gal drums for sale/disposal, inventorying expenses, advertising for bid solicitations, bid evaluation, bid letting, and accounting. Draft USEPA regulations, when finalized, could increase the workload of sales personnel slightly by requiring the selling installation (or DRMO/DRMS) to notify the USEPA of the intent to market used lubricating oil and obtain an identification number. Certified analyses on each batch of used oil will also be required, and if the oil is classified as a hazardous waste, it must be manifested and transported by a licensed hazardous waste hauler and may be distributed only to an industrial user.

Antifreeze Solutions - Onsite Recycling

In addition to reducing the quantity of waste produced, there is a major economic incentive for recycling and reusing antifreeze solutions. Because of the shortage of ethylene, the price of antifreeze has more than doubled in the past 2 years (\$3 to \$8/gal) and it is in short supply. A simple recycling method is available.⁵⁵ This method includes mechanical filtration that removes large particles before the solution is pumped into a large tank. An antifreeze extender is added to the tank based on the measured pH. The extender neutralizes the acidic byproducts in used antifreeze. The whole recycling system is available as a skid-mounted, 100-gal batch unit.

Lead-Acid Batteries - Offsite Recycling

Because of their weight, lead-acid batteries are the largest quantity of waste generated from vehicle maintenance facilities. Battery recyclers pay between \$1.00 and \$1.50 per battery (or \$0.20 to \$0.40 per pound, wet or dry). The batteries are rebuilt or processed to recover lead. Approximately 20 percent of the batteries can be rebuilt. Table 29 lists processors and smelters of lead-acid batteries. Installation logistics personnel can transport "intact" lead-acid batteries to a recycling facility if one is located nearby. A bill of lading is required if more than 10 batteries are transported at any time. Use of a registered hazardous waste hauler is not required and the waste does not have to be manifested. However, cracked or broken batteries must be transported as hazardous waste by registered haulers.

Aqueous or Caustic Wastes - Equipment Leasing

Hot tanks and spray washers are also available from equipment leasing companies (Table 30). The leasing service fee is site-specific and usually includes the raw materials, equipment maintenance, and waste disposal costs.

Dirty Rags/Uniforms - Onsite/Offsite Recycling - Laundry Service

Rags used to wipe up spills or clean off grease must not be disposed of as trash in a solid waste container. They must be collected and sent with dirty uniforms to a laundry for cleaning.

Treatment

Used Oil - Onsite Pretreatment - Filtration

A number of filtration devices are available for removing solids from used oil. Simple screen filters must be used when draining oil into containers to prevent entry of large objects (e.g., rags, cans, trash, etc.). Other filter media ranging from sand to fibrous material are available in filtration units for removing solids and even water.

⁵⁵ GLYCLEAN - Anti-freeze Recycling System, brochure (FPPF Chemical Co., Inc., 117 W. Tupper St., Buffalo, NY 14201, 1988).

Used Oil - Onsite Pretreatment - Gravity Separation

Gravity separation units are composed of a series of tanks used to contain oil and allow for gradual sedimentation of solids and water because of gravitational force and buoyancy. These units usually include skimmers and pumps to remove the water and solids. Some of the units use heat to enhance separation. Gravity separators are effective on used oils that do not contain emulsions and when a sufficient residence time can be provided for settling to occur.⁵⁶

Used Oil - Onsite Treatment - Blending/Burning

Used oil exceeding any of the specification levels for toxic metals, flash point, or total halogen content is termed "off specification used oil" and is subject to regulatory controls. Furthermore, an installation without an industrially classified boiler and whose used oil has hazardous characteristics (heavy metals, halogens, toxics) must blend the oil to meet burning specifications. Regulations regarding used oil for burning can be found in a DOD Memorandum.⁵⁷

Classification as an industrial boiler requires that energy from the boiler be used in manufacturing operations. The manufacture of steam or heat does not satisfy this criteria.⁵⁸ The amount of used oil to be blended with the fuel is not likely to have short-term impacts on the combustion efficiency of a boiler, but long-term use will likely present a problem in repeated clogging of pipes and nozzles, accelerated corrosion of pipes and tanks, and a reduction of heat transfer efficiency.⁵⁹ Current Navy regulations limit the amount of used oil in fuel oil blends to 1 percent.⁶⁰ Mixtures up to 5 percent oil, however, appear to have no appreciable impact on the Btu value of the fuel oil mixture and result in only minor additional maintenance costs, although long-term impacts of blending/mixing on operating parameters of boilers are unknown.

Before blending and burning, used oils must be filtered to remove any large impurities. Other important characteristics of used oils as a boiler fuel are API gravity and viscosity. Viscosity will impact the flow rate of the fuel and the spray pattern from the nozzle as the fuel is introduced to the boiler. The API gravity of an oil is a function of the specific gravity and is related to the heat of the burning oil. Firing temperatures for a given viscosity and discussions of the relationships between specific gravity, API gravity, and heating value can be found in literature.⁶¹

Aqueous Wastes - Onsite Pretreatment - Filtration

Installing filters on aqueous waste streams to collect grit and heavy residue increases the life of the wash solution. In one case,⁶² providing a pump-around loop through a 25-micron filter bag (on a slipstream from a jet spray washer) extended the solution life by 2 weeks, thus minimizing the quantity requiring subsequent treatment or disposal.

⁵⁶ R.H. Salvesan Associates, pp 54-57.

⁵⁷ DOD Memorandum for Deputy of Environment, Safety and Occupational Health, OASA (I&L); Deputy Director for Environment, OASN (S&L); Deputy for Environment and Safety and Occupational Health (SAF/MIQ); Director, Defense Logistics Agency (DLA-S); 28 January 1986, subject: Regulation of Used Oil for Burning.

⁵⁸ D.W. Brinkman, M.L. Whisman, and C.J. Thompson, p 34.

⁵⁹ L.C. Chicoine, G.L. Gerdes, and B.A. Donahue, pp 33-43.

⁶⁰ C.W. Anderson, *Cost-Effectiveness Analysis of Lubricant Reclamation by the Navy*, Technical Note 1481 (Naval Civil Engineering Research Laboratory [NCEL], Port Hueneme, CA, 1977).

⁶¹ T.T. Fu and R.S. Chapler, *Utilization of Navy-Generated Waste Oils as Boiler Fuel - Economic Analysis and Laboratory Tests*, Technical Note N-1570 (U.S. Navy Construction Battalion Center, 1980), pp 14-44.

⁶² W.M. Toy, p 27.

Aqueous Wastes - Onsite Treatment - Evaporation

Aqueous wastes consist primarily of water with various amounts of contaminants. Evaporating the water minimizes the amount of waste requiring disposal. In an evaporation device, the water is heated away (using an electric or natural gas heating device) leaving behind a semisolid or solid residue requiring disposal. Oil, if present in the waste, could inhibit boiling. Solid residue accumulated on the inner surface of the evaporator could inhibit heat transfer and, therefore, it may have to be cleaned frequently. Table 34 is a list of suppliers of aqueous waste volume reduction equipment.

Aqueous Wastes - Onsite Treatment - Waste Treatment

Onsite batch treatment devices that neutralize and precipitate heavy metals from aqueous wastes are available.⁶³ A pretreatment system is included to separate oil and grease. Sulfuric acid is added to reduce the pH to between 2 and 3 to reduce any hexavalent chrome to a trivalent state. Adding sulfites leads to precipitation of trivalent chrome. Sodium hydroxide is then added to raise the pH and precipitate the remaining metallic species. The precipitates settle to the bottom as a sludge and the water decanted from the top may be reused in cleaning processes. A filter press is included to reduce the water content of the sludge produced, thus also minimizing the volume to be disposed of.

Carburetor Cleaner - Offsite Treatment

Some solvent recyclers (e.g., Safety Kleen, Safe-Way Chemical) send spent carburetor cleaners to another company (e.g., Solvent Services) for treatment. This treatment process produces a lacquer wash from the spent carburetor cleaner.⁶⁴ Lacquer wash can be recycled and used in paint stripping processes.

Antifreeze Solution - Offsite Treatment

If large quantities of spent antifreeze solutions are generated at vehicle maintenance operations, the solutions can be treated at an approved treatment facility (Table 29) for recovery of ethylene glycol that may be used as waste fuel.

Lead-Acid Battery Electrolyte - Treatment

Lead-acid batteries must not be drained. These batteries are not a hazardous waste if they are sold to a recycler. Draining the batteries creates two types of wastes: lead dross, and spent sulfuric acid contaminated with lead. The electrolyte, if drained, must be neutralized and tested for lead and lead salts before draining into the sewer.

NICAD Battery Electrolyte - Treatment

NICAD battery cells contain a caustic potassium hydroxide solution (31 percent by weight). This electrolyte is corrosive. The electrolyte also contains cadmium and cadmium salts that are listed by the USEPA as hazardous wastes. The electrolyte must therefore be tested for cadmium and neutralized before disposal in the sewer.

⁶³ W.M. Toy, p 25-27.

⁶⁴ W.M. Toy, pp 31-32.

Table 27

Typical MPVM and AMF Operations With Materials Used and Wastes Generated*

Process/ operation	Materials used	Ingredients	Wastes generated
Oil and grease removal	degreasers - (gunk), carburetor cleaners, engine cleaners, varsol, solvents, acids/alkalis	petroleum distillates, aromatic hydrocarbons, mineral spirits	ignitable wastes, spent solvents, combustible solids, waste acid/alkaline solutions
Engine, parts, and equipment cleaning	degreasers - (gunk), carburetor cleaners, engine cleaners, solvents, acids/alkalis cleaning fluids	petroleum distillates, aromatic hydrocarbons, mineral spirits, benzene, toluene, petroleum naphtha	ignitable wastes, spent solvents, combustible solids, waste acid/alkaline solutions
Rust removal	naval jelly, strong acids	phosphoric acid, hydrochloric acid, hydrofluoric acid, sodium hydroxide	waste acids, waste alkalis
Solution replacement	antifreeze solution, petroleum oil	ethylene glycol, petroleum distillates	hazardous liquid, combustible liquid
Lead-acid batteries; recharging, repair, draining	automobile, truck, tracked vehicle, and other equipment batteries	lead dross, less than 3 percent free acids	used lead-acid batteries, strong acid
NICAD batteries; repair, draining	helicopter and airplane batteries	battery cells containing KOH	used NICAD battery cells, strong alkali

*Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986).

Table 28

Waste Classification for MPVM and AMF*

Process Description		Waste Description			Number
Typical process/ operation	Materials used/ wastes produced	HW code	DOT shipping name	Hazard class	
Vehicle oil changes	Used crankcase oil (not manifested)	None	Waste petroleum oil, NOS	Combustible liquid	NA1270
Oil/grease removal and equipment cleaning	Acids	D002	Depends on type of acid	Corrosive material	Varies
	Potash	D002	Waste potassium hydroxide	Corrosive material	UN1814
	Caustic soda	D002	Waste sodium hydroxide solution	Corrosive material	UN1824
	Carburetor cleaners	F002/F004	Waste solvent NOS	ORM-A	UN1591/3
	Chlorinated solvents	F001	Waste (main ingredient)	ORM-A	Varies
	Ignitable (flammable) degreasers	D001	Waste flammable liquid NOS	Flammable liquid	UN1268
	Mineral spirit solvents	D001	Waste naphtha	Flammable liquid	UN2553
	Petroleum naphtha	D001	Waste naphtha	Flammable liquid	UN1255
	Petroleum distillates	D001	Waste petroleum distillate	Flammable liquid	UN1268
	1,1,1-trichloroethane	F001	Waste 1,1,1-trichloroethane	ORM-A	UN2831
	Trichloroethylene	F001	Waste trichloroethylene	ORM-A	UN1710
	"MEK"	F005	Waste Methylcelkylene	Flammable liquid	UN1193
	Acids	D002	Depends on type of acid	Corrosive material	Varies
Rust removal	Naval jelly	D002	Waste phosphoric acid	Corrosive material	UN1805
Solution replacement	Ethylene glycol	None	Waste hazardous liquid	ORM-E	UN9189
Used lead-acid batteries	Sulfuric acid Lead dross/scrap	D002 D008	Waste sulfuric acid Hazardous waste solid NOS	Corrosive material ORM-C	UN1830 NA9189
Used NICAD batteries	Potassium hydroxide Battery cells	D002 D002/D006	Waste potassium hydroxide Hazardous waste solid NOS	Corrosive material ORM-C	UN1814 NA9189

*Vehicle Maintenance/Equipment Repair, Hazardous Waste Fact Sheet (Small Quantity Generators Activities Group, Minnesota Technical Assistance Program, 1986).

Table 29

**Partial Listing of Waste Recyclers, Haulers, Equipment Leasing Companies,
and Equipment Manufacturers***

Company and address	Telephone and services	Solvent waste	Caustic waste	Waste oil	Used antifreeze	Used batteries
Acto-Kleen P.O. Box 278 Pico Rivera, CA 90660	(213) 723-5111 (714) 944-3330 Hauler, seller	X				
American Labs 5701 Compton Avenue Los Angeles, CA 90011	(213) 588-7161 Hauler, transfer facility, and recycler	X	X			
Antifreeze Environmental Svc. Corp. 2081 Bay Rd., P.O. Box 50757 Palo Alto, CA 94303	(415) 325-2666 Recycler					X
Antifreeze Environmental Svc. Corp. 16031 E. Arrow Hwy, Unit H Irwindale, CA 91706	(818) 337-3877 Recycler				X	
Appropriate Technologies II 1700 Maxwell Road Chula Vista, CA 92011	(619) 421-1175 Processor	X	X			
Baron Blakeslee, Inc. 3596 California Street San Diego, CA 92101	(619) 295-0041 Hauler, processor, seller	X				
Baron Blakeslee, Inc. 8333 Enterprise Drive Newark, CA 94560	(415) 794-6511 Hauler, processor, seller	X				
Battery Exchange 2195 Story Road San Jose, CA 95122	(408) 251-3493 Lead-acid battery processor, 7,000 lb/month processed					X
Bayday Chemical 2096-B Walsh Avenue Santa Clara, CA 95050	(408) 727-8634 Hauler, processor	X				
Bud's Oil Service, Inc. 1340 West Lincoln Street Phoenix, AZ 85007	(602) 258-6155 Processor			X		
California Oil Recyclers, Inc. 977 Bransten Road San Carlos, CA 94070	(415) 795-4410 Processor			X	X	
Chem-Tech Systems 3650 East 26th Street Los Angeles, CA 90023	(213) 268-5056 Processor			X		

*Source: *Hazardous Waste Reduction Checklist - Automotive Repair Shops* (California Department of Health Services and Northrop Corporation, 1987).

Note: Names of other companies specific to each area can be obtained from trade publications, associations, and local telephone directories.

Table 29 (Cont'd)

Company and address	Telephone and services	Solvent waste	Caustic oil	Waste oil	Used antifreeze	Used batteries
Chem-Tak 1719-B Marshall Court Los Altos, CA 94022	(415) 968-1861 Equipment leasing and service company		X			
Demunno/Kerdoon 2000 North Alameda Street Compton, CA 90222	(213) 537-7100 Processor			X		
Detrex Chemical Industries 3027 Fruitland Avenue Los Angeles, CA 90058	(213) 588-9214 Hauler, processor	X				
Environmental Pacific Corp. 5258 SW Meadows Rd, Suite 120 Lake Oswego, OR 97035	(916) 989-5130, (503) 226-7331 Processor, recycler All lead batteries					X
Equipment Manufacturing Corp. 1433 Lidcombe Avenue South El Monte, CA 91733	(818) 575-1644 Hot tank and jet spray washer manufacturer		X			
Evergreen Oil 6880 Smith Avenue Newark, CA 94560	(415) 795-4400 Recycler			X		
EKOTEC 27833 Industrial Pk, Bldg 1, Unit 1 Valencia, CA 91355	(805) 257-9390 Processor, recycler			X		
Fuel Processors, Inc. P.O. Box 1407 Woodland, WA 98674	(503) 286-8352 Rerefiner			X		
Gibson Oil & Refining Co. 3121 Standard Street Bakersfield, CA 93308	(805) 327-0413 Processor			X		
GNB, Inc. - Metals Division 2700 South Indiana Street Los Angeles, CA 90023	(213) 262-1101, Lead-acid battery processor, 9,000 lbs. min, non-metallic cases					X
Hedrick Distributors, Inc. 210 Encinal Street Santa Cruz, CA 95060	(408) 427-3773 Hauler, storage			X		
Holchem/Service Chemical 1341 East Maywood Santa Ana, CA 92706	(714) 546-5890 (714) 538-4554 Processor	X				
Hot Tank Supply 3733 E. Clinton Avenue Fresno, CA 93703	(209) 229-0565 Equipment leasing and service		X			
Industrial Oils, Inc. P.O. Box 1221 Klamath Falls, OR 97601	(503) 884-4685 Rerefiner			X		
IT Corp/Vine Hill Facility 4575 Pacheco Blvd. Martinez, CA 94553	(415) 372-9100 Hauler, Processor	X	X			

Table 29 (Cont'd)

Company and address	Telephone and services	Solvent waste	Caustic oil	Waste oil	Used antifreeze	Used batteries
JJS Warehouse, Inc. 1076 Park Avenue San Jose, CA	(408) 294-9717 Solvent parts washer manufacturer	X				
Kinsbursky Bros. Supply North Lemon Street Anaheim, CA 92801	(714) 738-8516 Recycler, spent batteries					X
Lubrication Co. of America 4212 East Pacific Way Los Angeles, CA 90223	(213) 264-1091 Hauler, processor			X		
McKesson Chemical Co. 5353 Jillson Street Commerce, CA 90040	(213) 269-9531 Hauler, seller	X				
Nelco Oil Refining Corp. 600 West 12th Street National City, CA 92050	(619) 474-7511 Processor					
Oil and Solvent Process Co. 1704 West First Street Azusa, CA 91702	(818) 334-5117 Hauler, processor, seller	X				
Omega Chemical Company 12504 W. Whittier Blvd. Whittier, CA 90602	(213) 698-0991 Hauler, processor, seller	X				
Orange County Chemical Co. 425 Ancleason Drive Escondido, CA 92025	(619) 489-0798 Hauler, seller	X				
Orange County Chemical Co. 1230 E. Saint Gertrude Place Santa Ana, CA 92707	(714) 546-9901 Hauler, seller, processor	X				
Pacific Treatment Corp. 2190 Main Street San Diego, CA 92113	(619) 233-0863 Processor		X	X		
Pepper Oil Company, Inc. 2300 Tidelands Avenue National City, CA 92050	(619) 477-9336 Processor			X	X	
Petroleum Recycling Corp. 1835 East 29th Street Signal Hill, CA 90806	(213) 595-4731 Processor			X		
Plastic Materials, Inc. 3033 West Mission Road Alhambra, CA 91083	(818) 289-7979 Hauler, seller, processor	X				
Rho-Chem Corporation 425 Iris Avenue Inglewood, CA 90301	(213) 776-6233 Hauler, processor	X				
Romic Chemical Corp. 2081 Bay Road East Palo Alto, CA 94303	(415) 324-1638 Hauler, processor	X				

Table 29 (Cont'd)

Company and address	Telephone and services	Solvent waste	Caustic oil	Waste oil	Used antifreeze	Used batteries
RSR Quemetco, Inc. 720 South 7th Avenue City of Industry, CA 91746	(800) 527-9452 Lead acid battery processor					X
Safety Kleen Corporation 777 Big Timber Rd Elgin, IL 60120	(800) 323-5740 Equipment leasing & service from locations throughout CA	X				
Safe-Way Chemical 909 Stockton Avenue San Jose, CA 95110	(408) 292-9289 Equipment leasing and service company	X	X			
SDI Company P.O. Box 835 Upland, CA 91785	(714) 982-0553 Solvent parts washer manufacturer	X				
Solvent Services 1021 Berryessa Road San Jose, CA 95113	(408) 286-6446 Hauler, processor	X				
Tanks-A-Lot 220 W. Santa Ana Anaheim, CA 92805	(714) 778-5155 Radiator flush booth manufacturer				X	
Triad Marine & Industrial Cleaning 1668 National Avenue San Diego, CA 92113	(619) 239-2024 Processor			X	X	
Van Waters and Rogers 2256 Junction Avenue San Jose, CA 95131	(408) 435-8700 Hauler, seller	X				
Van Waters and Rogers 1363 S. Bonny Beach Place Los Angeles, CA 90023	(213) 265-8123 Hauler, seller	X				

Table 30
Equipment Leasing Costs*

Equipment	Size	Approximate cost (November 1986 prices)
Solvent Sink Includes monthly leasing of solvent sink with recirculation pump, monthly maintenance service, removal of spent solvent, and replacement with fresh solvent.	11 gal of solvent with 22-gal barrel	\$38/mon
	10 gal of solvent with 16-gal barrel	\$33.75/mon
	10 gal of solvent with 16-gal barrel	\$36.75/mon
Hot Tank Includes monthly hot tank leasing, monthly maintenance service, removal of 10 gal of solution and sludge, and recharge of solution with caustic detergent and water.	60 gal	\$93/mon
Jet Spray Washer Includes monthly jet spray washer leasing, monthly maintenance service, removal of 10 gal of solution and sludge, and recharge with caustic detergent and water.	90 gal	\$242/mon

*Source: *Hazardous Waste Reduction Assessment Handbook - Automotive Repair Shops*, p 20.

Table 31
Parts Cleaning Equipment Purchase Costs*

Equipment	Size	Approximate cost (November 1986 prices)
Solvents parts washer	Small: fill/capacity = 11/22 gal or 10/16 gal	\$200 - \$300
	Large: fill/capacity = 15/30 gal or 20/30 gal	\$250 - \$400
Jet spray washer	45 gal	\$3400
	85 gal	\$3800
	100 gal	\$4500
Hot tank	60 gal	\$300

*Source: *Hazardous Waste Reduction Assessment Handbook - Automotive Repair Shops*, p 20.

Table 32
Test Criteria for Used Cleaning Solvent (PD680-II)

Rating	Absorbance (500 nm)	Specific Gravity (17°C)	Viscosity cp (18°C)	Conductivity nmho (23°C)
0	< 0.6	< 0.773	< 1.35	< 22.5
1	0.6 - 0.8	0.773 - 0.779	1.35 - 1.85	> 22.5
2	0.8 - 1.0	0.779 - 0.785	> 1.85	
3	1.0 - 1.2	> 0.785		
4	> 1.2			

Table 33
Solvent Recovery Equipment

Supplier	Model	Capacity	Temperature limits	Approximate cost*
Acra Electric Corp 3801 N. 25th Avenue Schiller Park, IL 60176 (solvents: TCE, 1,1,1-TCE,PCE,etc.)	SD-15	5 gal	--	\$750
Artisan Industries 73 Pond Street Waltham, MA 02154	--	5-1440 gal/h	--	\$4000 to \$1.4 million
Baron Blakesless, Inc. 2001 N. Janice Avenue Melrose Park, IL 60160 (solvents: TCE, 1,1,1-TCE, PCE)	NRS-60 HRS-60	45-60 gal/h 45-60 gal/h	-- --	-- --
Branson Cleaning Equip. Co. Parrot Drive, P.O. Box 768 Shelton, CT 06484 (solvents: 1,1,1-TCE, Freon TF)	S111W S121W	9-15 gal/h 21-31 gal/h	-- --	-- --
Crest Ultrasonics Corporation Scotch Road Mercer County Airport Trenton, NJ 08628 (solvents: TCE, 1,1,1-TCE, PCE)	CRS-10H CRS-10U CRS-20H CRS-20U	10 gal/h 10 gal/h 20 gal/h 20 gal/h	-- -- -- --	-- -- -- --
DCI Corporation 5752 W. 79th Street Indianapolis, IN 46268 (solvents: chlorinated, aliphatic, aromatic fluorocarbons)	D1-DG-15	15 gal/h	--	--
Detrex Chemical Industries, Inc. P.O. Box 501 Detroit, MI 48232 (solvents: TCE, 1,1,1-TCE, Freon TF)	FC-6-EW FC-6-ER	7-25 gal/h 7-25 gal/h	-- --	-- --

Table 33 (Cont'd)

Supplier	Model	Capacity	Temperature limits	Approximate cost
Finish Engineering Company 921 Greengarden Road Erie, PA 16501 (814)455-4478, (415)821-4154 (hazardous waste solvents)	LS-Jr. LS-15 LS-15V	3-5 gal/8h 15 gal/8h 15 gal/8h	<320 °F <320 °F <320 °F	\$2995 \$5895 \$9390
Garden Machinery Corp. 700 N. Summit Avenue Charlotte, NC 28233 (petroleum solvents and oils)	#50	50-60 gal/h	--	\$4950
Hoyt Corporation Westport, MA 02790 (hazardous waste solvents)	EP8 EP20	4-8 gal/h <20 gal/h	<330 °F <330 °F	\$14,500 \$26,945
Interel Corporation P.O. Box 4676 Englewood, CO 80155 (solvents: chlorinated, petroleum)	-- --	7.5 gal/h 15 gal/h	-- --	\$8950 \$11,850
Kontes Scientific Glassware/Instruments Spruce Street, P.O. Box 729 Vineland, NJ 08360	K-547100 K-547700	0.8 gallons 2.5 gallons	-- --	\$1961 \$2723
O-I/Shott Process Systems, Inc. 1640 SW Blvd., P.O. Box T Vineland, NJ 08360	-- --	13.2 gallons 26.4 gallons	-- --	-- --
Phillips Manufacturing Co. 7343 N. Clark Street Chicago, IL 60626	RS-1 RS-3 RS-5 RS-15 RS-20	2-5 gal/h 4-10 gal/h 6-12 gal/h 13-28 gal/h 17-37 gal/h	-- -- -- -- --	-- -- -- -- --
Progressive Recovery, Inc. P.O. Box 521 Trumbull, CT 06611 (solvents: MEK, toluene, xylene, TCE, freon, etc.)	SC-Jr. SC-25	1-2 gal/h 2-4 gal/h	<400 °F --	\$4795 \$6495
Recyclene Product, Inc. 405 Eccles Ave. South San Francisco, CA 94080 (415)589-9600	R-2 RS-20 RS-35AF RX-35AF	5 gal/4h 5-7 gal/h (1) 6-8 gal/h (2) 12-16 gal/h (2)	<375 °F <375 °F <375 °F <375 °F	\$2495 \$11,000 \$21,000 \$25,850
Unique Industries, Inc. 11544 Sheldon Street Sun Valley, CA 91353 (solvents: chlorinated and fluorinated)	1100-10W 1100-10RW 1100-10RA	12 gal/h 12 gal/h 12 gal/h	-- -- --	-- \$5270 \$8250 \$8600

Table 34
Aqueous Waste Volume Reduction Equipment Suppliers*

Supplier	Model	Capacity	Approximate Cost
EMC Manufacturing 1433 Lidcombe Ave. El Monte, CA 91733 (818) 575-1644	EVAP-85E	85 gallons	\$ 1995
Nordale Fluid Eliminator 990 Xylite Ave., N.E. Minneapolis, MN 55434 (603) 668-7111 (714) 885-0691	FE-150	150 gallons	\$ 8000 - \$13,000
Wastewater Treatment Systems 440 N. Central Ave. Campbell, CA 95008 (408) 374-3030	BM-50	50 gallons	\$15,000 - \$18,000

*Source: *Hazardous Waste Reduction Assessment Handbook - Automotive Repair Shops*, p 22.

6 WASTE MINIMIZATION FOR HOSPITALS, CLINICS, AND LABORATORIES

Army hospitals, veterinary clinics, dental clinics, and other laboratories are usually tenants located on an installation. The types of wastes generated by these activities can be divided into infectious wastes (IW), pathological wastes (PW), sharps, pharmaceutical wastes (PhW), radioactive wastes (RW), laboratory wastes (LW), chemotherapy wastes (CW), infectious linen (IL), and general wastes (GW). Only the LW and CW are hazardous wastes by the RCRA and HSWA definition.

For this discussion, some of the definitions for hospital wastes are extracted from Army Regulation (AR) 40-5.⁶⁵ Detailed definitions and classifications of infectious wastes can be obtained from USEPA's *Guide to Infectious Waste Management*.⁶⁶

IW is from patients in strict or respiratory isolation, or with wound and skin precautions; wastes from microbiological laboratories; and surgical waste (at the discretion of the operating room supervisor). PW includes anatomical parts, excluding human corpses and animal carcasses. Sharps include discarded hypodermic needles, syringes, pipettes, broken glass, and scalpel blades that pose infection and physical injury hazards through cuts or puncture wounds. GW is all the waste not classified as infectious, pathological, or hazardous, for example: refuse generated from general patient units, emergency rooms, dental areas, surgical suites, administrative areas, and supply areas. PhW consists primarily of outdated medicines (drugs, vaccines, and physiological solutions). RW wastes emit ionizing radiation (such as alpha, beta, gamma, or X-rays).

The activities that generate most of the highly infectious wastes are: general surgery/recovery, vascular surgery, plastic surgery, pathology, blood bank, microbiology laboratory, labor and delivery rooms, obstetrics, emergency room isolation, and the morgue. Among the wastes generated are: (1) significant laboratory waste, including all tissue or blood elements, excreta, and secretions obtained from patients or laboratory animals and disposable fomites (items that may harbor or transmit pathogenic organisms); (2) surgical specimens and attendant disposable fomites; (3) disposable materials from outpatient areas and emergency departments; (4) equipment, instruments, utensils, and fomites of a disposable nature from isolation rooms; (5) animal feces, animal bedding, supplies, and fomites resulting from and/or exposed to infectious animal care and laboratory procedures; and (6) all disposable needles and syringes.⁶⁷

Radioactive wastes are usually generated by the radiology ward, nuclear medicine, clinical pathology, and laboratories that use radionuclides. Some of the radionuclides administered to patients during treatment include: ^{99m}Techetium, ⁵¹Chromium, ³²Phosphorus, and ¹³¹Iodine.⁶⁸ Most of the radioactive wastes that require special handling and disposal are generated by the use of radionuclides such as ¹⁴Carbon, ³Hydrogen, and ¹³¹Iodine, in clinical laboratories.

A number of different types of hazardous wastes are generated in HCL, although in small quantities. Table 35 lists processes and operations that generate wastes, and the corresponding DOT classifications. LW is mostly chemical wastes, including ignitable/chlorinated solvents and miscellaneous used chemicals (e.g., xylene, formalin, mercury, etc.) generated in analytical and clinical laboratories. These wastes may also be generated in maintenance, pharmacy, and nursing areas.

⁶⁵ Army Regulation (AR) 40-5, *Preventive Medicine* (HQDA, 30 August 1986).

⁶⁶ *Guide to Infectious Waste Management*, EPA/530-SW-86-014 (USEPA, Washington, D.C., 1986).

⁶⁷ D. Kraybill, T. Mullen, and B.A. Donahue, *Hazardous Waste Surveys of Two Army Installations and an Army Hospital*, Technical Report N-90/ADA088260 (USACERL, August 1980), pp 46-48.

⁶⁸ D. Kraybill, T. Mullen, and B.A. Donahue.

Photographic films and chemicals are used in radiology. Other toxics and corrosives are used throughout the hospitals.

CW is a large quantity HW generated by the use of antineoplastic, or cytotoxic agents in chemotherapy solutions administered to patients. The chemicals themselves are only a small volume of the waste; most of it consists of protective clothing and gauze pads that are lightly contaminated.

Most of the guidance on proper management and minimization of wastes discussed in this chapter has been obtained from *Protocol Health Care Facility Waste Management Surveys*,⁶⁹ and *Waste Audit Study - General Medical and Surgical Hospitals*.⁷⁰ The minimization of photographic wastes is discussed in Chapter 9.

Regulations

On October 21, 1988, the U.S. Congress passed the Medical Waste Sanctions Act (MWSA) which requires strict control on generation and disposal of medical wastes, and prohibits anyone from dumping the wastes in oceans and large water bodies (such as the Great Lakes).⁷¹ MWSA was initiated as an amendment to the original Marine Protection, Research and Sanctuaries Act (MPRSA) of 1972. MPRSA and MWSA define "medical waste" to include "isolation wastes; infectious agents; human blood and blood products; pathological wastes; sharps; body parts; contaminated bedding; surgical wastes and potentially contaminated laboratory wastes; dialysis wastes; and other equipment and material that the Administrator of the USEPA determines may pose a risk to public health, welfare, or the marine or Great Lakes environment." Of the 160 million tons of waste generated in the United States each year, 3.2 million tons of them are medical wastes from hospitals.⁷² These medical wastes do not include refuse from doctors' offices, laboratories, home health care, veterinary clinics, and blood banks. Of the 3.2 million tons of medical wastes, USEPA estimates that 10 to 15 percent are infectious.

MWSA was passed because medical wastes could be regulated under the RCRA and HSWA but are not under the USEPA rules. MWSA requires USEPA to develop rules and regulations for a cradle-to-grave manifest system to track the medical wastes from generation to disposal, and for record-keeping, reporting, and proper segregation (from ordinary refuse) and disposal requirements. The States have been given the authority to enforce MWSA more stringently than the USEPA requirements. Therefore, States such as Delaware, Louisiana, Maryland, Minnesota, New York, and Pennsylvania have passed stricter laws for tracking and disposing of medical wastes.

In the private sector, research and testing laboratories such as those located in Army hospitals and associated research facilities would be regulated as small quantity generators of hazardous laboratory waste. All the rules of RCRA and HSWA would apply and cradle-to-grave management and development of minimization strategies would be necessary.

⁶⁹ *Protocol Health Care Facility Waste Management Surveys* (USAEHA, 1987).

⁷⁰ Ecology and Environment, Inc., *Waste Audit Study - General Medical and Surgical Hospitals* (California Department of Health Services, Sacramento, CA, 1988).

⁷¹ *Medical Waste Sanctions Act of 1988*, Report 100-1102 (House of Representatives, 100th Congress, October 1988).

⁷² *Medical Waste Sanctions Act of 1988*.

Source Reduction - All Wastes

IW/PW/GW/Sharps - Better Operating Practices - Segregation

IW and PW must be segregated from GW and sharps. GW such as surgical glove wrappers should not be placed in IW containers (e.g., red bags in rigid containers). Sharps must be placed in separate containers (e.g., rigid plastic boxes) in every room where they are used. Separate containers (e.g., yellow or white bags) must be used for general wastes including paper and trash.

Source Reduction - Infectious and Pathological Wastes

IW/PW - Better Operating Practices - Segregation/Labeling

All the containers must be rigid and must be lined with impervious, tear resistant, and distinctively colored bags (e.g., red bags for infectious wastes only). The same type and color bags must be used at all waste generation points and marked/labeled with the universal biohazard symbol. Standardized procedures (labeling, color, etc.) reduce confusion among personnel and improve waste management, thus minimizing quantities of wastes generated.

IW/PW - Better Operating Practices - Collection/Transportation

Sufficient numbers of IW/PW containers must be provided and conveniently located in all rooms where the wastes are generated. They should also be located in such a way as to minimize patients/personnel exposure to the wastes. The containers must be cleaned and disinfected every time they are emptied. All the containers should have tight-fitting lids and the lids should be in place when the containers are not in use. To minimize exposure for patients and staff, IW/PW must be collected frequently from all the generation points by trained personnel only. The transport containers must have tight-fitting lids and should be used exclusively for IW/PW. The interior of the transport containers must be cleaned and disinfected regularly.

IW/PW - Better Operating Practices - Storage

All IW/PW storage areas (including access doors, containers, freezers, refrigerators, etc.) must be labeled and marked with the universal biohazard symbol.

Treatment - Infectious and Pathological Wastes

IW/PW - Treatment/Better Operating Practices - Incineration

Incineration is one of the options used to treat infectious wastes. The manufacturer's operating instructions and standard operating procedures must be posted on the incinerator. A State or local air quality permit must be obtained and the incinerator must be operated in compliance by following the manufacturer's recommended temperature to reduce emissions and opacity problems.

The incinerator ash could be a hazardous waste. It should be tested annually for hazardous characteristics. Testing of incinerator ash at Army installations⁷⁹ has revealed that it is Extraction Procedure (EP) toxic for heavy metals.

⁷⁹ Protocol Health Care Facility Waste Management Surveys.

The red bags used to contain IW/PW burned in incinerators are made of chlorinated plastics (PVC). Burning these red bag wastes generates a number of air pollutants of concern including: hydrochloric acid, dioxins, furans, and particles. These toxic stack emissions are a significant hazard to the community. As public concern increases (and regulations change) proper flue-gas cleanup will be required. Some of the air emission control devices that could be installed include: dry impingement separators, dry cyclonic separators, venturi scrubbers, electrostatic precipitators, fabric filters, wet acid gas scrubbing devices, and dry scrubbing systems.

IW/PW - Treatment/Better Operating Practices - Autoclaves/Retorts

Autoclaves or retorts are used in several hospitals to disinfect IW/PW before landfill disposal. All the operators should be trained in proper equipment use. The bags used in autoclaves should allow sufficient steam penetration and yet contain the wastes. Compaction of wastes must always follow the autoclaving process. Spore strips should be used to check the effectiveness of the operation.

Source Reduction - Sharps

Clipping needles after use is prohibited by AR 40-5 to prevent generation of pathogen-containing aerosols. Used syringes must be placed only in rigid impervious containers marked with the universal biohazard symbol. Adequate containers must be provided and managed by trained personnel.

Source Reduction - Hazardous Wastes

HW - Better Operating Practices - Inventory

A current and comprehensive inventory must be developed for all the hazardous materials used and hazardous wastes generated. The inventory must contain the following for each HW: a description; hazard code; USEPA (or State) number; physical form; rate of generation; method of treatment, storage, and disposal; and an indication if the waste is infectious. All HW on the inventory must be reviewed annually and reported to the installation environmental office.

Infectious hazardous wastes could be generated at the histology (waste xylene), parasitology (hazardous fluids), and radiology (waste barium) laboratories. A proper inventory must be developed for these wastes. The procedures for handling these wastes are outlined in *Infectious Hazardous Waste Handling and Disposal*.⁷⁴

HW - Better Operating Practices - Proper Storage

Proper containers must be used to store hazardous wastes; they must be properly labeled. They must contain liners compatible with the wastes. Upon exceeding the 55-gal (or 1 qt for acute HW) storage limit in the satellite accumulation areas, the 90-day temporary storage requirements⁷⁵ have to be complied with and the wastes must be turned in to the installation's hazardous wastes storage building.

⁷⁴ *Infectious Hazardous Waste Handling and Disposal*, Technical Guide Number 147 (USAEHA, 1986).

⁷⁵ 40 CFR 262.34, *Onsite Accumulation Requirements*.

HW (solvents) - Better Operating Practices - Segregation

Solvent wastes must be segregated according to the recycling or treatment processes used for their recovery or disposal. Some of the criteria useful for segregation are:⁷⁶ flash point, Btu value, viscosity, halogen content (e.g., chlorine), and water content. Segregating wastes as individual chemicals (with minimal contamination) simplifies waste management.

HW (solvents) - Product Substitution

Nonhalogenated solvents must be substituted for halogenated solvents (e.g., TCE, 1,1,1-trichloroethane, MC, etc.). Simple alcohols and ketones are good substitutes for petroleum hydrocarbons (e.g., toluene, xylene, etc.). Aqueous reagents must be used whenever possible. The feasible substitutions have to be determined by laboratory managers on a case-by-case basis.

Xylene is commonly used as a tissue cleaning agent at hospitals. Use of a nonhazardous substitute (such as Histoclear™) must be examined to determine its effectiveness.

HW (solvents) - Process Change

Cleaning processes that use alcohol-based disinfectants must be modified to use ultrasonic or steam cleaning methods. Premixed containerized test kits must be used for solvent fixation (making slides). Calibrated solvent dispensers must be used for routine tests. Minimizing the sizes of cultures or specimens in the pathology, histology, and other laboratories, minimizes the quantities of solvent wastes produced.

Modifying laboratory methodologies to use modern technologies (e.g., monoclonal antibodies, radioisotope labeled immunoassays, and ultrasensitive analytical devices) minimizes or even eliminates the need for extractions and fixation with solvents. Sensitive analytical equipment can reduce analyte volume requirements.

LW - Better Operating Practices - Disposal

All the laboratory hazardous wastes that may be discharged into the sanitary sewer must be identified. Approval must also be obtained from local authorities. According to USEPA requirements [40 CFR 261.3(a)(2)(iv)(E)] the following conditions must be met:

1. Only low toxic hazard, and biodegradable wastes may be discharged,
2. The annualized average flow rate of laboratory wastewater must not exceed 1 percent of the total wastewater flow into the inflow of the wastewater treatment plant,
3. The combined annualized average concentration must not exceed one part per million (ppm) of the inflow to the wastewater treatment plant.

Proper standard operating procedures must be developed and used for disposal of chemicals in the sanitary sewer system.⁷⁷ Disposal actions must be coordinated with the installation's environmental

⁷⁶ Ecology and Environment, Inc., pp 5-1 through 5-3.

⁷⁷ National Research Council, *Prudent Practices for Disposal of Chemicals from Laboratories* (National Academy Press, Washington, DC, 1983).

office. Sewer disposal is an environmentally unsound practice and must be avoided. However, controlled disposal is allowed by law.

HW (mercury) - Better Operating Practices

Waste mercury can be recycled and must be recovered from spills and from crevices of broken devices. All the residual mercury contained in broken thermometers, blood pressure reservoirs, or other devices should be drained. However, proper spill cleanup and handling operations have to be designed to protect the employees. Special mercury vacuums and spill absorbing kits are available.

HW (mercury) - Process Change

Many hospitals in the United States are using electronic piezometric sensing devices instead of mercury-based thermometers and blood pressure instruments. Such a substitution eliminates both the hazards and cleanup costs associated with broken glass and spilled mercury.

HW (formaldehyde) - Better Operating Practices

Reducing both the cleaning frequency of hemodialysis and reverse osmosis (RO) water supply equipment and the solution strength will minimize the quantities of waste formaldehyde generated. The membranes used in RO units have to occasionally be flushed with formalin. A laboratory standard for formalin solutions should be developed based on microbial culture studies that compare microbial residue with variations in strength, cleaning frequency, and water supply systems.⁷⁸

HW (formaldehyde) - Process Change

The dialysis equipment used in the hospital can be used to capture and concentrate waste formalin (containing 4 percent formaldehyde, 1 percent methanol, and 95 percent water).⁷⁹ Formaldehyde extracted and concentrated with the used dialysis membranes can then be sent for proper disposal (e.g., incineration), thus minimizing the waste and associated costs.

CW - Better Operating Practices - Collection/Disposal

Special dedicated containers must be used to collect antineoplastics, cytotoxins (cancer treatment agents), and other controlled drugs. Many of these drugs are listed hazardous wastes and must be managed using proper turn-in procedures.

CW - Better Operating Practices

Segregation of CW from other wastes is an effective minimization practice. Personnel must be properly trained and separate containers (with distinct labels) must be placed in all the drug handling areas.

The cleaning frequency for hoods used for compounding drugs should be reduced. According to OSHA recommendations, hoods should be wiped down daily with 70 percent alcohol and decontaminated weekly with an alkaline solution.⁸⁰ However, the actual cleaning frequency must be determined based on the use and amount of spillage in the hood.

⁷⁸ Ecology and Environment, Inc.

⁷⁹ Ecology and Environment, Inc.

⁸⁰ Ecology and Environment, Inc.

Spill cleanup kits, for small and large spills, must be readily available in the drug compounding and use areas. The garments, except gloves, worn by employees should be disposed of with non-hazardous refuse if no spills occurred.

The location of compounding and administration areas should be centralized to minimize spillage and exposure hazards. Drug purchases must be controlled such that only the appropriate container sizes are procured and no residue is left for disposal. Outdated drugs should be returned to the manufacturer.

CW - Product Substitution

Antineoplastics and cytotoxic agents are highly toxic and environmentally persistent. They must be substituted with biodegradable drugs. In some cases, the shelf life can be used as an indicator of environmental persistence. Doctors and pharmacists must be encouraged to choose less environmentally hazardous drugs of equal effectiveness.

RW - Product Substitution

A knowledge of the properties of radionuclides (Table 36) is required for the minimization of RW. A stable radionuclide with a short half-life, low energy, nontoxic decay product, and minimal extraneous radiation emissions must be chosen. Extraneous radiation is the radiation generated that is not required in a test or procedure. If a beta emitter is required, a radionuclide with minimal gamma emissions must be chosen. Containment of gamma rays is difficult.

A radiation safety committee should be established to advise researchers about alternative isotopes that are less environmentally hazardous than those currently in use.

RW (²²⁶Radium) - Product Substitution

²²⁶Radium is the most hazardous radionuclide used for cancer treatment in hospitals. It has a very long half-life and its decay products are unstable. ¹⁹²Iridium or ¹³⁷Cesium needles have been found to be good substitutes for ²²⁶Radium needles.⁸¹

Recycling Onsite/Offsite - Hazardous Wastes

HW (xylene, other solvents) - Recycle Onsite - Distillation

All the spent solvents generated in the laboratories must be accumulated in proper segregated containers. The recyclability of solvents is greater if contamination is minimal. Small distillation stills can be used to recover solvents for reuse.

Table 33 lists manufacturers of industrial distillation equipment. For laboratories, stills made of glassware (process-spinning band distillation⁸²) may be more suitable. Appropriate manufacturers (e.g., B/R Instrument Corporation, P.O. Box 7, Pasadena, MD 21122; 301-647-2894) must be contacted for information on technical feasibility and costs.

⁸¹ Ecology and Environment, Inc.

⁸² L.M. Gibbs, "Recovery of Waste Organic Solvents in a Health Care Institution," *American Clinical Products Review* (November/December 1983).

Xylene wastes generated at the hospitals are contaminated with paraffin and tissue samples, and their recyclability depends on the content of the contaminants. Small stills can be used to distill out pure xylene for reuse. The still bottoms must be properly disposed of as HW. The still can be used to recycle other solvents (e.g., ethanol).

HW (solvents) - Offsite Recycling

A number of commercial recyclers process solvents for reuse. Table 29 lists some of them.

HW (mercury) - Offsite Recycling

If more than 10 lb of liquid mercury is accumulated, it can be sold to a commercial reprocessor.⁸³ Large quantities can be sent in standard (76-lb) flasks supplied by the reprocessor. These reprocessors are willing to purchase from institutions rather than individuals. Therefore, DRMO must pursue this option for Army installation generators such as hospitals, laboratories, etc.

HW (formaldehyde) - Onsite Recycling - Reuse

Direct reuse of formaldehyde solutions in autopsy and pathology laboratories is possible, depending on the type of specimen. Reuse is possible because the specimen holding times are short and formalin solutions retain their properties for a long time. Additionally, the desired preservative properties may be more effective at lower concentrations than the 10 percent formaldehyde solutions commonly used in pathology laboratories.⁸⁴ Minimum effective strength of formalin solutions should be determined based on microbial culture studies.

HW (photographic chemicals) - Recycle Onsite/Offsite - Silver Recovery

Silver recovery methods such as those described in Chapter 8 must be used.

Treatment - Hazardous Wastes

HW (solvents) - Onsite Treatment - Incineration

If recovery by distillation is not a feasible option, onsite incineration should be considered. A permit is needed to operate an incinerator to burn solvents. Therefore, onsite incineration may not be a practical option for most Army hospitals. However, with the increase in offsite incineration costs and the ban on land disposal of liquid wastes and long-term liabilities, onsite incineration may become a viable treatment method in the future.

Waste designated for incineration must have a high Btu content, a high flash point, low specific gravity, and a low solids content. The incinerator must be designed to achieve complete destruction while generating negligible quantities of air pollutants. Both technical and institutional problems have to be addressed before acquiring an incinerator to burn small amounts of a wide variety of chemical wastes.⁸⁵

⁸³National Research Council, pp 44-55.

⁸⁴National Research Council, Chapter 4.

⁸⁵National Research Council, Chapter 9, pp 111-125.

HW (solvents) - Offsite Treatment - Incineration

Use of offsite facilities to incinerate solvent wastes may be a feasible option for most laboratories. Commercial incineration facilities require generators to segregate wastes and arrange for transportation.

LW (acids/alkalis) - Treatment - Neutralization

Elementary neutralization of corrosive liquids is exempt from treatment permit requirements. Acids ($\text{pH} < 2$) and alkalis ($\text{pH} > 12.5$) must be neutralized before they are allowed to flow into the drain.

Table 35
Waste Classification for HCL

Process Description		Waste Description			
Typical operation	process/ operation	Materials used/ wastes produced	HW code	DOT shipping name	Hazard class Number
Analytical/clinical laboratories, Pathology, Histology, Embalming, Sterile processing, Facilities maintenance, Laundry		Nonhalogenated solvents:	R003	Waste acetone	Flammable liquid UN1090
		Acetone	D001	Waste acetone	Flammable liquid UN1648
		Acetonitrile	R003	Waste ethyl alcohol	Flammable liquid UN1170
		Ethanol	R003	Waste ethyl acetate	Flammable liquid UN1173
		Ethyl acetate	D001	Waste isopropyl alcohol	Flammable liquid UN1219
		Isopropanol	R003	Waste methanol	Flammable liquid UN1230
		Methanol	R005	Waste toluene	Flammable liquid UN1294
		Toluene	R003	Waste xylene	Flammable liquid UN1307
		Xylene			
		Halogenated solvents:		Waste chloroform	ORM-A UN1888
		Chloroform	R001	Hazardous waste liquid, NOS	ORM-A UN9189
		Freon	R001	Waste methylene chloride	ORM-A UN1593
		Methylene chloride	R001	Waste 1,1,1-trichloroethane	ORM-A UN2831
		1,1,1-trichloroethane	R001	Waste trichloroethylene	ORM-A UN1710
		Trichloroethylene			
		Acids/bases:	D002	Waste acetic acid (solution)	Corrosive material UN2790
		Acetic acid	D002	Waste hydrochloric acid	Corrosive material UN1789
		Hydrochloric acid	D002	Waste nitric acid, > 40%	Oxidizer UN2031
		Nitric acid	D002	Waste Nitric Acid, < 40%	Corrosive material NA1760
			D002	Waste sulfuric acid	Corrosive material UN1830
		Sulfuric acid	D002	Waste sulfuric acid, spent	Corrosive material NA1831
			D002	Waste ammonium hydroxide, < 12%	Corrosive material NA2672
		Ammonium hydroxide	D002	Waste ammonium hydroxide, > 12% < 44%	ORM-A NA2672
			D002	Waste potassium hydroxide, solid	Corrosive material UN1813
		Potassium hydroxide	D002	Waste potassium hydroxide, liquid	Corrosive material UN1814
			D002	Waste sodium hydroxide, solid	Corrosive material UN1823
		Sodium hydroxide	D002	Waste sodium hydroxide, liquid	Corrosive material UN1824
		Others:	D009	Waste mercury	ORM-A UN2809
		Mercury		Waste oxidizer, NOS	Oxidizer UN1479
		Oxidizers		Waste oxidizer, corrosive, liquid, NOS	Oxidizer NA9193
				Waste oxidizer, corrosive, solid, NOS	Oxidizer NA9194
		Poisons		Waste poison B, liquid, NOS	Poison B UN2810
				Waste poison B, solid, NOS	Poison B UN2811
				Waste corrosive liquid, poisonous, NOS	Corrosive material UN2922
		Poisonous, oxidizers		Waste poisonous solid, corrosive, NOS	Poison B UN2928
				Waste oxidizer, poisonous, liquid, NOS	Oxidizer NA9199
		Nonspecific hazardous Wastes		Waste oxidizer, poisonous, solid, NOS	Oxidizer NA9200
				Hazardous waste liquid, NOS	ORM-E NA9189
				Hazardous waste solid, NOS	ORM-E NA9189
Chemotherapy, pharmacy, clinics		Antineoplastics			UN2209
		Cytotoxic drugs			UN1198
Radiology		Photographic chemicals:			ORM-A
		Fixer			ORM-A
Hemodialysis, Pathology, Autopsy, Embalming, Nursing		Formaldehyde		Waste formaldehyde solution, flash point > 141 °F	
				Waste formaldehyde solution, flash point ≤ 141 °F	
Clinical Testing		Radioisotopes			

Table 36
Properties of Radionuclides used in Hospitals*

Nuclide	Type of Radiation	Energies (MEV)	Physical Half-Life	Effective Half-Life	R/hr per C _i at 1 meter**	Daughters
¹⁴ Carbon	beta no gamma	0.156 max	5730 years	12 days	n/a	¹⁴ Nitrogen(s)***
³² Phosphorus	beta no gamma	1.7 max	14 days	14 days	n/a	³² Sulfur(s)
⁵¹ Chromium	gamma	0.32	28 days	27 days	0.018	⁵¹ Vanadium(s)
⁶⁷ Gallium	gamma	0.093 (40%)	78 hours	5 hours	0.059	⁹⁹ Technetium(r)† ⁹⁹ Ruthenium(s)
¹¹¹ Indium	gamma	0.173	2.8 days			¹¹¹ Cadmium(s)
¹²⁵ Iodine	gamma	0.035	60 days	42 days	0.07	¹²⁵ Tellurium(s)
³ Tritium	beta no gamma	0.0186 max	12.3 years	12 days	n/a	³ Helium(s)
¹³¹ Iodine	beta gamma	0.606 max 0.365	8 days	8 days	0.21	¹³¹ Xenon(s)
¹³⁷ Cesium	beta gamma	1.176 max (7%) 0.514 max 0.662	30 years	70 days	0.32	¹³⁷ Barium(s)
^{137m} Barium	gamma	0.662	2.5 min			¹³⁷ Barium(s)
¹⁹² Iridium	beta	0.666 max	74 days			¹⁹² Platinum(s)
²²⁶ Radium	alpha gamma	4.78 0.186	1600 years	44 years	0.825	²²² Radon(r)
⁶⁰ Cobalt	beta	0.318 max	5.27 years	10 days	1.33	⁶⁰ Nickel(s)

* Ecology and Environment, p 5-9.

** Source: *R/hr per C_i at one meter*: Unit of Specific Activity for gamma emitting radionuclides, which indicate Roentgen/hour measurement expected at a distance of 1 meter from a 1 Curie point source.

*** (s) - stable daughter.

† (r) - radioactive daughter.

7 WASTE MINIMIZATION FOR PAINT SHOPS

Paints are applied to metal or other surfaces (e.g., wood) for waterproofing, flameproofing, rustproofing, insulating, etc. There are three different categories of paints: architectural, original equipment manufacture (OEM), and special purpose. Architectural paints are used on buildings. OEM paints are used in industries that manufacture automobiles, appliances, and furniture.⁸⁶ Special purpose paints such as chemical agent resistant coating are used in maintenance operations in some industries, the armed services, and highway maintenance. Forty-four percent of the special purpose coatings are used on automobiles, 18 percent in industrial maintenance, and the remaining distributed between aerosols, traffic paints, and other categories.⁸⁷

The painting process involves: paint stripping and surface preparation, application of the paint, and curing. Paint stripping (using wet or dry techniques) and surface preparation are necessary to clean the substrate and prepare it for adhesion of the paint. Paint is then applied to the surface. The method used depends on the size, shape, complexity, and number of items. After painting, the items are placed in a curing oven to remove excess solvent and make the coating uniform. Some of the common painting techniques are: dip painting, flow painting, roll painting, curtain painting, spray painting, and bulk painting. Spray painting is the most commonly used technique and can be manual or automatic. Spray painting techniques (including conventional pressure/air atomized, and electrostatic centrifugal/air atomized) have transfer efficiencies that range from 30 to 95 percent. The overspray from the paint application process can be as high as 50 to 70 percent, and is in most cases collected and disposed of. The method of painting may sometimes be dictated by the type of paint formulation (e.g., water-based enamels cannot be sprayed).

Most paint formulations use solvents as carriers for binders such as pigments, powders, and adhesives. The solvent content can vary from 1 to 85 percent. Typical solvents include: acetone, n-butanol, o-dichlorobenzene, diethyl ether, ethyl acetate, butanol, MEK, methyl isobutyl ketone, MC, 1,1,1-trichloroethane, trichlorofluoro-methane, tetrahydrofuran, cyclohexanone, and petroleum derivatives such as naphtha, xylene, toluene, or hexane. Powder or water-based paints do not contain solvents. Solvent-based paints (e.g., acrylic lacquers) have the advantage of durability, fast drying time, low corrosivity to substrate, and high gloss finish.⁸⁸ Some of the disadvantages include: emission control problems, worker exposure hazards, fire hazards, and waste management, disposal, and liability problems. The criteria used in choosing a solvent depends on the type of paint required, drying speed, the nature of the substrate, and the properties of the solvent.

In addition to the wastes from the painting process, a large quantity of solvent wastes are generated during equipment cleaning. Table 37 describes the wastes generated from the painting process and lists the corresponding DOT classifications.

Most of the minimization options discussed in this Chapter were obtained from *Guide to Solvent Waste Reduction Alternatives*.⁸⁹

⁸⁶ ICF Associates, Inc.

⁸⁷ P.L. Layman, "Paints and Coatings: the Global Challenge," *Chemical and Engineering News* (September 30, 1985), pp 27-68.

⁸⁸ ICF Associates, Inc.

⁸⁹ ICF Associates, Inc.

Source Reduction

Solvent-Based Paints - Product Substitution - Powder Coatings

Powder coating is an effective alternative to solvent-based paints. In a powder coating process, the paint powder is applied to a substrate with an electrostatic spray gun. The carrier is pressurized air, rather than solvents. The powder coating adheres to the surface because of electrostatic forces. Excess powder that does not cling to the surface can be recycled. Heating in the curing oven ensures that the powder fuses to the surface. Powder coatings can also be applied using a fluidized bed process where the heated objects are immersed in the fluidized bed.

Because powder coatings contain no solvents, emissions of volatile organic compounds and the related air pollution problems are eliminated. Fire hazard and insurance rates are reduced and better neighborhood relations develop as the odor associated with solvent-based application are eliminated. Preliminary toxicological studies indicate that many of the commercial powder formulations are nontoxic. Since the overspray powder can be recycled, material use is high and solid waste generation is minimal. Waste disposal and liability problems are reduced. The process also has a high transfer efficiency, resulting in a lower reject ratio of parts. Coating quality is claimed to be better than with solvent-based coating. The messy cleanup operations associated with liquid-based paints are avoided. Powder coating is easier to apply and it is easier to train people to use it. The operators' attitudes improve. The operation is less labor intensive. Maintenance is easier and the overall operating costs are lower. Powder costs are minimally affected by petroleum prices and the operation is more flexible to changing coating requirements.

However, powder application equipment is more expensive to install than solvent-based or high solids coating equipment. Another disadvantage is that powder coating must be done at elevated temperatures. It is not usable on heat sensitive substrates such as plastics, wood, and assemblies containing nonmetal parts. Formulations with lower cure temperatures (275 °F) are being developed.⁹⁰

Solvent-Based Paints - Product Substitution - Water-Based Formulations

Water-based formulations reduce the amount of solvents used and emitted in the coating process. Solvent-based paint equipment can easily be modified to apply water-based paints/coatings. The paint overspray can easily be collected with water in the spray booth and recycled. Though this can also be done in a solvent-based process, a difficult-to-treat aqueous waste stream may result due to direct contact with the solvent. Disposal and liability issues associated with wastes from the solvent-based formulation are reduced and the fire and explosion hazards present with the solvent-based process are eliminated. Concerns about worker exposure to solvents are also eliminated. Energy savings can be achieved by recirculating hot air in the ovens used to cure the paint. Similar recirculation is not possible in a solvent-based operation as the solvent levels in the recirculated air may reach explosive levels. The installed capital cost of water-based units is lower than that for high solids or powder coating.⁹¹

A number of private companies and a naval installation (Naval Air Rework Facility, Pensacola, Florida) have successfully converted from solvent-based painting to a water-based painting operation.⁹² Based on their experience, the annual cost to coat using water-based coating was higher compared to conventional solvent, high solids, or powder coating. The applied coating cost per square foot for a

⁹⁰ ICF Associates, Inc.

⁹¹ ICF Associates, Inc.

⁹² ICF Associates, Inc.

water-based unit is also higher and the coating may be inferior. The quality of water-based coatings varies with ambient conditions such as room temperature and humidity. The drying time is longer and could be a bottleneck in the production line. It may necessitate installing a drying unit. Surface treatment procedures may need extensive modification to convert to a water-based coating method.⁹³

One company that unsuccessfully tried to convert to water-based painting reported that the increased drying time led to production scheduling problems. The new system took several hours for drying, compared to the 30 minutes required for the solvent-based process. It required an increased amount of surface cleaning before the water-based coating could be applied. The time and cost involved in the extra cleaning were prohibitive. The water coating did not have the same hardness, durability, or gloss and the quality of the water-based paint varied with room temperature and humidity. The company also reported that the water environment was corrosive to galvanized steel. The existing equipment made of galvanized steel needed to be replaced with stainless steel, which involved considerable expense.⁹⁴

Solvent-Based Paints - Product Substitution - Two-Component Catalyzed Coatings

Two-component catalyzed coatings are comprised of isocyanates (highly toxic compounds) and hydroxyl compounds. These compounds polymerize on a surface to form a polyurethane coating. Their use has been extensively investigated by the automobile industry.⁹⁵ Substituting two-component catalyzed coatings for solvent-based formulations is not justified because of the toxicity of the components.

Solvent-Based Paints - Product Substitution - Radiation-Curable Coatings

Radiation-curable coatings do not contain solvents and therefore could be good substitutes. A liquid prepolymer is allowed to react with a thinner under ultraviolet light to form a coating. These coatings have been found to be effective on a number of surfaces.⁹⁶

Paint Wastes - Better Operating Practices - Segregation

The current practice for disposing of residual paint left in cans is to pour it into drums containing thinner wastes. However, segregating paints from thinner wastes maintains the purity of the thinner and improves its recyclability. Thinners can be recycled onsite or offsite and reused in painting and cleaning processes.

Excess paints should be given to customers for touchup use, thus reducing the improper disposal of cans containing liquid paint with other nonhazardous wastes. (Cans containing dried paint residue can be thrown out.)

Solvent Wastes - Better Operating Practices - Adopt Good Manual Spraying Techniques

When manual spraying practices are used, the amount of waste produced can be reduced by: using a 50 percent overlap in the spray pattern, maintaining a 6- to 8-in. distance between the spray gun and the surface, maintaining a gun speed of 250 ft/min, holding the gun perpendicular to the

⁹³ ICF Associates, Inc.

⁹⁴ ICF Associates, Inc.

⁹⁵ M.E. Campbell and W.M. Glenn, *Profit from Pollution Prevention - A Guide to Industrial Waste Reduction and Recycling* (The Pollution Probe Foundation, Toronto, Canada, 1982).

⁹⁶ M.E. Campbell and W.M. Glenn.

surface, and triggering at the beginning and end of each pass.⁹⁷ In addition to reducing the amount of waste produced, an increase in the production rate and a decrease in the rejection rate can be realized.

Solvent Wastes - Better Operating Practices - Avoid Adding Excess Thinner

The tendency to use excess thinners should be avoided. If the paint is difficult to apply, adding thinner may make it easy. However, adding excess thinner affects the film thickness, density, and durability.⁹⁸

Solvent Wastes - Better Operating Practices - Avoid Excessive Air Pressures for Atomization

Using excessive air pressure to atomize paint particles leads to increased emissions and overspray, and must be avoided. By adjusting the air pressure, a 30 percent decrease in overspray and therefore a savings in raw material costs could be realized.⁹⁹

Solvent Wastes - Better Operating Practices - Maintain Equipment Properly

Proper equipment maintenance is critical to reducing the number of reject products and improving productivity.¹⁰⁰ Proper maintenance also reduces the quantity of waste produced from paint stripping and repainting operations.

Solvent Wastes - Better Operating Practices - Lay Out Equipment Properly

Proper layout of equipment in a work area can also reduce emissions and improve the quality of the finished products. Solvent tanks must be kept away from heat sources such as curing ovens. This will help minimize evaporation of the solvents and will also prevent the solvent vapors from entering the curing oven and affecting the curing rate or decreasing the quality of the finish.¹⁰¹

Solvent Wastes - Better Operating Practices - Isolate Solvent-Based Spray Units From Water-Based Spray Units

Isolation of solvent-based spray units from water-based spray units is a good segregation practice. The oversprays from these operations should not be allowed to mix; the mixture could be classified as a hazardous waste. If the units are segregated, the filters from the water-based paint spray booths are not classified as hazardous waste.

Solvent Wastes - Better Operating Practices - Close Floor Drains in Production Area

Closing the floor drains will reduce the amount of water used to clean up spills. This practice promotes the use of rags that must be drycleaned. Thus the generation of large quantities of rinse water containing solvents can be minimized.¹⁰²

⁹⁷ J. Kohl, P. Moses, and B. Triplett, *Managing and Recycling Solvents: North Carolina Practices, Facilities, and Regulations* (North Carolina State University, Raleigh, NC, 1984).

⁹⁸ L.J. Durney, "How to Improve Your Paint Stripping," *Product Finishing* (1982), pp 52-53.

⁹⁹ ICF Associates, Inc.

¹⁰⁰ ICF Associates, Inc.

¹⁰¹ ICF Associates, Inc.

¹⁰² L.J. Durney.

Solvent Wastes - Better Operating Practices - Purchase Proper Quantities of Paints

Buying paint in large containers is preferable to buying the same quantity in smaller containers. The amount of residual materials can thus be reduced. Large containers can be returned to manufacturers for cleaning and reuse. Ordering extra paint for any given job should also be avoided. The exact amount of paint required must be calculated to reduce the number of small cans containing residues for disposal.

Solvent Wastes - Better Operating Practices - Segregate Wastes

Segregating wastes is extremely important to reducing the amount of hazardous wastes generated and to improve the recyclability of solvents. If many solvents are used, they should be segregated. Some solvents can be directly reused in equipment cleaning operations.

Proper labels must be attached to containers. Hazardous wastes must be segregated from nonhazardous wastes and handled and disposed of properly. Labeling a container containing non-hazardous waste as "hazardous" can result in an unnecessary increase in disposal costs.

Solvent Wastes - Better Operating Practices - Standardize Solvent Use

Standardizing solvent use will reduce the numbers of different types of thinners and solvents used in coating formulations. If fewer solvents are stocked, the possibility of mixing of the wastes is reduced. Only one type of thinner or solvent corresponding to each type of paint should be purchased.

Solvent Wastes - Product Substitution - Use High-Solids Formulations

High-solids formulations contain a reduced quantity of solvent. Using high-solids formulations will therefore reduce the amounts of wastes and emissions generated from the painting operations.

Solvent Wastes - Process Change - Choose Proper Coating Equipment

The proper choice of coating equipment can reduce the quantity of wastes produced and result in raw material savings. Overspray from painting operations generates the most waste. Equipment with high transfer efficiencies must be chosen.

Solvent Wastes - Process Change - Replace Conventional Spray Units With Electrostatic Units

Electrostatic units (either centrifugally- or air-atomized spray) have high transfer efficiencies. Converting from conventional equipment to electrostatic equipment may lead to a 40 percent reduction in overspray and considerable savings.¹⁰³ The overspray collects on the spray booth walls that are electrically grounded. Thus, the amount of residues in the rest of the work area is reduced. However, the complete conversion requires a lot of time and work in testing, visiting other plants, engineering, and maintenance.

¹⁰³ L.J. Durney.

Solvent Wastes - Process Change - Replace Air-Spray Guns With Pressure Atomized Spray Guns

Replacing air-spray guns with airless spray guns increases the transfer efficiencies. A 23 percent reduction in raw material costs has been reported.¹⁰⁴ Also, the cleaning frequency is increased from once every 3 weeks to once a week.

Aqueous Wastes - Process Change - Dry Paint Booths

Large volumes of wastewater are generated from "water curtain" paint booths. The water curtain is used to remove the paint overspray particulates from the exhaust system. A significant concentration of paint, solvents, and flocculating/coagulating agents accumulates in the wastewater. This wastewater must be treated to remove hazardous contaminants and the sludge must be disposed of as a hazardous waste.

Converting from a wet to a dry paint booth eliminates the problem of wastewater generation. In a dry booth, the contaminated air (laden with paint particles) is drawn through fibrous filters which must then be disposed of as hazardous waste. A much smaller volume of waste is generated. Results of a Navy study¹⁰⁵ indicate that converting to dry operation is technically feasible and cost effective (payback 8 months to 2 years) for small, medium, and large painting facilities.

Recycling Onsite/Offsite

Paint Wastes - Onsite Recycling - Recycle Paint Overspray/Sludge

In water curtain spray booths, the overspray impinges on a water curtain. The paint/water mixture is then pumped to a separator. If the paints used are immiscible in water, they can be separated out and recycled. Also, the water can be recycled back into the water curtain. Recycling of the water and paint reduces the amount of wastes produced and results in a savings in raw materials costs.

Solvent Wastes - Onsite Recycling - Ultrafiltration, Distillation, or Evaporation

In ultrafiltration, the sludge containing solvents is filtered using membranes with pore sizes of 0.01 microns. Paint particles, usually larger than 1 micron, collect on the membranes and are removed continuously. A series of membranes filter the waste to produce a pure solvent that can be recycled.¹⁰⁶

Distillation stills can be used to recover solvents. The solvent is indirectly heated and the vapors are condensed and collected. Purities of 90 to 99 percent can be obtained by this process. Table 33 lists manufacturers of distillation stills and associated costs. The concentrated still bottoms containing paint sludge must be shipped for proper disposal as a hazardous waste. Another possibility is to ship the still bottoms to a cement kiln for use as a supplemental fuel through a waste exchange program.

¹⁰⁴ J. Kohl, P. Moses, and B. Triplett.

¹⁰⁵ Acurex Corporation, *Navy Paint Booth Conversion Feasibility Study*, CR 89.004 (Prepared for the Naval Civil Engineering Laboratory [NCEL], Port Hueneme, CA, 1989).

¹⁰⁶ Y. Isooka, Y. Imamura, and Y. Sakamoto, "Recovery and Reuse of Organic Solvent Solutions," *Metal Finishing* (June 1984), pp 113-118; W.H. Reay, "Solvent Recovery in the Paint Industry," *Paints & Resins* (March/April 1982), pp 41-44.

Evaporation, using drum-dryers or thin-film evaporators, is effective on solvents that are heat-sensitive. Large scale equipment is necessary for evaporation and, therefore, is cost effective only for large quantities of solvents. Many commercial solvent recyclers use agitated thin-film evaporators.

Solvent Wastes - Offsite Recycling - Closed-Loop Contract

Wastes consisting primarily of thinners, paint sludge, and paint can be reclaimed at an offsite facility. This closed-loop service is provided by many paint and thinner suppliers. Usually the purchase price includes delivery, waste hauling, recycling, and disposal. Such a service removes the wastes when it delivers the new product. The waste is processed at a licensed treatment, storage, and disposal facility. Processes used for recycling thinners are well-established and widely used.¹⁰⁷ Commercial recyclers have the versatility and have developed technologies for recycling large varieties of waste solvents. Between 70 and 80 percent of spent thinners can be recycled into a useful product.

Treatment

Solvent Waste - Onsite Pretreatment - Gravity Separation

Gravity separation is a relatively inexpensive option that is easy to implement. In this treatment process, the thinner and paint sludge mixture is allowed to separate by the force of gravity without external disturbance or agitation. The heavier paint sludge particles settle to the bottom of the container and the supernatant can be decanted off. The decanted thinner can be used as a "wash thinner" for cleaning equipment or for thinning primer and base coatings.¹⁰⁸

Paint/Solvent/Aqueous Wastes - Offsite Treatment

Although most waste associated with paint can be treated using a number of different physical, chemical, and biological techniques, these techniques are not feasible for most Army installations that generate small quantities. However, licensed TSDFs can use a number of processes such as activated carbon adsorption, chemical oxidation, solvent extraction, solid/liquid separation, stabilization/solidification, thermal destruction, volume reduction, and biological treatment. The applicability of each technique will not be discussed here.

¹⁰⁷ SCS Engineers, Inc., *Waste Audit Study - Automotive Paint Shops* (California Department of Health Services, January, 1987).

¹⁰⁸ SCS Engineers, Inc.

Table 37

Waste Classification for Paint Removal, Painting, and Brush Cleaning

Materials used/ wastes produced	Waste Description			
	HW code	DOT shipping name	Hazard class	Number
Acetone	F003	Waste acetone	Flammable liquid	UN1090
Alcohols	D001	Waste alcohol, NOS	Flammable liquid	UN1987
Caustic paint stripper	D002	Waste paint related material	Corrosive material	NA1760
Chlorobenzene	F002	Waste chlorobenzene	Flammable liquid	UN1134
Enamel liquids	D001	Waste enamel	Combustible liquid	UN1263
Ethylene dichloride		Waste ethylene dichloride	Flammable liquid	UN1184
MEK	F005	Waste methylethylketone	Flammable liquid	UN1193
Methylene chloride	F002	Waste methylene chloride	ORM-A	UN1593
Stripper	D001	Waste naphtha	Flammable liquid	UN2553
Mineral spirits	None	Waste paint dryer, liquid	Combustible liquid	UN1263
Paint dryer	D001	Waste paint	Flammable liquid	UN1263
Paint liquids	Varies	Hazardous waste (solid), NOS	ORM-E (if solid)	UN9189
Paint solids (toxic)	D001	Waste paint related material	Flammable liquid	NA1263
Paint thinners, lacquers	Varies	Hazardous waste liquid, NOS	ORM-E	NA9189
Paint waste with heavy metals	D001	Hazardous waste solid, NOS	ORM-E	NA9189
Petroleum distillates	F005	Waste petroleum distillate	Flammable liquid	UN1268
Toluene (Toluol)	D001	Waste toluene	Flammable liquid	UN1294
VM&P naphtha	F003	Compound, paint removing liquid	Flammable liquid	NA1142
Xylene (Xylol)		Waste xylene	Flammable liquid	UN1307

8 WASTE MINIMIZATION FOR PHOTOGRAPHY, PRINTING, AND ARTS/CRAFTS SHOPS

Photography and photoprocessing are common operations at Army installations. Among the source types that use photography are: training and audiovisual centers, hospitals, dental clinics, and research laboratories (as discussed in Chapter 4). Printing operations are limited to training and audiovisual centers. The materials used in producing a photograph are paper, plastic film, or a sheet of glass containing light-sensitive photographic emulsion. The emulsion is a gelatinous substance containing silver halides (chloride, bromide, and iodide). Some photographic films may be made of cellulose acetate. However, most are made of polyester. In photography, a negative containing different shadings is produced. The dark portions on a negative contain heavy deposits of silver. The processing that follows the exposure of a film or emulsion consists of developing, fixing, and washing. Wastewater containing photoprocessing chemicals and silver is the primary wastestream of concern.

A printing process usually follows image processing, including typesetting and the photographic processing step discussed above. However, an intermediate step to prepare plates to carry the image to paper is necessary. A roller transfers ink onto a plate or a cylinder. The image on the plate or cylinder is transferred to a rubber blanket which in turn transfers it to paper. There are four different types of image carriers: manual - in screen printing; mechanical - for relief printing; electrostatic - in offset duplicating; and photomechanical - most common method of platemaking.¹⁰⁹ Preparation of plates is followed by the actual printing. Two common types of printing presses used are: sheet-fed presses that can print up to 3 impressions per second and web presses that operate at the rate of 1000 to 1600 feet per minute.¹¹⁰

In the printing process, the plate (a thin aluminum sheet) is first attached to the plate cylinder of the press. Each unit of a printing press then prints a single color. Four units (red, blue, yellow, and black) are required for a full color illustration. The raw materials typically used in a printing operation are ink, paper or other print substrate, and fountain solution. Wastes generated from a printing process include waste inks, used ink containers, used plates, damaged or worn rubber image transfer blankets, waste press oils, cleanup solvents, rags, and trash.¹¹¹

The arts and crafts shops are educational and vocational shops that provide training in automobile maintenance/repair, metalworking, graphic arts, and woodworking. Only the minimization of wastes from the photography and printing section of arts and crafts shops is considered in this chapter. Minimization of wastes from automobile maintenance/repair and metalworking are discussed in Chapters 5 and 6, respectively. A summary of processes, corresponding waste streams, and Department of Transportation (DOT) classifications is provided in Tables 38 and 39.

Most of the waste minimization options discussed in this chapter have been extracted from *Waste Audit Study - Commercial Printing Industry*.¹¹²

¹⁰⁹ Jacobs Engineering Group, Inc., *Waste Audit Study - Commercial Printing Industry* (California Department of Health Services, Sacramento, CA, May 1988).

¹¹⁰ Jacobs Engineering Group, Inc.

¹¹¹ Jacobs Engineering Group, Inc.

¹¹² Jacobs Engineering Group, Inc.

Source Reduction - Photography and Printing Operations

All Wastes - Better Operating Practices - Proper Material Handling and Storage

Raw materials may become obsolete and get spoiled due to improper storage and handling. Therefore, proper storage and handling is a good operating practice that will reduce the amount of waste generated and result in savings in raw materials costs.

Photographic and printing chemicals require proper storage, which is usually indicated on the containers. They are sensitive to light and temperature. Proper storage under recommended conditions increases their shelf life and results in savings in raw materials costs and disposal costs.

The storage area must be kept clean. One way to keep the storage area clean is to prohibit through traffic and restrict entry to only a few persons. Traffic increases the amount of dirt and the possibility of contamination. It is easier to contain spills if the entry is restricted to only a few persons.

Proper inventory control is necessary to decrease the possibility of the material's shelf life expiring before the materials are used. The materials should be arranged and labeled on shelves so that those that were purchased first must be used first. Computerized inventory control and materials tracking will help manage the inventory.

Material with an expired shelf life should not be discarded. Tests must be used to determine the effectiveness and usability. Waste disposal may thus be minimized. Excess material should be recycled through a manufacturer or a waste exchange.

Ordering excess material should be avoided. Material ordering should be based on use. Small printing operations should purchase inks in small containers to limit the possibility of the ink spoiling in large containers that may not be properly sealed. Large printing operations should order materials in large containers that can be returned to manufacturers for cleaning and reuse.

Raw materials should be inspected when they arrive and before use. Unacceptable and/or damaged items must be returned to manufacturers to avoid disposal problems and to avoid creating defective products.

Source Reduction - Photographic Operations

Photographic Chemicals - Better Operating Practices - Proper Chemical Storage

Many of the photographic chemicals degrade in the presence of air. Small photographic operations store chemicals in plastic containers. Adding glass beads to the containers to bring the liquid level up to the brim has been found to be useful.¹¹³ The life of the chemicals can thus be extended.

Photographic Films - Material Substitution - Nonsilver Films

Substituting films containing silver with those containing nonhazardous chemicals reduces hazardous waste generation. The silver from silver films makes the photographic wastes (e.g., fixing

¹¹³ Jacobs Engineering Group, Inc.

bath solutions, rinse water, etc.) hazardous. Only very low silver concentrations are allowed in wastewaters treated at wastewater treatment plants operated by county sanitation districts.

Some substitutes to silver-halide films include vesicular (diaz), photopolymeric, and electrostatic films.¹¹⁴ However the disadvantage of these films is that they are slower than silver films. Vesicular films consist of a honeycomb structure and are constructed from a polyester base coated with a thermoplastic resin. These films are also coated with a light-sensitive diazonium salt. Photopolymeric films use carbon black instead of silver. A weak alkaline solution is used to process these films. The spent bath solution is a nonhazardous waste that can be neutralized before disposal. An electrostatic charge makes electrostatic film light sensitive. The speed of this nonsilver film is comparable to silver films and it has a high resolution.

Other Photographic Wastes - Material Substitution

Other photographic wastes such as intensifiers and reducers also contain hazardous compounds (e.g., mercury, cyanide salts, etc.). Use of available nonhazardous substitutes will reduce the amount of hazardous wastes generated.

Fixing Bath Solutions - Process Change - Extend Bath Life

The life of fixing baths can be extended to reduce the quantities of wastes generated from photographic operations. Some of the techniques that could be used include:¹¹⁵

1. Adding ammonium thiosulfate which increases the bath life by doubling the allowable silver concentration,
2. Using an acidic stop-bath before the fixing bath,
3. Adding acetic acid to the fixing bath to keep the pH low.

Photographic Wastewater - Process Change - Reduction in Water Use

Parallel rinsing is commonly used in photographic processing operations. Converting to countercurrent rinsing reduces the amount of wastewater generated. In countercurrent rinsing, the water flows in a direction that is opposite to the film movement. Thus, fresh water in the final tank is used in the final film washing stage after most of the contamination has been rinsed off. The most contaminated water is in the very first washing stage. A countercurrent system, however, requires more equipment and space.

Sponges or squeegees must be used in nonautomated operations to remove excess water from the films. Thus the dragout of chemicals from one tank to another can be reduced by almost 50 percent.¹¹⁶ Minimizing contamination of processing baths has many advantages including: increasing the recyclability of solutions, extending solution life, and reducing the quantities of raw materials (replenishments) required.

¹¹⁴Jacobs Engineering Group, Inc.

¹¹⁵Jacobs Engineering Group, Inc.

¹¹⁶Jacobs Engineering Group, Inc.

Another method of reducing waste chemicals is to add accurate amounts of replenishment chemicals and properly monitor the chemical concentrations of baths. Exposing the process baths to air must be minimized to prevent oxidation reactions.

All Photographic Wastes - Process Change

With the recent advances in desk top publishing systems and the use of personal computers, "electronic prepress photographic systems" are gaining widespread popularity. In such a system, the graphics, photographs, and layouts are scanned into the computer. Editing is accomplished on the monitor rather than on paper. Only the final version is printed on paper. Use of electronic systems will greatly reduce the quantities of wastes generated from photographic operations conducted at printing facilities.

Source Reduction - Printing Operations

Metal Etching/Plating Wastes - Process Change

If printing operations still include metal etching and plating, alternative processes (e.g., lithographic plate, hot metal, flexographic, etc.) must be examined as substitutes. These alternative processes do not present the problems associated with treatment and disposal of hazardous wastes.

Metal Etching and Plating Wastewater - Process Change - Reducing Water Use

The wastewater produced from metal etching and plating is a hazardous waste. Efforts must be made to reduce the toxicity of wastewater by reducing the dragout from process tanks and by using countercurrent rinsing. Dragout reduction can be achieved by: (1) positioning parts on racks so they drain properly, (2) using drip bars and drain boards to collect the dragged-out chemicals and returning them to the process tanks, and (3) increasing the process tank temperature to reduce surface tension of the solution thereby minimizing its tendency to cling to parts.

Countercurrent rinsing reduces the amount of wastewater leaving an operation. However, it does not reduce the hazardous material content in wastewater.

Lithographic Plate Processing Chemicals - Better Operating Practices - Reduced Chemical Use

The use of plate processing chemicals must be reduced. One way to reduce chemical consumption is to frequently monitor the pH, temperature, and chemical concentration of the bath. Bath life can thus be extended and changing of solutions can be reduced to only a few times a year. Using automatic plate processors facilitates precise monitoring of bath conditions.

Lithographic Plate Processing Plates - Better Operating Practices - Proper Storage/Recycling

Proper storing of plates reduces the possibility of them getting spoiled and maintains their effectiveness. Used plates are not a hazardous waste and must be collected and sold to an aluminum recycler.

Lithographic Plate Processing Plates - Material Substitution

Alternative "presensitized plates" are available that can be processed with water. Other plates available include "Hydrolith" plates manufactured by 3M Corporation.¹¹⁷ 3M has also developed a platemaking system that eliminates the need for photoprocessing, and has been found to be economical for large printing operations.¹¹⁸

Web Press Wastes - Process Change - Break Detectors

Using break detectors in web presses prevents severe damage to the presses and also reduces the quantities of wastes from spillage of inks, fountain solutions, and lubricating oil. Web break detectors detect tears in a web as it passes through a high speed press. Broken webs tend to wrap around rollers and force them out of their bearings.

Waste Inks/Cleaning Solvents/Rags - Better Operating Practices

Rags dampened with cleaning solvents are used to clean presses. The amount of solvent and number of rags used can be minimized by reducing the cleaning frequency and by properly scheduling cleaning. Ink fountains must be cleaned only when a different color ink is used or if the ink has dried out. Overnight drying of ink may be reduced by using compounds that are dispensed as aerosol sprays.¹¹⁹ Thus, the amount of waste ink, solvents, and rags is reduced.

Waste Inks - Better Operating Practices

The amount of waste ink generated can be reduced by implementing better operating practices. Only the required amount of ink must be put in an ink fountain before starting a print job. Resealing the ink containers after use is a good practice that prevents contamination by dust/dirt, formation of a "skin" on the ink surface, loss of solvents, and hardening. As much of the ink as possible must be scraped from the container for use.

Automatic ink levelers, when used in large presses, improve the print quality and reduce the amount of trash and the likelihood of accidental spills.

Waste (Flexographic) Inks - Product Substitution - Water-Based Inks

Substituting water-based inks for solvent-based inks in flexographic printing reduces the quantity of hazardous wastes generated. Use of water-based inks also eliminates the problems encountered with volatilization of solvents. Some of the disadvantages of water-based inks include: limited range of colors, higher energy requirement for drying because of high heat of vaporization, higher equipment operating costs, lower capacity, lower speed, and difficult cleaning requirements.¹²⁰ Water-based inks are not available for lithographic printing operations.

¹¹⁷M.E. Campbell and W.M. Glenn.

¹¹⁸M.E. Campbell and W.M. Glenn.

¹¹⁹Jacobs Engineering Group, Inc.

¹²⁰Jacobs Engineering Group, Inc.

Waste Inks - Product Substitution - UV Inks

Ultraviolet (UV) inks are those that dry when exposed to UV light. UV inks contain: monomers, photosynthesizers, and pigments rather than solvents. Because they do not dry in fountains, the need for cleaning is reduced. The advantages of UV inks include:¹²¹

1. UV inks eliminate "set-off" -- the unintentional transfer of ink from one sheet to the back of the preceding sheet after the sheets have been stacked, which occurs when the ink has not completely dried.
2. UV inks eliminate the need for anti-offset sprays that prevent set-off.
3. UV inks eliminate the need for ventilated storage of sheets when using oxidative drying processes.

Disadvantages of UV inks include:¹²²

1. The cost is 75 to 100 percent higher than conventional heat-set inks.
2. UV light is a hazard to plant personnel.
3. The interaction of UV light and atmospheric oxygen forms ozone.
4. Conventional paper recycling procedures will not deink paper printed by this process. This creates a waste source from an otherwise recyclable material.
5. Some of the chemicals in the inks are toxic.

Waste Inks - Product Substitution - EB Inks

Electron beam (EB) inks are those that are dried by electron beams and are similar to UV inks in operational concept. They have the same advantages as UV inks. However, operator protection from X-rays is necessary and these inks degrade the paper.

Waste Inks - Product Substitution - Heat Reactive Inks (Web Presses)

Heat reactive inks contain a prepolymer, a cross-linking resin, and a catalyst. At 350 °F, the inks are activated to polymerize and set. These inks contain much less solvent than the conventional heat-set inks.

Cleaning Solvents - Good Operating Practices - Pour Cleaning

Whenever possible "pour" cleaning with solvent followed by "wipe" cleaning with a rag could be used to clean presses. The drained solvent must be collected and recycled. Although more solvent is used in this process, less ink ends up on the rags. Cross-contamination of inks must be avoided. The used solvent can be used to clean rollers and blankets, thus reducing the amount of fresh solvent used.

¹²¹Jacobs Engineering Group, Inc.

¹²²Jacobs Engineering Group, Inc.

Use of wipe cleaning with rags may be preferable to pour cleaning in some cases because the quantity of solvent wastes is considerably reduced.

Cleaning Solvents - Good Operating Practices

Detergents or soap solutions rather than solvents should be used for general cleaning. Use of solvents should be limited to removing inks and oils.

Cleaning Solvents - Product Substitution - Nonhazardous Formulations

Hazardous materials such as benzene, carbon tetrachloride, TCE, and methanol were previously used as cleaning solvents. Several "blanket washes" containing glycol ethers and other heavy hydrocarbons that are less toxic and flammable are now available. Using nonhazardous blanket washes is recommended for all cleaning requirements in a printing operation.

Fountain Solutions - Product Substitution

Conventional fountain solutions contain water, isopropyl alcohol, gum arabic, and phosphoric acid. These compounds are transferred to the printing paper or they evaporate causing volatile organic compounds to be released. Substitute formulations must be used to reduce the emissions.

Waste Paper - Good Operating Practices - Reduce Usage

Printing operations generate a large quantity of waste paper. Although paper is not a hazardous waste, reducing paper consumption and thus the purchase of new paper is a good operating practice.

Recycling Onsite/Offsite - Photographic Operations

Spent Fixing Bath Solution - Onsite Recycling - Silver Recovery

Spent fixing bath solutions contain silver that can be recovered. Following recovery, the bath can be reused or discharged to a sewer. Some of the reasons for recovering silver from the solution include:¹²³ reducing the amount of hazardous silver compounds in wastewaters, extending the useful life of fixing baths, and redeeming the precious metal value of silver.

Electrolytic deposition is the most common method of recovering silver. The electrolytic recovery units have carbon anodes and steel cathodes. Applying a low voltage results in the plating of metallic silver on the cathode. The fixing bath solution, after silver removal, can be mixed with fresh solution and reused in the photographic development process.

A second method of silver recovery is the use of steel wool cartridges to replace silver in an oxidation-reduction reaction. In this process, the spent fixing bath solution is pumped through the steel wool cartridge and iron replaces silver in the solution. Silver sludge settles to the bottom of the cartridge.

A detailed discussion of methods and procedures for silver recovery including: general procedures for hypo collection and recovery, procedures for removing silver from recovery units, recommended recovery procedures for use with automatic film processors, and procedures for using the metallic

¹²³ Jacobs Engineering Group, Inc.

replacement recovery cartridges are outlined in the Defense Logistics Agency's *Defense Utilization and Disposal Manual*.¹²⁴

Photographic Films - Offsite Recycling - Silver Recovery

Photographic laboratories and many other facilities that use X-ray films generate used photographic films that contain 1 percent (0.15 troy ounces) of silver.¹²⁵ These films must be sold to recyclers for silver recovery.

Recycling Onsite/Offsite - Printing Operations

Metal Etching and Plating Wastewater/Sludge - Onsite/Offsite Recycling - Material Recovery

The wastewater from metal etching and plating operations contains heavy metals and various quantities of process chemicals. Material recovery processes can be implemented to recover some of the process chemicals and thus reduce raw material costs.

Used Metal Wastes - Offsite Recycling

Linotype operations used for letterpress printing generate used metal wastes. The process uses an alloy with a low melting point to create the letters in lines of text. The metal must be melted in the linotype machines and/or recycled. The manufacturer or metal supplier may be willing to buy the used metal and recycle it.

Waste Inks - Onsite Recycling

A simple recycling technique is to blend all the waste inks together to form black ink. It may be necessary to add small amounts of color and toner to obtain an acceptable black color. The reformulated black ink is similar in quality to new newspaper ink. Most newspaper printing presses use recycled black ink.¹²⁶

Waste Inks - Offsite Recycling

Contract recycling of waste inks can be used to produce black ink. This black ink can be used to print newspapers or flyers. In such a contract, waste inks are bottled and shipped to the recycler (or manufacturer) and the reformulated black ink is shipped back. The costs of buying new black inks and disposing of waste inks can thus be reduced.

Cleaning Solvents - Onsite Recycling - Distillation

Small distillation units are available for recycling solvent used in pour cleaning. Proper segregation of solvents and trash is necessary. Still bottoms have to be disposed of as hazardous waste.

¹²⁴ *Defense Utilization and Disposal Manual*, DOD 41620.21-M (Defense Logistics Agency, Office of the Assistant Secretary of Defense, Alexandria, VA, September 1982), pp VI-42 and XVII-A-5 through XVII-A-10.

¹²⁵ *Defense Utilization and Disposal Manual*.

¹²⁶ C. Woodhouse, *Waste Ink Reclamation Project* (California Department of Health Services, Toxic Substances Control Division, August 1984).

Waste Paper - Offsite Recycling

Waste paper must be collected and recycled. Manufacturers or paper recyclers remove the ink and repulp the paper. Pulp from recycled paper adds strength and durability to many other paper products.

Treatment - Printing Operations

Wastewater from metal etching and plating operations is classified as hazardous and must be treated before discharge to a municipal sewer. If not treated, it must be put in drums and disposed of as hazardous waste. Packaged treatment units that neutralize and precipitate the heavy metals are available. The sludge generated from treatment is also a hazardous waste and is banned from land disposal.

Table 38

Typical PPAS Operations With Materials Used and Wastes Generated*

Process/ Operation	Materials Used	Ingredients on Labels	Wastes Generated
Apply light sensitive coating	resins, binders, emulsion, photosensitizers, gelatin, photoinitiators	PVA/ammonium dichromate, polyvinyl cinnamate, fish glue/albumin, silver halide/gelatin emulsion, gum arabic/ammonium dichromate	photographic waste
Develop plates	developer	lactic acid, zinc chloride, magnesium chloride	photographic waste
Wash/clean plates	alcohols, solvents	ethyl alcohol, isopropyl alcohol, methyl ethyl ketone, trichloroethylene, perchloroethylene	spent solvents
Apply lacquer	resins, solvents, vinyl lacquer	PVC, PVA, maleic acid, methyl ethyl ketone	spent solvents
Counter-etch to remove oxide	phosphoric acid	phosphoric acid	acid/alkaline wastes
Deep-etch coating of plates	deep etch bath	ammonium dichromate, ammonium hydroxide	acid/alkaline waste, heavy metal solutions, waste etch bath
Etch baths	etch bath for plates	ferric chloride (copper), aluminum chloride/zinc chloride/hydrochloric acid (chromium), nitric acid (zinc, magnesium)	waste etch bath, acid/alkaline waste, heavy metal solutions
Printing (Ink)	pigments, dyes, varnish, drier, extender, modifier	titanium oxide, iron blues, molybdated chrome orange, phthalocyanine pigments, oils, hydrocarbon solvents, waxes, cobalt/zinc, magneze oleates, plasticizers	waste ink with solvents/heavy metal, ink sludge with chromium/lead
Making gravure cylinders	acid plating bath	copper hydrochloric acid	spent plating waste

*Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986), pp 146-147.

Table 39
Waste Classification for PPAS

Process Description		Waste Description			
Process/ operation	Materials used/ wastes produced	HW code	DOT shipping name	Hazard class	Number
Photographic processing	Carbon tetrachloride Waste solutions with heavy metals (Cd, Cr, Pb, etc.)	F001	Waste carbon tetrachloride	ORM-A	UN1846
		Varies	Hazardous waste solution, NOS	ORM-E	NA9189
Washing, clean- ing plates; press cleanup	Ethyl alcohol	D001	Waste ethyl alcohol	Flammable liquid	UN1170
	Isopropyl alcohol	D001	Waste isopropyl alcohol	Flammable liquid	UN1219
	Methylethylketone	F005	Waste methylethylketone	Flammable liquid	UN1193
	Naphtha	D001	Waste naphtha	Flammable liquid	UN2553
	Perchloroethylene	F002	Waste perchloroethylene	ORM-A	UN1897
	Petroleum distillates	D001	Waste petroleum distillates	Flammable liquid	UN1268
	Press wash	D001	Waste flammable liquid, NOS	Flammable liquid	UN1993
	Trichloroethylene	F001	Waste trichloroethylene	ORM-A	UN1710
	Xylene	D001	Waste xylene	Flammable liquid	UN1307
Etching, plating	Ammonium hydroxide	D002	Waste ammonium hydroxide	Corrosive material	NA2672
	Hydrochloric acid (Cr)	D002	Waste hydrochloric acid	Corrosive material	NA1789
	Nitric acid (Zn, Mg)	D002	Waste nitric acid	Corrosive material	NA1760
	Phosphoric acid	D002	Waste phosphoric acid	Corrosive material	UN1805
Printing	Waste ink (containing various solvents and heavy metals)	D002	Waste ink	Combustible liquid Flammable liquid	UN2867 UN1210
	Ink sludge (heavy metals - Cr or Pb)	D002	Hazardous waste liquid, NOS Hazardous waste solid, NOS	ORM-E ORM-E	NA9189 NA9189

9 WASTE MINIMIZATION FOR INDUSTRIAL MAINTENANCE, SMALL ARMS SHOPS

Most of the hazardous wastes generated from IMSS operations can be categorized as corrosive wastes (acids and alkalis), spent solvents, paint stripping wastes, and wastes containing toxic metals. The operations that generate these wastes include: equipment and vehicle repair, metal cleaning, surface preparation, and metal finishing. A summary of processes, wastes generated, and DOT classifications are listed in Table 40. The minimization options for vehicle maintenance repair wastes are discussed in Chapter 5.

Chlorinated or nonchlorinated solvents are commonly used to clean or degrease parts before repair, rebuilding, or finishing. Nonchlorinated solvents (e.g., petroleum distillates) are normally used in cold cleaning operations using solvent sinks or dip tanks. Chlorinated solvents such as TCE, 1,1,1-trichloroethane, methylene chloride (MC), and perchloroethane (PC), are used in vapor degreasers, where condensing solvent vapors remove the grease, oil, or wax from the dirty parts. 1,1,1-trichloroethane is the safest of these four solvents and is the most commonly used. Of the several different vapor degreasers commercially available, the open top vapor degreasers are the most common at Army installations. In such a vapor degreaser, the heater coils at the bottom of a tank boil nonflammable solvent. The solvent vapors that are denser than air, displace the air and form a vapor zone. A condensing coil at the top of the tank prevents the vapors from escaping from the open top. The parts are lowered into the vapor zone and pure solvent vapors condense on them and solubilize the soil and grease. The solvent drips off or evaporates as the parts are removed after they are cleaned. The soil accumulates at the bottom of the tank. This contaminates the solvent which has to be changed periodically. Also, because the solvent evaporates, fresh solvent must be added frequently.

Cleaning with caustic compounds or detergents also occurs at IMSS operations. Cleaning is usually followed by surface preparation such as painting or scale stripping. Sand, glass, or shot blasting are common methods of removing paint or scale. In some cases, paint stripping is accomplished with solvent (MC) or caustic strippers.

Metal finishing operations, such as surface finishing of small arms, and metalworking, such as cutting and threading are also common at IMSS. A small arms shop conducts weapons rebuilding on many types of small arms. Chemicals such as chromic acid, phosphoric acid, etc., are used. Manganese phosphate coatings are the most common surface finishing treatments used on small arms components. The phosphate coating is dull black and provides wear resistance to the cast iron/steel surfaces. The first step in the process is to clean the parts. The methods include: vapor degreasing or alkali cleaning, blasting with sand/walnut shells, self-emulsified solvent treatment, and phosphoric acid-solvent-detergent cleaning. The parts are then rinsed in water and coated with phosphate. The parts are rinsed in water immediately after the phosphate coating. The next step is to use a hot oil conditioning rinse and then dry the coated and rinsed surfaces. Any supplementary coatings are then applied.¹²⁷ The typical coating time is 15 to 40 minutes. The phosphate immersion coating bath is maintained between 200 and 210 °F. The phosphate tank and heating elements are usually made of acid-resistant material. Some of the equipment used in the immersion coating process include: conveying equipment, if necessary; work-supporting equipment such as hooks, racks, baskets, and tumbling barrels; tanks associated with water and heat (steam or electricity); a drain to the sewer line; ventilation equipment; and drying equipment such as ovens, air heaters, fans, and compressors.¹²⁸ The

¹²⁷ A. Douty and E.A. Stockbower, "Surface Protection and Finishing Treatments - A Phosphate Coating Processes," revised by W.C. Jones, in *Electroplating Engineering Handbook*, Fourth Edition, L.J. Durney, Ed. (Van Nostrand Reinhold Co., 1984), pp 366-390.

¹²⁸ A. Douty and E. A. Stockbower.

operator of the small arms shop must account for all materials used in the process. The potential for severe environmental hazards exists in the operation of a small arms shop.

The metalworking operations in IMSS use petroleum and synthetic oils and small quantities of solvents in cleaning, cutting, and threading metallic pipes and other surfaces. Used oil and waste solvents are commonly generated. Painting vehicles, equipment, and parts is also conducted by IMSS. The minimization options for painting and surface coating are discussed in Chapter 7.

Since Fort Sam Houston does not conduct any vapor degreasing, only the following three categories of processes are discussed in this chapter: alkaline cleaning, dry media blasting, and cutting and threading.

Treatment - Alkaline Cleaning

Cleaning metal substrates using alkaline cleaners generates a corrosive waste that must be neutralized. In addition to neutralization, removing grease and heavy metals may also be necessary. Batch treatment units are commercially available. A precipitation/neutralization system can also be designed for onsite use.

Another waste stream of concern is sludge collected on the bottom of the tank which must be tested for hazard characteristics and disposed of properly.

Source Reduction - Dry Media Blasting

Dry Wastes - Product Substitution - Plastic Media Blasting

Plastic media blasting (PMB) is a relatively new method to remove paint and rust from a variety of metallic and alloy substrates such as aluminum, steel, titanium, copper, and zinc. It is a good substitute for organic chemical stripping (using mixtures of MC and other toxic compounds) and abrasive blasting with sand, glass beads, or agricultural media (walnut shells, rice hulls, corn cobs, etc.).

Agricultural media blasting has several drawbacks such as high explosion potential, poor paint/rust removal, high contamination, low recycle rate, and generation of large quantities of wastes. Comparatively, sand and glass beads are better for blast cleaning because of good performance and low explosion potential; however they also have a very low recycle rate. Some of the advantages of PMB are: (1) it is aggressive and requires less operating time (compared to agricultural media only); (2) the plastic maintains its size and hardness; (3) the plastic does not break up and thus can be recycled 10 to 20 times,¹²⁹ resulting in lower replacement and disposal costs; and (4) overall, the method is economically favorable.

PMB is slower than sand or glass bead blasting; however, it produces a better quality finish. Also, the amount of waste produced in PMB is greatly reduced because most of the media can be

¹²⁹ J. Gardner, *Dry Paint Stripping Utilizing Plastic Media: A New Solution to an Old Problem*, Technical Bulletin (Clemco Industries, 1987).

recycled many times. Assuming a labor rate of \$15/hr and a media recycle rate of 90 percent, the costs of sand blasting and PMB are \$0.62 and \$0.36/sq ft, respectively.¹³⁰

Suppliers of plastic media include: Aerolyte Systems, 1657 Rollins Rd., Burlingame, CA 94010, (415) 570-6000; E.I. du Pont de Nemours & Co., Inc., Fabricated Products Dept., Wilmington, DE 19898, (800) 441-7515; and U.S. Blast Cleaning Media, 328 Kennedy Drive, Putnam, CT 06260. The price of plastic media (available on a GSA contract, 1988 prices) ranges from \$1.75 to \$2.50 per pound.

Dry Wastes - Process Change - Plastic Media Blasting

Existing abrasive blasting machines can be replaced with more efficient plastic media blasting machines. A number of companies manufacture PMB machines; however, design consultants must be retained to design specific applications. Two types of PMB machines are available: cabinets and open blast systems. Cabinet systems are very similar to the conventional abrasive blasting machines. The most commonly used cabinet has an opening that measures about 5 ft by 4 ft. Small open blast systems are portable and self-contained.

Source Reduction - Cutting and Threading

Cooling/Cutting Oils - Better Operating Practices - Material Conservation

The application of cooling/cutting oils in metalworking must be limited to the area that has to be cooled without using it in excess. Efficient applicators or directional delivery systems, if used, can reduce the amount of coolant delivered to a surface. This efficient use extends the life of oils and minimizes the amount of oil purchased and wastes generated.

Cooling/Cutting Oils - Better Operating Practices - Proper Concentration Maintenance

The coolant performance depends on maintaining the proper coolant-to-water ratio. Accurate measurements of the concentrations can be obtained by using refractometers. Also, coolant proportioning devices are available to ensure accurate mixing. Specific information on coolant maintenance must be obtained from the manufacturer; the recommendations must be followed.

Cooling/Cutting Oils - Better Operating Practices - Proper Storage

Water soluble oils can be stored easily. Proper storage avoids deterioration by biodegradation. The manufacturer's storage recommendations must be followed.

Cooling/Cutting Oils - Better Operating Practices - Operator Handling/Segregation

The operators of metalworking equipment must be cautioned about minimal use of coolant. They should also be trained about the hazards of mixing oils and chlorinated/nonchlorinated solvents and the associated disposal problems.

¹³⁰ C.H. Darwin and R.C. Wilmoth, *Technical, Environmental, and Economic Evaluation of Plastic Media Blasting for Paint Stripping*, EPA/600/D-87/028 (U.S. Environmental Protection Agency [USEPA], Water Engineering Research Laboratory, 1987); J.B. Mount, et al., *Economic Analysis of Hazardous Waste Minimization Alternatives*, Draft Technical Report (USACERL, 1989).

Cooling/Cutting Oils - Better Operating Practices - Chemical Purchase

When purchasing oils, screen them for undesirable hazardous components. If such information is not available in the manufacturers' Material Safety Data Sheets (MSDSs), testing may be required.

Cooling/Cutting Oils - Better Operating Practices - Metal Chips Removal

Metal chips that accumulate in a coolant must be removed frequently. They interfere with the machine's performance and serve as a site for bacterial growth. Filter screens, when placed at the entrance to the sump and at the exit from the holding trays, can prevent chips from entering the sump. The chips can then be vacuumed from the screens.

Cooling/Cutting Oils - Product Substitution

Several different brands of water soluble oils are available. Some of them contain small amounts of hazardous materials such as cresol (< 1 percent). Only those oils that do not contain hazardous materials can be purchased.

Cooling/Cutting Oils - Process Change - Equipment Modifications

Worn equipment must be repaired or replaced to optimize performance and minimize waste generation (e.g., leaks). Older models should be replaced with automated equipment.

Adding skimmers (belts or disks) to remove "tramp" petroleum oil from the cooling/cutting oils can minimize the quantities of mixed wastes produced. These skimmers must be placed near the sump containing the coolant. Timers are also available to control equipment operation and to ensure that the quantities of coolant removed with the oil are minimal.¹³¹

Cooling/Cutting Oils - Process Change - Process Controls

The loss of cooling/cutting oils during metalworking operations must be minimized. Adding splash guards or drip trays allows the excess oils to be collected and possibly recycled/reused. Splash guards and drip trays can also be used to contain spills in the machining areas, thus reducing the use of adsorbent material (e.g., DRY-SWEEP) and wastes generated.

Cooling/Cutting Oils - Process Change - Control Bacterial Growth

Bacterial growth in coolants can be controlled by: cleaning the sump whenever the coolant is replaced, using biocides, adjusting the pH, and adequately circulating the coolant.¹³² The sump must be cleaned with steam or chemicals. In some cases, its design may have to be modified to provide sufficient access for cleaning tools.

When using biocides to control bacterial growth, it is important to realize the "ultimate" treatment or fate of the coolant. Bacterial test kits must be used to determine the exact amount of biocide to be added. The use of biocides can be minimized by proper pH control. Bacterial growth decreases the pH of the coolant. Measuring the pH (with a pH meter or litmus paper) and adjusting it (with caustic soda) to the manufacturer's recommended level can control bacterial growth. It is also

¹³¹ *Prolonging Machine Coolant Life*, Fact Sheet (Minnesota Technical Assistance Program, Minneapolis, MN, 1988).

¹³² *Prolonging Machine Coolant Life*.

necessary to maintain proper circulation of the coolant to ensure an oxygen enriched environment in the sump. A mixer or an agitator can be used for this.

Treatment - Cutting and Threading

Cooling/Cutting Oils - Onsite Treatment

Fine particles in oils, such as metal cuttings, can be removed in a pretreatment step by using a centrifuge. Batch centrifuges are available for small metalworking equipment. Large continuous centrifuges are available for removing particles from oils generated continuously in large volumes.

Mobile treatment services are provided by some companies to generators that produce large quantities of water soluble oils. The cost for such a service depends on the volume of oil and the concentration of contaminants.

Another physical treatment technique is ultrafiltration to remove fine particles. About 90 percent of the water fraction can be extracted and discharged directly to the sewer system.¹³³ The oil recovered is high quality and can be recycled.

Epsom salts (magnesium sulfate) can be used to reduce volume by precipitation and separation before disposal. However, this method is less efficient than other volume reduction techniques available.

To reuse water soluble oils, it is necessary to treat them by pasteurization followed by filtration. The biological contamination accumulated during use can thus be removed. The blend ratio of recycled oil to new oil is determined before use with a refractometer.

Cooling/Cutting Oils - Offsite Treatment

Several offsite treatment and recovery techniques are available for cutting/cooling oils, including ultrafiltration, evaporation, and thermal destruction by incineration. The choice of a method depends on the volume of wastes and their physical/chemical state.

¹³³ Fred C. Hart Associates, *Aerospace Waste Minimization Report* (California Department of Health Services, 1987).

Table 40

Waste Classification for IMSS*

Process Description		Waste Description			Hazard class	Number
Process/operation	Materials used wastes produced	HW code	DOT shipping name			
Degreasing metal surfaces/parts and other metal surface preparation	Caustic soda	D002	Waste sodium hydroxide solution		Corrosive material	UN1824
	Chlorinated solvents	F001	Waste (main ingredient)		ORM-A	Varies
	Freon	F001	Hazardous waste liquid, NOS		ORM-A	UN9189
	Ignitable (flammable) degreasers	D001	Waste flammable liquid, NOS		Flammable liquid	UN1993
	MEK	F005	Waste methylethylketone		Flammable liquid	UN1193
	Methylene chloride	F001	Waste methylene chloride		ORM-A	UN1593
	Mineral spirits solvents	D001	Waste naphtha		Flammable liquid	UN2553
	Petroleum naphtha	D001	Waste naphtha		Flammable liquid	UN1255
	Petroleum distillates	D001	Waste petroleum distillate		Flammable liquid	UN1268
	1,1,1-trichloroethane	F001	Waste 1,1,1-trichloroethane		ORM-A	UN2831
Metal finishing (including etching)	Trichloroethylene	F001	Waste trichloroethylene		ORM-A	UN1710
	Spent acid solutions	D002	Waste chromic acid solution		Corrosive material	UN1755
	Chromic solutions	D002	Waste hydrochloric acid		Corrosive material	NA1789
	Hydrochloric solutions	D002	Waste nitric acid > 40%		Oxidizer	UN2031
	Nitric stripping solutions	D002	Waste nitric acid < 40%		Corrosive material	NA1760
	Phosphoric solutions	D002	Waste phosphoric acid		Corrosive material	UN1805
	Sulfuric solutions	D002	Waste sulfuric acid		Corrosive material	UN1832
	Acetone	F003	Waste acetone		Flammable liquid	UN1090
	Alcohols	D001	Waste alcohol, NOS		Flammable liquid	UN1987
	Caustic paint stripper	D002	Waste paint related material		Corrosive material	NA1760
Surface preparation	Methylene chloride stripper	F002	Waste methylene chloride		ORM-A	UN1593
	Mineral spirits	D001	Waste naphtha		Flammable liquid	UN2553
	Used oils (not manifested)	None	Waste petroleum oil, NOS		Combustible liquid	NA1270
	Spent solvents		Varies		Varies	Varies

*Metal Manufacturing and Finishing Hazardous Waste Fact Sheet (Small Quantity Generators Activity Group, Minnesota Technical Assistance Program, Minneapolis, MN, 1987)

10 WASTE MINIMIZATION FOR OTHER SOURCE TYPES

Heating and Cooling Plants

Army installations have a number of heating and cooling plants that generate power and steam. Hazardous wastes are generated by using various combustible (e.g., cyclohexylamine) and corrosive (e.g., caustic soda, caustic potash, hydrochloric acid) chemicals to adjust pH, prevent scaling or corrosion, clean the interior of the boiler, and to test feedwater. In addition, boiler blowdown liquid mixed with water is a hazardous waste generated periodically. Waste oil blended with virgin fuel oil is burned in boilers at some installations. The waste oil may be a hazardous waste, depending on the content, and should be burned only in permitted facilities.

A number of efficiency related boiler maintenance procedures can be used to minimize environmental pollution, while correcting malfunctions in boiler operation and preventing performance degradation. Component malfunction or performance degradation can cause increases in: stack gas temperature; excess air requirements; carbon monoxide, smoke, or unburned carbon in ash; convection or radiation losses from the boiler exterior, ductwork, and piping; blowdown above that required to maintain permissible water concentrations; and auxiliary power consumption by fans, pumps, or pulverizers. In addition to the normal maintenance recommended by manufacturers, efficiency-related maintenance procedures must be performed to extend equipment life and for personnel safety. These procedures include:¹³⁴ efficiency spotchecks of combustion conditions, establishing best achievable performance goals, monitoring performance (boiler log) to document deviations, periodic equipment inspection, and troubleshooting. Boiler tuneups also improve efficiency and fuel conservation.

Some modifications to the boiler operating practices improve boiler efficiency, save fuel, and reduce continuous blowdowns. These practices include: reducing boiler steam pressures, controlling the water quality by continuous blowdowns instead of infrequent blowdowns, and proper load management. Efficient boiler operation also minimizes the amounts of air pollutants (particulates, carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, and oxidants) released to the atmosphere.

Inventory management of chemicals and reducing their use in water treatment and scale removal minimizes the amounts of wastes produced. Nonhazardous substitutes must be developed and used instead of the combustible and corrosive chemicals normally found at heating and cooling plants.

Used Oil Burning

Used lubricating oil generated by vehicle maintenance activities can be recycled as a fuel and blended and burned in boilers. Before burning, however, it is necessary to determine if the oil meets fuel specifications (Table 41). Used oil that meets the specifications can be burned in any burner

¹³⁴*Efficient Boiler Operations Sourcebook*, F.W. Payne, Ed. (The Fairmont Press, Inc., Atlanta, GA, 1986), pp 79-106.

(space heater, nonindustrial boiler, industrial boiler, utility boilers, and industrial furnaces),¹³⁵ whereas other waste oils can only be burned in high-efficiency industrial boilers, industrial process furnaces, or boilers that have demonstrated compliance with performance standards set for hazardous waste incinerators. Nonspecification used oils can be blended with virgin oil to meet specifications and burned in an industrial or nonindustrial boiler.

It is necessary to test the used oil for halogen and heavy metal content before burning. Other treatment techniques such as filtration, oil-water separation, etc. (discussed in Chapter 5), must be used to improve the quality of the oil and its heating value.

Laundry and Drycleaning Facilities

Laundry and drycleaning facilities on an Army installation are the responsibility of the DOL. Caustic soda and other corrosive chemicals are used in the laundry. Perchloroethylene (PERC) is the most common drycleaning solvent used. The two other solvents used are ValcleneTM (fluorocarbon 113 or tetrachloroethylene), and petroleum solvent (Stoddard). Use of solvents and corrosive chemicals in these processes results in the generation of contaminated wastewater and dry wastes (Table 42). Table 43 lists the wastes generated and the corresponding DOT classifications.

PERC drycleaning plants generate: (1) still residues from solvent distillation (entire weight), (2) spent filter cartridges (total weight of cartridge and solvent remaining after draining), and (3) cooked filter residue (the total weight of drained powder residue from diatomaceous or other powder filter systems after heating to remove excess solvent). Valclene plants generate still residues and spent filter cartridges. Petroleum solvent plants generate still residues only. Proper disposal is required for all the hazardous wastes generated at laundry and drycleaning facilities. Among the acceptable options are recycling, incineration, or disposal in an authorized hazardous waste landfill. However, source reduction by material substitution seems to be the most effective minimization technique for drycleaning operations. The possibility of replacing PERC or Valclene with Stoddard (PD680-II) or petroleum naphtha must be explored. As is obvious from Table 42, using Stoddard produces the smallest amount of hazardous waste. If the petroleum solvent has a flash point greater than 140 °F, the wastes are not considered hazardous and are exempt from reporting requirements. Drycleaning plants generally have stills for continuous distillation of solvents, which are constantly recycled. However, the still bottoms must be disposed of properly.

Woodworking and Preserving

Table 44 lists the woodworking and preserving operations and corresponding waste classifications. Some of the wastes are generated by carpentry shops that manufacture or refinish wooden cabinets, softwood and hardwood veneer and plywood, household or office furniture, and other furniture (including reupholstery and repair). Typical wood preserving operations used to condition wood

¹³⁵ Industrial boilers are defined as utility or power boilers used to supply heated or cooled air or steam for a manufacturing process, and are usually rated at greater than 25×10^6 Btu/hour. In addition to being located at a manufacturing facility, it must be a device using controlled flame combustion and have the following characteristics: (1) a combustion chamber and primary energy recovery section of integral design, (2) thermal energy recovery efficiency of at least 60 percent, and (3) at least 75 percent of recovered energy must be exported.

Utility boilers are boilers not located at a manufacturing facility and have the above listed characteristics. They must be used to generate electric power, steam, heated or cooled air, or other gases or fluids for sale.

Nonindustrial boilers are those that do not fall in the above two categories. They are subject to prohibition.

include: steaming, boultonizing, kiln or air drying (under pressure or vacuum), and applying agents such as creosote, pentachlorophenol (PCP), and other arsenical compounds.

Inventory control and management is an effective technique for minimizing hazardous wastes associated with woodworking and preserving. Proper disposal practices must also be used.

Pesticide Users

Army installations have a number of pesticide users including the entomology shop (pest control services), the garden shop (lawn, garden, and tree services), and the golf courses. Table 45 lists a variety of pesticides used and their waste classifications. Use of pesticides in activities ranging from protecting food and structures to pest and disease control results in generation of hazardous rinsewater, empty containers with pesticide residue, unused pesticides, and possibly contaminated soil.

Very dilute rinsewaters or soil contaminated with very low concentrations may not be hazardous. However, chemical analysis is necessary to verify the concentrations. Pesticide containers are not a hazardous waste if they are triple rinsed. The rinsewater, however, is a hazardous waste. Some pesticides that contain flammable solvents or ignitable material are also hazardous wastes when discarded. A number of pesticides exhibit acute toxicity characteristics. Therefore, all the discarded and off-specification products, containers, and spill residues containing acute toxic species are listed as "P" hazardous wastes [40 CFR 261.33(e)]. All the hazardous material/wastes related to pesticides must be managed carefully to prevent environmental problems and to protect the health and safety of personnel.

The amounts of pesticide rinsewaters generated can be minimized by using multiple rinse tanks, installing drain boards and drip tanks, and recycling and reusing the water for rinsing.¹³⁶ Treatment methods include destruction with chlorine or lime, incineration, and carbon adsorption.¹³⁷ Minimization of empty containers and contaminated soil wastes is discussed in Chapter 11.

Open Burning/Open Detonation

Open burning/open detonation (OB/OD) is one option used to demilitarize ordnance containing propellants, explosives, and pyrotechnics (PEP). Other methods are washout/steamout/meltout and deactivation in a furnace. Ingredients of some common explosive compounds are listed in Table 46. OB/OD is the simplest and has been the primary method of demilitarization used at Army installations.¹³⁸ Active and inactive sites of OB/OD are commonly found. The environmental contaminants generated from OB/OD activity include gases and particles (carbon, soot, etc.) released into the atmosphere and as residues in soils. The soil residues are comprised mainly of undetonated PEP materials and combustion/detonation products. Table 47 lists the elements found in soils, including some that are regulated under RCRA and HSWA. Soils at all the active and inactive sites must be analyzed to determine the chemical content and proper disposal.

¹³⁶ Ventura County Environmental Health, *Hazardous Waste Reduction Guidelines for Environmental Health Programs* (California Department of Health Services, Sacramento, CA, 1987).

¹³⁷ *Standard Handbook of Hazardous Waste Treatment and Disposal*, H.M. Freeman, Ed. (McGraw Hill, New York, NY, 1989).

¹³⁸ D.W. Layton, et al., *Demilitarization of Conventional Ordnance: Priorities of Data-Base Assessments of Environmental Contaminants*, UCRL-15902 (U.S. Army Medical Research and Development Command [USAMRDC], Fort Detrick, MD, 1986).

Some of the materials in the demilitarization inventories at installations may have a recovery value in excess of the cost of the original item because of the increase in material and manufacturing costs.¹³⁹ Recovery and reuse of such materials before burning will reduce raw material costs and production requirements, and, thereby, minimize wastes generated. A number of processes (e.g., resolution of ground propellants, selective solvent extraction, disposal of scrap propellant, solution-pelletization, etc.) are available for recovery and reuse of propellants or their ingredients. Processing propellants by such reclamation techniques¹⁴⁰ minimizes environmental discharges, conserves strategic materials, and provides cost savings.

Under USEPA and State regulations, OB/OD is considered a treatment technique for hazardous wastes (ordnance). Therefore, installations are required to obtain a Part B permit. The generation of contaminated soil residues from OB/OD activity can be minimized by conducting the activity on steel "burn-pans" instead of on open ground. Incineration must also be explored as a possible minimization alternative. Controlled incineration allows for better control of air pollutants. However, proper disposal is required for residues generated in any of the operations.

Firefighting and Training

Aqueous film forming foam (AFFF) is considered a hazardous material in a number of states. Firefighting operations that use AFFF must be replaced with nonhazardous substitutes. All other wastes generated by maintenance of fire trucks and other equipment can be minimized by methods discussed in Chapters 5 and 6.

Another waste generated from fire training activities is contaminated soils in the training pits. Typically, contaminated fuel (e.g., JP-4, gasoline) is used to generate a fire in the pits for training exercises. The soil from the pits must be analyzed for chemical contaminants and properly disposed of.

Underground Storage Tanks (USTs)

Discovery of a number of leaking USTs throughout the United States prompted Congress to add Subtitle I to RCRA in 1984. Subtitle I requires the USEPA to develop regulations for leaking USTs to safeguard human health and environment. In September 1988, USEPA finalized the UST rules and regulations¹⁴¹ that cover the technical requirements for designing, installing, testing, and monitoring USTs, and the requirements for cleanup following releases from leaking USTs. Many USTs are located on each Army installation. They must all be tested for leaks and any leaking tanks must be managed according to the rules. Proper management of USTs will minimize the quantities of vapor emissions, soil contamination, and potential groundwater contamination.

A data base of information of Army-owned USTs was developed at USACERL.¹⁴² Many of the Army's USTs are more than 30 years old, greater than 10,000 gal, may contain hazardous substances, are made of steel, and have a high potential for leakage. A leak potential index (LPI)

¹³⁹D.W. Layton, et al.

¹⁴⁰F.W. Nester and L.L. Smith, *Propellant Reuse Technology Assessment*, AMXTH-TE-CR-86076 (USATHAMA, Aberdeen Proving Ground, MD, 1986).

¹⁴¹40 CFR Parts 280-281, *Underground Storage Tanks: Technical Requirements and State Program Approval; Final Rule*, pp 37081 - 37247.

¹⁴²B.A. Donahue, T.J. Hootor, and K. Piskin, *Managing Underground Storage Tank Data Using dBase III Plus*, Technical Report N-87/21/ADA182452 (USACERL, June 1987).

associated with the data base has been devised to indicate the likelihood of individual tank leakage.¹⁴³ The LPI is a tool that enables tank managers to group tanks based on the likelihood of leaks. This information indicates which tanks should be monitored more closely, which should be tested, and which should be considered for replacement.

The HAZMIN technique of inventory control is very effective in detecting tank leaks. This method requires regular measurement of the level of substances in the tanks. Records must also be maintained concerning addition and withdrawal of products. Comparison of inflow, outflow, and the inventory indicates product loss. Other leak detection methods can be grouped into volumetric methods, nonvolumetric methods, and leak effects monitoring.¹⁴⁴ Volumetric methods measure the change in volume with time and are the most fully developed and popular. Site-specific decisions have to be made regarding the use of the most appropriate leak detection method. Nonvolumetric methods measure changes in a variable, such as a tracer gas or acoustic signal, to determine changes in the level of the tank contents. Leak effects monitoring refers to methods used to determine leaks in the surrounding environment (e.g., soil vapor analysis).

Table 41
Used Oil Fuel Specifications*

Constituent or Property	Allowable Level
Arsenic	5 mg/kg maximum
Cadmium	2 mg/kg maximum
Chromium	10 mg/kg maximum
Lead	100 mg/kg maximum
Total Halogens	4,000 mg/kg maximum**
Flashpoint	37.7 °C (100 °F) minimum

*Source: Federal Register, Vol 50, No. 23, pp 49, 164 - 49,249.

**Used oil containing more than 1000 mg/kg total halogens must be shown not to have been mixed with hazardous waste. This is called the "rebuttable presumption."

¹⁴³S. Dharmavaram, et al., "A Profile and Management of the US Army's Underground Storage Tanks," *Environmental Management*, Vol 13 (1989), pp 333-338.

¹⁴⁴J. Makwinski and P.N. Cheremisinoff, "Special Report: Underground Storage Tanks," *Pollution Engineering*, Vol 20 (1988), pp 60-69.

Table 42

Amounts of Typical Hazardous Wastes Generated from Drycleaning Operations*

Waste Type	Cleaning Solvent**		
	PERC	Valclene	Stoddard
Still Residues	25		
Spent Cartridge Filters		10	20
Standard (carbon core)	20	15	***
Adsorptive (split)	30	20	***
Cooked Powder Residue	40	n/a	n/a
Drained Filter Muck	n/a	n/a	***

* Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986), p 144.

** In pounds per 1000 pounds of clothes cleaned.

*** Well-drained filter cartridges and filter muck are solids that do not meet the criteria for classification as an ignitable solid, and are therefore not considered hazardous wastes.

Table 43
Drycleaning and Laundry Operations and Wastes Classification*

Process/ operation	Materials used	HW code	Waste Description		
			DOT shipping name	Hazard class	Number
Drycleaning	PERC	F002	Waste perchloroethylene or waste tetrachloroethylene	ORM-A	UN1897
	Valclene	F002	Hazardous waste liquid or solid, NOS	ORM-E	UN9189
	Petroleum solvents	D001	Waste petroleum distillate	Combustible liquid	UN1268
			Waste petroleum naphtha	Combustible liquid	UN1255
Laundering	Caustic soda	D002	Waste sodium hydroxide	Corrosive material	UN1824
	Cleaning compound	D001	Hazardous waste liquid, NOS	Flammable liquid	UN9189

* Source: *Drycleaning and Laundry Plants*, Hazardous Waste Fact Sheet (Small Quantity Generators Activity Group, Minnesota Technical Assistance Program, University of Minnesota, Minneapolis, MN, 1988).

Table 44

Wastes Classification: Woodworking and Preserving Operations*

Process/ operation	Materials used	Waste Description			
		HW code	DOT shipping name	Hazard class	Number
Wood cleaning and wax removal	Petroleum distillates White spirits	D001	Waste flammable liquid	Flammable liquid	UN1993
		D001	Waste naphtha	Combustible liquid	UN2553
			Waste naphtha solvent	Flammable liquid	UN2553
			Waste naphtha solvent	Combustible liquid	UN1256
				Flammable liquid	UN1256
Refinishing/ stripping; brush cleaning and spray gun cleaning	Paint strippers (containing methylene chloride)	F002	Hazardous waste liquid or waste methylene chloride	ORM-E ORM-A	UN2553 UN1593
	Paint removers (containing distillates, acetone, toluene)	D001	Waste flammable liquid, NOS	Flammable liquid	UN1993
	Paint removers (containing caustic)	D002	Corrosive liquid	Corrosive material	NA1760
Staining	Stains (mineral spirits, alcohols, pigments)	D001	Waste flammable liquid	Flammable liquid	UN1993
Painting	Paints (enamels, lacquers, epoxy, alkyds, acrylics)	D001	Waste paint or enamel liquid	Flammable liquid	UN1263
Finishing	Varnish, shellac, lacquer	D001	Waste flammable liquid, NOS	Flammable liquid	UN1993
Preserving	Creosote	K001	Hazardous waste liquid or solid, NOS	ORM-E	NA9189
	Pentachlorophenol	K001	Waste pentachlorophenol, liquid	ORM-E	NA2020
	Chromated copper arsenate	D004/ D007	or solid Waste arsenical compounds, liquids	Poison B	UN1557
	Ammoniacal copper arsenate	D004	Waste arsenical compounds, solids	Poison B	UN1556
			Waste arsenical compounds, liquids	Poison B	UN1557
			Waste arsenical compounds, solids	Poison B	UN1556
	Other wood preservatives	Varies	Hazardous waste liquid or solid, NOS	ORM-E	NA9189

*Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986), pp 146-147.

Table 45
Waste Classification: Pesticides*

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Pesticides Containing Arsenic:				
Arsenic pentoxide	Arsenic acid anhydride Arsenic (V) oxide	Waste arsenic pentoxide, solid	Poison B	UN1559
Arsenic trioxide	Arsenic sesquioxide Arsenic (III) oxide Arsenous acid (anhydride) White arsenic	Waste arsenic trioxide, solid	Poison B	UN1561
Cacodylic acid	Hydroxydimethylarsine oxide	Waste arsenical pesticide, solid, NOS ³	Poison B	UN2759
	Dimethylarsinic acid	Waste arsenical pesticide, liquid, NOS	Poison B	UN2759
	Phytar	Waste arsenical pesticide, liquid, NOS	Flammable liquid	UN2760
Monosodium Methanearsonate	MSMA	Waste arsenical pesticide, solid, NOS	Poison B	UN2759
	Ansar 170 H.C. and 529 H.C.	Waste arsenical pesticide, liquid, NOS	Poison B	UN2759
	Arsanote liquid	Waste arsenical pesticide, liquid, NOS	Poison B	UN2759
	Bueno 6	Waste arsenical pesticide, liquid, NOS	Flammable liquid	UN2760
	Daconate 6	Waste arsenical pesticide, liquid, NOS	Flammable liquid	UN2760
	Dal-E-Rad			
	Herb-All			
	Merge 823			
Disodium Monomethanearsonate	Mesamate			
	Monate			
	Trans-Vert			
	Weed-E-Rad			
	Weed-Hoe			
	DSMA	Waste arsenical pesticide, solid, NOS	Poison B	UN2759
	Ansar 8100	Waste arsenical pesticide, liquid, NOS	Poison B	UN2759
	Arrhenal	Waste arsenical pesticide, liquid, NOS	Poison B	UN2759
	Arsinyl			
	Dinate			
	Di-Tac			
	DMA			
	Methar 30			
	Sodar			
	Versar DSMA-LQ			
	Weed-E-Rad			

*Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL 1986), pp 150-161.

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Pesticides Containing Carbomates:				
Temik	Aldicarb	Waste carbamate pesticide, solid, NOS	Poison B	UN2757
	OMS 771	Waste carbamate pesticide, liquid, NOS	Poison B	UN2757
	UC 21149	Waste carbamate pesticide, liquid, NOS	Flammable liquid	UN2758
Pesticides Containing Mercury:				
2-Methoxyethyl-mercuric Chloride	MEMC	Waste mercury based pesticide, solid, NOS	Poison B	UN2777
	Agallol	Waste mercury based pesticide, liquid, NOS	Poison B	UN2777
	Cekusil Universal-C Ceresan-Universal-Nassbeize Emisan 6	Waste mercury based pesticide, liquid, NOS	Flammable liquid	UN2778
Phenylmercuric acetate	PMA	Waste mercury based pesticide, solid, NOS	Poison B	UN2777
	PMAS	Waste mercury based pesticide, liquid, NOS	Poison B	UN2777
	Agrosan	Waste mercury based pesticide, liquid, NOS	Flammable liquid	UN2778
	Cekusil	Waste mercury based pesticide, liquid, NOS	Flammable liquid	UN2778
	Celmer	Waste mercury based pesticide, liquid, NOS	Flammable liquid	UN2778
	Gallolox Hong Nien Liquidphene Mersolite Pamisan Phix Seedtox Shimmer-ex Tag HL 331	Waste mercury based pesticide, liquid, NOS	Flammable liquid	UN2778
Pesticides Containing Substituted Nitrophenols:				
Dinitrocresol	DNC	Waste substituted nitrophenol pesticide, solid, NOS	Poison B	UN2779
	DNOC	Waste substituted nitrophenol pesticide, liquid, NOS	Poison B	UN2779
	Chemset	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Detal	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Elgetol 30	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Nitrador	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Selinon	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Sinox Trifocide Trifrina	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
Dinoseb	DNBP	Waste substituted nitrophenol pesticide, solid, NOS	Poison B	UN2779
	Basanite	Waste substituted nitrophenol pesticide, liquid, NOS	Poison B	UN7890
	Caldon	Waste substituted nitrophenol pesticide, liquid, NOS	Poison B	UN7890
	Chemox general	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Chemox PE	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Dinitro	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Dinitro general	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780
	Dynamite Elgetol 318 Gebutox	Waste substituted nitrophenol pesticide, liquid, NOS	Flammable liquid	UN2780

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Dinoseb (Cont'd)	Hel-Fire Nitropone C Premerge 3 Sinox general Subitex Vertac general weed killer Vertac selective weed killer			
Organophosphate pesticides:				
Dimetboate	AC-12880	Waste organophosphorous pesticide, solid, NOS	Poison B	UN2783
	Bi 58 EC	Waste organophosphorous pesticide, liquid, NOS	Poison B	UN2783
	Cekuthoate	Waste organophosphorous pesticide, liquid, NOS	Flammable liquid	UN2784
	Cygon	Waste organophosphorous pesticide, liquid, NOS		
	Daphene			
	De-Fend			
	Demos-L40			
	Devigon			
	Dimet			
	Dimethogen			
	Perfekthion			
	Rebelate			
	Rogdial			
	Rogor			
	Roxion			
	Trimetion			
Disulfoton	Bay 19639 and S276	Waste disulfoton	Poison B	NA2783
	Dithiodemeton	Waste disulfoton mixture, dry	Poison B	NA2783
	Dithiosystox	Waste disulfoton mixture, liquid	Poison B	NA2783
	Di-Syston	Waste organophosphorous pesticide, liquid, NOS	Flammable liquid	UN2784
	Ethylthiodemeton			
	Frumin AL			
	M-74			
Famphur	Solvirex			
	Thiodemeton			
	Bash	Waste organophosphorous pesticide, solid, NOS	Poison B	UN2783
	Bo-Ana	Waste organophosphorous pesticide, liquid, NOS	Poison B	UN2783
	Dovip	Waste organophosphorous pesticide, liquid, NOS	Flammable liquid	UN2784
	Famfos			
	Warbex			
Methylparathion	Cekumethion	Waste methyl parathion, liquid	Poison B	NA2783
	E-601	Waste methyl parathion mixture, dry	Poison B	NA2783
	Devithion	Waste methyl parathion mixture, liquid, (containing 25% or less methylparathion)	Poison B	NA2783
	Folidon M			
	Fosferno M50	Waste methyl parathion mixture, liquid, (containing more than 25% methylparathion)	Poison B	NA2783
	Gearphos			
	Methacide			
	Metaphos			
	Nitrox 80	Waste organophosphorous pesticide, liquid, NOS	Flammable liquid	UN2784
	Parataf			
	Paratox			
	Partron M			

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Methylparathion (Cont'd)	Pennacap-M Wofatox			
Parathion	AC-3422	Waste parathion, liquid	Poison B	NA2783
	Alkron	Waste parathion mixture, dry	Poison B	NA2783
	Alleron	Waste parathion mixture, liquid	Poison B	NA2783
	Aphamite	Waste organophosphorous pesticide, liquid, NOS	Flammable liquid	UN2784
	Bladan			
	Corothion			
	E-605			
	ENT 15108			
	Ethyl parathion			
	Etilon			
	Folidol E-605			
	Fosterno 50			
	Niran			
	Orthophos			
	Panthion			
	Paramar			
	Paraphos			
	Parathene			
	Parawet			
	Phoskil			
	Rhodiatox			
	Soprathion			
	Stathion			
	Thiophos			
Strychnine Pesticides:				
Strychnine	Strychnine salts	Waste strychnine, solid	Poison B	UN1692
		Waste strychnine salt, solid	Poison B	UN1692
Thallium Sulfate Pesticides:				
Thallium sulfate	Thallous sulfate	Waste thallium sulfate, solid	Poison B	NA1707
	Ratox	Waste flammable liquid, poisonous, NOS	Flammable liquid	UN1992
	Zelio			
Triazine Pesticides:				
Amitrole	Amerol	Waste triazine pesticide, solid, NOS	Poison B	UN2763
	Amino triazol weedkiller 90	Waste triazine pesticide, liquid, NOS	Poison B	UN2763
	Amizol	Waste triazine pesticide, liquid, NOS	Flammable liquid	UN2764
	AT-90			
	AT liquid			
	Azolan			
	Azole			
	Cytrol			
	Diuro			
	Farmco			
	Herbizole			
	Simazol			
	Weedazol			
	Weedazol TL			

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Flammable Solvents Used in Pesticides:				
Methyl alcohol	Methanol	Waste methyl alcohol	Flammable liquid	UN1230
Ethyl alcohol	Ethanol Alcohol	Waste ethyl alcohol	Flammable liquid	UN1170
Isopropyl alcohol	Isopropanol	Waste isopropanol	Flammable liquid	UN1219
Toluene	Methyl benzene Toluol	Waste toluene (tuluol)	Flammable liquid	UN1294
Xylene	Dimethyl benzene Xylol	Waste xylene (xylol)	Flammable liquid	UN1307
Solvent mixtures		Waste combustible liquid, NOS Waste flammable liquid, NOS	Combustible liquid Flammable liquid	NA1993 UN1993
Phenoxy Pesticides:				
2,4-D	Amoxone	Waste 2,4-dichlorophenoxyacetic acid	ORM-A	NA2765
	Brush Killer	Waste 2,4-dichlorophenoxyacetic acid ester	ORM-E	NA2765
	Brush-Rhap	Waste phenoxy pesticide, liquid, NOS	Flammable liquid	UN2766
	Chloroxone			
	Crop Rider			
	D50			
	DMA 4			
	Dacamine			
	Ded-Weed			
	Desormone			
	Dinoxol			
	Emulsamine BK and E3			
	Envert DT and 171			
	Hedonal			
	Miracle			
	Pennamine D			
	Rhodia			
	Salvo			
	Super-D Weedone			
	Verton			
	Visko-Rhap			
Weed Tox				
Weed-B-Gone				
Weed-Rhap				
Weedar				
Weedone				
Weedtrol				
2,4,5-T	Brush-Rhap	Waste 2,4,5-trichlorophenoxyacetic acid	ORM-A	NA2765
	Dacamine	Waste 2,4,5-trichlorophenoxyacetic acid (amine, ester, or salt)	ORM-E	NA2765
	Ded-Weedon	Waste phenoxy pesticide, liquid, NOS	Flammable liquid	UN2766
	Esteron			
	Farmco Fence Rider			
	Forron			
	Inverton 245			
	Line Rider			

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
2,4,5-T (Cont'd)	Super D Weedone Tormona Transamine U 46 Veon 245 Weedar Weedone			
Silvex	2,4,5-TP	Waste 2-(2,4,5-trichlorophenoxy) propionic acid	ORM-A	NA2765
	Fenoprop	Waste 2-(2,4,5-trichlorophenoxy) propionic acid ester	ORM-E	NA2765
	AquaVex	Waste phenoxy pesticide, liquid, NOS	Flammable liquid	UN2766
	Double Strength			
	Fruitone T			
	Kuron			
	Kurosai			
	Silver-Rhap			
	Weed-B-Gone			
Organochlorine Pesticides:				
Aldrin	HHDN	Waste aldrin	Poison B	NA2761
	Aldrex 30			
	Aldrite	Waste aldrin mixture, dry (with more than 65% aldrin)	Poison B	NA2761
	Aldrosol	Waste aldrin mixture, liquid (with 65% or less aldrin)	ORM-A	NA2761
	Alttox	Waste aldrin mixture, liquid (with more than 60% aldrin)	Poison B	NA2762
	Drinox	Waste aldrin mixture, liquid (with 60% or less aldrin)	ORM-A	NA2762
	Octalene	Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
	Seedrin liquid			
Chlordan	Belt	Waste chlordane, liquid	Flammable liquid	NA2762
	Chlordan			
	ChlorKil	Waste chlordane, liquid	Combustible liquid	NA2762
	Chlortox			
	Corodane			
	Gold Crest C-100			
	Kypchlor			
	Vesicol 1068			
	Topiclor 20			
	Niran			
	Octachlor			
	Octa-Klor			
	Ortho-Klor			
	Synklor			
	Termi-Ded			
DDT	Dedelo	Waste DDT	ORM-A	NA2761
	Didimac			
	Digmar	Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
	Genitox			
	Gyron			
	Gildit			
	Kopsol			
	Neocid			

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
DDT (Cont'd)	Pentachlorin Rukseam Zerdand			
Dichloropropene	1,3-dichloropropene Telone II Soil Fumigant	Waste dichloropropene	Flammable liquid	UN2047
Dieldrin	Dieldrex	Waste dieldrin	ORM-A	NA2761
	Dieldrite Octalox Panoram D-31	Waste organochlorine pesticide, liquid, NOS	Flammable Liquid	UN2762
Endrin	Endrex	Waste Endrin	Poison B	NA2761
	Hexadrin	Waste Endrin mixture, liquid	Poison B	NA2761
		Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
Endosulfan	Beosit	Waste Endosulfan	Poison B	NA2761
	Chlorthiepin	Waste Endosulfan mixture, liquid	Poison B	NA2761
	Crisulfan	Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
	Cyclodan			
	Endocel			
	EnSure			
	FMC 5462			
	Hildan			
	Hoc 2671			
	Malix			
	Thifor			
	Thimul			
	Thiodan			
	Thiofor			
	Thionex			
	Tiovel			
Heptachlor	Gold Crest H-60	Waste Heptachlor	ORM-E	NA2761
	Drinox H-34	Waste organochlorine pesticide, liquid	Flammable liquid	UN2762
	Heptamul	NOS		
	Heptox Chlordecone			
Kepone	Exagama	Waste Kepone	ORM-E	NA2761
	Forlin	Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
Lindane	Gallo gama	Waste Lindane	ORM-A	NA2761
	Gamaphex	Waste organochlorine pesticide, liquid, NOS		
	Gammex		Flammable liquid	UN2762
	Inexn			
	Isotox			
	Lindafor			
	Lindagam			
	Lindagrain			
	Lindagranox			
	Lindalo			
	Lindamul			
	Lindapoudre			

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Lindane (Cont'd)	Lindaterra Novigam Silvanol			
Methoxychlor	Flo Pro McSeed Protectant Marlate	Waste Methoxychlor	ORM-E	NA2761
		Waste organochlorine pesticide, solid, NOS	Poison B	UN2761
		Waste organochlorine pesticide, liquid, NOS	Poison B	UN2761
		Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
Propylene Dichloride	1,2-dichloropropane	Waste propylene dichloride	Flammable liquid	UN1279
Toxaphene	Attac 4-2, 4-4, 6, 6-3, 8	Waste toxaphene	ORM-A	NA2761
	Camphochlor	Waste organochlorine pesticide, liquid, NOS	Flammable liquid	UN2762
	Motox			
	Phenacide			
	Phenatox			
	Strobane T-90			
Other Pesticides:	Toxakil			
	Toxon			
Thiram	TMTD	Waste Thiram	ORM-A	NA2771
	AAatak	Waste flammable liquid, poisonous, NOS	Flammable liquid	UN1992
	Arasan			
	Aules			
	Evershield T Seed Protectant			
	Fermide 850			
	Fernasan			
	Flo Pro T Seed Protectant			
	Hexathir			
	Mercuram			
	Nomersan			
	Pomarsolforte			
	Polyram-Ultra			
	Spotrete-F			
	Tetrapom			
	Thimer			
	Thionock			
	Thiotex			
	Thiramad			
	Thiuramin			
	Tirampa			
	Trametan			
	Tripomol			
	Thylate			
	Tudas			
	Vancide TM			
Warfarin	Co-Rax	Hazardous waste solid, NOS	ORM-E	NA9189
	Cov-R-Tox			
	Kypfarin	Hazardous waste liquid, NOS	ORM-E	NA9189
	Liqua-Tox			

Table 45 (Cont'd)

Process/operation	Materials used	Waste Description		
		DOT shipping name	Hazard class	Number
Pentachlorophenol	RAX	Waste flammable liquid, NOS	Flammable liquid	UN1993
	Rodex			
	Rodex Blax	Waste combustible liquid, NOS	Combustible liquid	NA1993
	Tox Hid			
	PCP	Waste pentachlorophenol	ORM-E	NA2020
	Penta			
	Penchlorol	Waste flammable liquid, NOS	Flammable liquid	UN1993
	Pentacon			
	Penwar	Waste combustible liquid, NOS	Combustible liquid	NA1993
	Sinitudo			
Pentachloronitrobenzene	PNCB			
	Avicol	Hazardous waste, solid	ORM-E	NA9189
	Botrilex	Hazardous waste, liquid	ORM-E	NA9189
	Brassicol			
	Earthcide	Waste flammable liquid, NOS	Flammable liquid	UN1993
	Folosan			
	Kobu	Waste combustible liquid, NOS	Combustible liquid	NA1993
	Pentagen			
	Saniclor 30			
	Terraclor			
Hexachlorobenzene	Tilcarex			
	Tritesan			
	Perchlorobenzene	Hazardous waste, solid	ORM-E	NA9189
	Anticarie			
	Ceku C.B.	Hazardous waste, liquid	ORM-E	NA9189
1,2-Dibromo 3-Chloropropane	HCB			
	No Bunt	Waste flammable liquid, NOS	Flammable liquid	UN1993
	DBCP	Waste combustible liquid, NOS	Combustible liquid	NA1993
	Nemafume	Hazardous waste, solid, NOS	ORM-E	NA9189
	Nemanox	Hazardous waste, liquid, NCS	ORM-E	NA9189
	Nemaset	Waste flammable liquid, NOS	Flammable liquid	UN1993
	Nematocide	Waste combustible liquid, NOS	Combustible liquid	NA1993

Table 46

Ingredients Contained in Propellants, Explosives, and Pyrotechnics

Compound	Type
2,4,6-Trinitrotoluene (TNT)	EX*
Cyclotrimethylenetrinitramine (RDX)	EX
Pentaerythritol Tetranitrate (PETN)	EX
2,4,6-Trinitrophenylmethylnitramine (Tetryl)	EX
Ammonium Picrate (Explosive D)	EX
Cyclotetramethylenetetranitramine (HMX)	EX
2,4-Dinitrotoluene (DNT)	PP
Nitroglycerin (NG)	PP
Nitroguanidine (NQ)	PP
Dibutyl phthalate	PP
Diethyl phthalate	PP
Diphenylamine	PP
Benzene	EX
Toluene	EX
Sodium Nitrate	PY
Barium Nitrate	PY
Magnesium Nitrate	PY
Strontium Peroxide	PY
Strontium Oxalate	PY
Calcium Resinate	PY

*EX = explosives; PP = propellants; PY = pyrotechnics.

Table 47

Common Elements Found in PEP and OB/OD Soil Residue

Element	OB % of samples greater than EP toxic limits	OD
Strontium		
Cadmium	2.5	1.3
Arsenic	0.3	0.0
Antimony		
Lead	6.0	0.7
Mercury	0.6	0.0
Barium		

*Source: D.W. Layton, p 29.

11 WASTE MINIMIZATION FOR MISCELLANEOUS WASTES

Polychlorinated Biphenyls

PCBs are chlorinated organic compounds with a wide range of physical properties. There are 209 possible PCBs of which tri-, tetra-, penta-, and hexachloro biphenyls are the most important. They were commonly used in coolants and insulation fluids in transformers. Some of the older products that may contain PCBs or oils with PCBs include: heat-transfer fluids, lubricants, paints, plastics, air conditioners, fluorescent lights, and televisions. PCBs were most widely used in capacitors and transformers because of their low conductivity and thermal stability.

In several cases of poisoning in Japan and Taiwan, PCBs and their secondary products such as polychlorinated dibenzofurans were found to be the major contaminants in bran oil used to cook rice. Since then, PCBs have been linked to severe health problems (e.g., gastric disorders, skin lesions, swollen limbs, cancers, tumors, eye problems, liver disorders, menstrual irregularities, etc.) and birth defects (e.g., reproductive failures, mutations, etc.). Compounding the problem of PCBs' toxicity is their bioaccumulation in cells and fatty tissues of micro-organisms and animals, which are then consumed by other animals higher in the food chain.

PCBs are regulated by the Toxic Substances Control Act (TSCA) passed in 1976. Manufacture of PCBs was banned under TSCA and deadlines were provided for removing capacitors and transformers containing PCBs. One year was allowed for storage before disposal. If regulatory agencies determine that the use of PCB transformers poses no risk, the use will be allowed to continue. All capacitors were to have been removed by October 1988, and transformers of certain size in or near commercial buildings should be removed by October 1990.

If the concentration of PCBs in a product is greater than 50 parts per million (ppm), the product is regulated as hazardous under TSCA. Some States have set limits that are stricter than Federal limits (e.g., California, 5 ppm).

PCBs in Transformers

In the United States, there are 150,000 askarel (nonflammable electrical fluid) transformers, each of which contains thousands of pounds of PCBs with a wide range of concentrations.¹⁴⁵ Many of these transformers develop leaks.

The transformers are generally classified as: PCB transformers (greater than 500 ppm), PCB-contaminated transformers (50 to 500 ppm), and Non-PCB transformers (less than 50 ppm). PCB transformers must be inspected quarterly for leaks; detailed records must be kept. No maintenance work involving removal of the coil or casing is allowed. PCB-contaminated transformers must be inspected annually. Their requirements for maintenance and recordkeeping are less restrictive than for PCB transformers. Non-PCB transformers are exempt from regulation.

The importance of analyzing all transformers for PCBs must be stressed. All the transformers on an installation must be inventoried and tested for PCBs. If the PCB levels are greater than 50 ppm, appropriate actions must be taken.

¹⁴⁵ P.N. Cheremisinoff, "High Hazard Pollutants: Asbestos, PCBs, Dioxins, Biomedical Wastes," *Pollution Engineering*, Vol 21 (1989), pp 58-65.

PCB Waste Management

There are no minimization options available for PCB wastes. Recycling of PCBs is illegal. Nevertheless, containers and oils contaminated with PCBs may be recycled if the PCBs are removed.

Federal regulations require that PCBs be destroyed in approved high-temperature incinerators. Oils containing 50 to 500 ppm PCBs can be burned in high-efficiency boilers. Alternate technologies capable of operating at the high incinerator efficiencies, such as the molten salt processes or UV/Ozonation may also be considered for "ultimate" treatment/disposal. In addition to incineration, which is the most common, chemical dechlorination technologies have also been successful. Table 48 lists the names and addresses of incineration facilities and available chemical dechlorination services.

The most common practice at Army installations is to retain PCB transformers in service until the end of their useful life or they leak. They are then replaced with non-PCB transformers. The other possible options that may be available are decontaminating and/or retrofitting the transformers. Table 49 lists the names and addresses of companies that provide retrofitting services.

USACERL's PCB Transformer System

A computer-aided, fate-decision analysis tool was developed at USACERL to help users make decisions about transformers containing PCB levels greater than 50 ppm. The computer model is available to Army users through the Environmental Technical Information System (ETIS) on the mainframe computer at USACERL. A PC-based model is also available.*

The model provides users with information about PCBs and appropriate regulations, and allows them to input information for risk assessment, fate-decision analysis, and life cycle cost analysis. The options considered in the final economic analysis are: retaining, retrofitting, decontaminating, and replacing transformers.

Onsite Mobile Treatment Units

Mobile incineration and chemical dechlorination units can decontaminate insulating oils from transformers. One dechlorination process, the "PCBX" process developed by ENSR, is a self-contained continuous-flow unit. It is designed and equipped to destroy PCBs (up to 2600 ppm) from transformer oil without moving the transformer. The operating capacity of the unit is up to 600 gallons per hour. Exceltech, Inc., based in California, also markets mobile dechlorination units for removing PCBs from transformers.

Ordnance

A number of hazardous ordnance materials are used on Army installations. Ingredients contained in some of them are listed in Table 46. Further details are available in Technical Manual (TM) 9-1300-214.¹⁴⁶ Army directives prohibit burial of ordnance materials or dumping them in waste places, pits, wells, marshes, shallow streams, rivers, inland waterways, or at sea. All existing locations of buried explosives must be identified and marked accordingly. The only means of disposal available is destruction by burning and detonation (discussed in Chapter 10). Proper operating procedures for disposal of discarded ordnance materials should be developed and updated frequently to comply with Federal, State, and local regulations.

* For information, contact Bernard Donahue or Keturah Reinbold at USACERL-EN, P.O. Box 4005, Champaign, IL 61824-4005, or telephone 800-USACERL (outside Illinois) 800-252-7122 (within Illinois).

¹⁴⁶ Technical Manual (TM) 9-1300-214, *Military Explosives* (Headquarters, Department of the Army, 20 September 1984).

Contaminated Soil

Contaminated soil is generated because of leaks or spills of hazardous materials. Some effective source reduction techniques include: installing splash guards and dry boards on equipment, preventing tank overflow, using bellow sealed valves, installing spill basins, using seal-less pumps, secondary containment, plant maintenance, and personnel training to develop good operating practices.

A number of nonthermal and thermal treatment techniques are available for decontamination of soil.¹⁴⁷ Nonthermal techniques include: aeration, biodegradation, carbon adsorption, chemical dechlorination, solvent extraction, stabilization/fixation, and ultraviolet photolysis. Thermal treatment techniques include: stationary rotary-kiln incineration, mobile rotary-kiln incineration, liquid injection incineration, fluidized bed incineration, high-temperature fluid-wall destruction, infrared incineration, supercritical-water oxidation, plasma-arc pyrolysis, and in situ vitrification.

Empty Containers

Containers with residual hazardous materials/wastes must also be treated as hazardous wastes. Under HSWA, if a container with hazardous residue is found in a cleanup (Superfund) site or other landfill, the generator (Army) is liable and has to pay for part of the cost of cleanup. Even "triple rinsed" containers could contain some residue. Scrap dealers and landfills are becoming reluctant to accept "clean" empty 55-gal drums or other containers.

The problem of disposing of empty drums and containers can be minimized by giving careful consideration to the kinds and sizes of containers in which materials are originally received. When purchasing materials in bulk, the suppliers must be asked to send them in rinsable and/or recyclable containers. A number of commercial recyclers (listed in Regional Waste Exchange bulletins/newsletters or directories) accept containers less than 30 gal.¹⁴⁸ Treating empty containers by triple rinsing is a good waste minimization technique. However, the rinsate, if hazardous, must be properly managed.

Some of the other options to consider when procuring materials, and in the ultimate disposal of containers, are:¹⁴⁹ returning drums to suppliers, contracting with a drum conditioner, contracting with a scrap dealer, and, lastly, disposal in an approved landfill.

Returning Drums to Suppliers

When buying material, a purchase agreement must be established to include the option of returning empty containers to the suppliers. Cash deposits may be required and drums should be maintained in good condition. All the accessories, such as bungs, rings, and closures, must also be kept and returned with the drums.

Contracting With a Reconditioner

If the suppliers do not sell chemicals in returnable drums, ask them to send materials in heavy steel (18 to 20 gauge) drums that can be reconditioned when "empty." A typical 55-gal heavy drum should have a 20-gauge side and 18-gauge ends. A good market exists for these drums and they can be sent to reconditioning contractors for minimal or no cost. Empty heavy drums must be treated as a valuable asset and personnel should be trained in their proper handling (including keeping the bungs,

¹⁴⁷ *Standard Handbook of Hazardous Waste Treatment and Disposal*.

¹⁴⁸ Ventura County Environmental Health, p 3-2.

¹⁴⁹ *Managing Empty Containers*, Fact Sheet (Minnesota Technical Assistance Program, University of Minnesota, Minneapolis, MN, 1988).

rings, etc.). Another good practice is to avoid accumulating the drums for long periods of time, thus preventing deterioration.

Contracting With a Scrap Dealer or Disposal in a Landfill

Scrap dealers and landfill operators usually require certain conditions to be met before they accept drums or other containers. Generators have to drain the drums or containers thoroughly, remove the residues by triple rinsing, certify that they do not contain hazardous materials, remove both the ends, crush them before transporting, and pay for disposal.

Table 48**PCB Replacement/Treatment/Disposal Services**

Company	Address
ENSCO	P.O. Box 1975, El Dorado, AR 71730, (501) 863-7173
ENSR (formerly SunOhio)	1700 Gateway Blvd. SE, Canton, OH 44707, (216) 452-0837
USEPA Mobile Incinerator	Woodbridge Ave., Raritan Depot Bldg. 10, Edison, NJ 08837, (201) 321-6635
GSX Chemical Services	121 Executive Center Dr., Congaree Bldg. # 100, Columbia, SC 29221, (800) 845-1019
Rollins	P.O. Box 609, Deer Park, TX 77536, (713) 479-6001
General Electric	One River Road/Bldg 2-111B, Schenectady, NY 12345, (518) 385-9763
SCA Chemical Services	1000 E. 111th St., 10th Fl., Chicago, IL 60628, (312) 660-7200

Table 49**PCB Transformer Retrofilling Services**

Company	Address
DOW Corning Corp	P.O. Box 0994, Midland, MI 48686-0994, (517) 496-4000
ENSR (formerly SunOhio and Retrotex)	1702 Gateway Blvd. SE, Canton, OH 44707, (216) 452-0837
General Electric	One River Road/Bldg 2-111B, Schenectady, NY 12345, (518) 385-9763
Hoyt Corporation	251 Forge Rd., Westport, MA 02790-0217, (800) 343-9411
Transformer Service Inc.	78 Regional Dr., P.O. Box 1077, Concord, NH 03301-9990, (603) 224-4006
Unison Transformer Services	1338 Hundred Oaks Dr., Charlotte, NC 28210, (800) 544-0030
Westinghouse/Industry Services	875 Greentree #8-MS 804, Pittsburgh, PA 15220, (800) 441-3134

12 ECONOMIC ANALYSIS FOR HAZARDOUS WASTE MINIMIZATION

HSWA requires generators of hazardous wastes to develop a waste minimization program that is economically practicable. Therefore, once the alternatives for minimization are identified, their economic feasibility must also be studied. A major source for funding for hazardous waste minimization projects has been through the Defense Environmental Restoration Account (DERA). If the pay-back from a project is expected to be 1 year or less, funding is also available from the Defense Productivity Enhancing Capital Investment (PECI) program. In many instances, minimization is a cost-effective means of conducting business. In such instances, any account may be used to finance minimization and benefit from the resultant savings. However, with the multiplicity of alternative treatment technologies available to treat various hazardous waste streams, it is imperative that installation environmental personnel use a standard methodology to evaluate hazardous waste minimization options.

In 1984, DOD initiated the USE program. In conjunction with the USE program, USACERL developed a model for performing an economic analysis on various alternatives for recycling or disposing of used solvents. Based on this earlier model, a microcomputer model has been developed for economic analysis of minimization options. (Refer to USACERL Draft Technical Report ¹⁵⁰ for a detailed discussion of the process of economic analysis and use of the model.) A part of the model related to nonspecific or "general" waste types is used to determine the life cycle costs and comparison of alternatives for waste streams in this report. Many other publications on economic analysis are available.

The caveat of an "economically practicable" level of waste minimization, as defined in HSWA, is very important. It is not necessary (and is impossible in most cases) to completely eliminate generation of wastes. An economic analysis provides a reasonable methodology for choosing between options for waste minimization. The typical costs considered for any option are initial capital costs and operating costs such as labor, materials, transportation, and waste disposal. Benefits achieved from a waste minimization option (e.g., reduced liability) can also be quantified and given dollar values.

The costs are summed to obtain life cycle costs over the assumed economic life for each option. Net present value (NPV) of the total life cycle costs can be calculated for each option. Comparing the NPVs provides a basis for selecting a minimization technique. Results of detailed economic analysis for the selected waste streams are provided in the sections below.

Used Oil

A large quantity of used oil, primarily engine lubricating oil, is generated on Army installations. Lubricating oil is drained from wheeled and tracked vehicles by the traditional drip-pan method and collected in 55-gal drums or larger storage tanks. Some of the contaminants found in used oil are trash/rags, solvents, hydraulic fluids, and wear metals. Oil is normally changed from vehicles based on the Army Oil Analysis Program (AOAP) test.

A source reduction method for minimizing waste oil generation is a change in the process of draining the oil. A Fast Lube Oil Change (FLOC) system can be implemented to replace the gravity-drain (drip-pan) method. A description of the technique is provided in Chapter 5. Adapters have to be purchased for all the different types of Army vehicles. The major savings is in the labor costs.

¹⁵⁰ J.B. Mount, et al.

The amount of extraneous contaminants in the used oil is considerably reduced if the procedure is implemented.

A comparison of the life cycle (10-year) costs for the two techniques was performed for fleets ranging from 50 to 5000 vehicles.

Investment costs for the purchase of a FLOC evacuation unit and engine adapter kits are assumed to all occur in the first year. A 10-yr economic life and midyear discounting at a rate of 10 percent are assumed for both options. The model's default values retained for analysis include: site preparation and installation - 15 percent of total equipment costs; logistics and procurement - 7 percent of installed equipment costs; contingencies - 10 percent of installed equipment costs; labor rate (manager) - \$16.00 per hour; labor rate (laborer) - \$11.00 per hour; adjustments for leave - 18 percent of total man-hours; adjustments for fringe benefits - 36.2 percent of adjusted base labor cost; number of work days in a year - 247; average maintenance - 5 percent of equipment costs; transportation of hazardous waste - \$0.04 per pound; and, annual logistics and procurement - 1.6 percent of other Operational and Maintenance (O&M) costs. Other assumptions made in the analysis are:

- The average crankcase oil per vehicle is 3.25 gal.
- The average number of oil changes per year is two.
- Liability due to spills, including labor costs for cleanup, is \$177 for the gravity drain system.
- The time required for an oil change using the gravity drain system is 15 minutes.
- The time required for an oil change using the FLOC system is 4.5 minutes.
- A labor time of 0.7 hours is assumed for removal of an accumulation of up to 50 gal in a 55-gal drum.
- The procurement cost of a small FLOC evacuation unit and necessary engine adapter kits is approximately \$2260. An additional \$2265 for site preparation and training of personnel is required to implement this system. The cost of larger evacuation units increases with size.
- The system is used 260 working days per year.
- The utility cost for each FLOC unit is \$75/yr/unit.
- Costs do not escalate.
- Repair and maintenance is \$50/yr/unit.
- One FLOC unit can handle approximately 35 to 40 vehicles per day. If more than 10,000 oil changes are conducted annually, two or more units will be required.

Table 50 lists the savings-to-investment ratios (SIRs) and discounted payback periods (DPPs) for implementing a FLOC system to service 100, 250, 500, 1000, and 5000 vehicles twice per year. In almost every case the SIR is 0.39 (1 = economical) and therefore provides no DPP within the expected

economic life of the equipment. Table 51 lists the computed SIRs and DPPs when the average number of oil changes per vehicle increases from two to six times per year for 1000 vehicles. Only when the number of oil changes per vehicle each year is six or greater, which is not likely to occur, does the FLOC system become cost effective to implement.

Other options that were analyzed for management of used oil include: (1) segregate solvents and other contaminants from oils and burn in existing facility (no additional investment), (2) offsite disposal (burning in industrial boiler) (status quo), and (3) blend and burn with minimal processing (with additional investment). Hazardous oil, when burned in a boiler without permits, is subject to fines. Operating without a permit or violating a permit will cause the facility to be shut down by the regulating agency.

The major assumptions made in the analysis were:

- Nonsegregated oil may be considered hazardous depending upon the concentration of halogens and heavy metals.
- Cost of oil is \$3.25 per gallon.
- Processing time is 40 hr/1000 gal for option 3 and 60 hr/1000 gal for option 1.
- Transport cost is same for all options within the installation.
- Sampling and testing costs (\$21.00) are assumed to be the same for all options.
- Liability costs are \$0.002/gal for options 1 and 3 and \$0.008/gal for option 1.
- Fuel to oil blend ratio is assumed to be 10 to 1.
- The disposal cost of filters, residues, etc. is \$0.25/gal for options 1 and 3 and \$1.22/gal for option 2.
- Escalation of raw materials, repair and maintenance, and liability costs is assumed to be 4 percent. Disposal costs are escalated by 6 percent and the transport cost for option 2 is escalated by 4 percent.
- Repair and maintenance for option 1 is assumed to be 1 percent of investment costs in option 3.
- Labor requirement for disposal of 1000 gal is assumed to be 8 hours for laborers and 1 hour for managers.

Figure 5 shows the comparison between the NPVs of the life cycle (10-yr) costs for the three used oil management options. Oil mixed with solvents can be a hazardous waste and must be tested to prove otherwise. Burning of hazardous waste in the Fort Sam Houston boilers is prohibited. Offsite disposal (option 2) is more expensive than segregation and burning (option 1). Option 3 is the most expensive option. Minimal processing assumed in option 3 requires investment in some physical

pretreatment devices. The associated operating costs are also higher because of increased maintenance costs.

Cleaning Solvent Waste

Cleaning solvents such as petroleum distillates (PD680-II), petroleum naphtha, varsol, etc., are used in parts cleaning operations as discussed in Chapter 5. At Fort Sam Houston, the most widely used practice is that of contract recycling. Safety Kleen is the contractor that leases parts cleaning equipment and replaces the solvent periodically. The estimated waste generation (or material usage) rate is 45,728 lb/yr (5940 gal/yr). Some of the operations (e.g., aircraft maintenance) have their own equipment and dispose of about 11,839 lb/yr (1538 gal/yr) of cleaning solvent wastes. A total of 7478 gal/yr of cleaning solvent waste is therefore generated.

An economic analysis was performed to compare the costs and benefits of the following solvent management practices: (1) the purchase of fresh solvent and offsite disposal of generated waste; (2) an offsite, closed-loop recycling program using the solvent provided by a private contractor and Fort Sam Houston parts-washing equipment (OE); (3) offsite, closed-loop recycling using the solvent and parts-washing equipment provided by a private contractor (LE); and (4) closed-loop recycling onsite through purchase and use of a 55-gal still. Investment costs for onsite distillation are assumed to all occur in the first year. A 10-yr economic life and midyear discounting rate of 10 percent is assumed for all the options. The model's default values retained for this analysis include: site preparation and installation - 15 percent of total equipment costs; logistics and procurement - 7 percent of installed equipment costs; contingencies - 10 percent of installed equipment costs; labor rate (manager) - \$16.00 per hour; labor rate (laborer) - \$11.00 per hour; adjustments for leave - 18 percent of total man-hours; adjustments for fringe benefits - 36.2 percent of adjusted base labor cost; number of work days in a year - 247; average maintenance - 5 percent of equipment costs; transportation of hazardous waste - \$0.04 per pound; and annual logistics and procurement - 1.6 percent of other Operations and Maintenance (O&M) costs.

Some of the other major assumptions applied in the calculations are listed below.

- An annual escalation rate of 4 percent was applied to raw materials and replacement materials, maintenance and repair, other materials and supplies, utilities, and liability;
- Escalation rates of 8 and 6 percent were used for disposal and contractual costs, respectively;
- The liability costs were assumed as follows: onsite distillation and reuse, \$0.03/gal; offsite disposal/sale, \$0.03/gal; and contract recycling, \$0.01/gal.
- Twenty percent of the solvents are assumed to evaporate because of open lids and other poor operating practices.
- The volume of the still bottoms is assumed to be 10 percent of the original volume.
- Fresh solvent is expected to be 30 percent of the original volume.

- Repair and maintenance costs are calculated as 5.75 percent of the original cost of the equipment (in dollars per year) and are based on 2080 hours of operation. If the equipment is used less, the costs are adjusted.
- Laboratory analysis costs are assumed to be a minimum of \$50.00.
- Transportation and warehousing costs are based on the volume of wastes generated.
- Cost of cooling water is \$0.70/1000 gal.
- Cost of electricity is \$0.05/kWh.
- The used cleaning solvent (assumed nonhazardous) disposal cost is \$1.65/gal.
- The still bottom (assumed hazardous) disposal cost is \$5.30/gal.
- Cost of new solvent (NSN 6850-00-285-8011) is \$1.60/gal.
- A vacuum attachment is used if the boiling point of the solvent is above 325 or 350 °F.
- Labor cost for loading and unloading the still will be less than 2 hours (default value in the model). According to manufacturers, loading and unloading a 55-gal still varies from 1/4 to 1/2 hours per batch.
- Utility costs are often provided by still manufacturers based on their estimates of machine performance. Typical utility costs range from \$0.06 to \$0.12/gal of solvent distilled.
- The still prices on the GSA schedule (by Finish Engineering, Table 39) were used in the analysis. Shipping costs for equipment are not included in the price.
- Seventy percent of the initial cost of raw materials is included in the investment cost. The remaining 30 percent is included in the annual O&M costs.
- The same amount of waste generated is assumed for owned equipment and disposal and contract recycling.

Figure 6 depicts the comparison of the NPVs of life cycle (10-yr) costs for the four management options listed above over waste generation rates ranging from 50 to 10,000 gal/yr.

Safety Kleen Corporation is a private vendor of cleaning and degreasing solvents (on GSA schedule through June 1990) that provides closed-loop recycling services to many DOD facilities nationwide. Safety Kleen offers two types of nonhalogenated degreasing solvents, equivalent to PD680-I and PD680-II, and provides the customer with the option of leasing parts-washing equipment (LE) or using customer owned (OE). In both cases spent solvent is changed by Safety Kleen on a periodic basis, determined by the customer, and replaced with fresh, recycled solvent of the same type. Waste

containerization, transportation, the disposal of degreaser tank bottoms, and manifest responsibilities are all assumed by Safety Kleen.

There are no investment costs associated with options 1, 2, and 3 under the assumption that necessary parts-washing equipment is already in place, either leased from Safety Kleen or existing property of the installation's units. The investment cost for option 4 includes the price of a new 55-gal distillation unit, site preparation and installation, and the purchase of a startup volume of fresh solvent. Table 53 summarizes the total (10-yr) life cycle costs of each management option at three different waste generation rates (1538, 5940, and 7478 gal/yr), representative of the different methods for managing degreasing solvent on Fort Sam Houston. The total waste solvent generation rate is estimated at 7478 gal/yr - 5940 gal/yr from facilities currently on contract with Safety Kleen and 1538 gal/yr from facilities that purchase their own solvent for use in their own equipment and dispose generated wastes offsite through DRMO.

At the total rate of waste generation, onsite distillation is the most economical management option, requiring an NPV investment of \$50,598. When compared to the current management practice, onsite distillation provides an NPV savings of \$60,377 over the projected 10-yr economic life of the equipment. The resultant SIR is 1.31 with a DPP of approximately 9.4 years (Table 54).

At 5940 gal/yr, an NPV investment of \$45,331 for a 55-gal still and startup solvent provides a NPV savings of \$48,561 over the current arrangement with Safety Kleen. The computed SIR and DPP for purchase of a 55-gal still and implementation of an onsite recycling program at this generation rate are 1.17 and approximately 10 years, respectively. Purchase and use of a 55-gal still is the least cost management option only beyond waste generation rates of 5000 gal/yr.

At a generation rate of 1538 gal/yr, the NPV of the current O&M cost of offsite disposal is \$37,142 (or \$3714 per year). A comparison between the estimated costs of the current practice of regularly purchasing fresh solvent and disposing generated wastes offsite and the option of using the services of Safety Kleen with leased equipment is also provided in Table 54. At a generation rate of 1538 gal/yr, switching to Safety Kleen could provide an NPV savings of \$3509 (or \$351 per year) over the current practice. Since no investment costs would be associated with this change in waste management, neither SIR nor DPP values could be derived. At waste solvent generation rates between 750 and 5000 gal/yr, using the services of Safety Kleen with leased equipment represents the least cost management option.

Onsite distillation at the total generation rate may be an economical option. However, the resultant savings are not very high to offset the investment costs. From a waste minimization perspective, contract offsite recycling (with leased equipment) is an effective option and is therefore recommended. Leasing additional equipment and extending the Safety Kleen contract to include the remaining generators should result in additional annual savings of \$351 per year.

Battery Acid

Approximately 180 lead-acid vehicle batteries are used and disposed from Fort Sam Houston each year. The electrolyte from unsealed batteries is drained into plastic drums and turned over to DRMO for disposal as hazardous waste. The drained casings and uncracked, sealed batteries with their acid are also turned in to DRMO for lead recovery. In this section the assumptions and results of an economic analysis that examines the costs and benefits of four management options for spent lead-acid batteries and battery electrolyte are presented. The options are: (1) drain and dispose of acid and turn the empty casings in to DRMO (status quo); (2) turning batteries in to DRMO with their

contained acid for lead recovery, assuming no batteries are cracked (Recycle Wet 100 percent); (3) turning batteries in to DRMO with their contained acid for lead recovery, assuming 25 percent of the batteries are cracked and require draining and neutralization of their acid onsite (Recycle Wet/Neutralization); and (4) complete draining and neutralization of all batteries and their acid onsite and turning the empty casings in to DRMO dry.

Investment costs for neutralization in options 3 and 4 are assumed to all occur in the first year. A 10-yr economic life and midyear discounting rate of 10 percent is assumed for all the options. The model's default values retained for this analysis include: site preparation and installation - 15 percent of total equipment costs; logistics and procurement - 7 percent of installed equipment costs; contingencies - 10 percent of installed equipment costs; labor rate (manager) - \$16.00 per hour; labor rate (laborer) - \$11.00 per hour; adjustments for leave - 18 percent of total man hours; adjustments for fringe benefits - 36.2 percent of adjusted base labor cost; number of work days in a year - 247; average maintenance - 5 percent of equipment costs; transportation of hazardous waste - \$0.04 per pound; and annual logistics and procurement - 1.6 percent of other O&M costs.

Some of the other assumptions used in the calculations are:

- The weight of a typical battery without electrolyte is 60 lb; the amount of electrolyte per battery is 1.5 gal (at 9.99 lb/gal).
- The sale price of casings through DRMO is \$0.021/lb.
- The cost of disposing of drummed electrolyte is \$3.55/gal.
- The cost escalation factors are: disposal - 8 percent; liability - 4 percent; and raw materials - 4 percent.
- Transportation and storage cost is \$0.08/lb (for lead-acid, mercury, nickel-cadmium batteries); \$0.001/lb for alkaline batteries.
- The liability costs are: disposal - \$0.013 and transport - \$0.002/lb of casings and draining - \$0.001, disposal - \$0.013, transport - \$0.002, and precipitation - \$0.001/lb of electrolyte.
- The cost of lime is \$0.02/lb of electrolyte.
- The quantity of gypsum sludge produced is 0.05/lb of electrolyte; disposal cost (including labor) is \$0.05/lb of sludge.
- Wastewater treatment cost is \$3.10/1000 gal.
- Labor hours to bring batteries to DRMO is 1 hr/40 units and labor hours to bring drummed electrolyte to DRMO is 0.5 hr/drum.
- Battery salvage value is \$0.021/lb.
- Labor hours for draining and drumming of electrolyte is 0.06 hr/lb; labor hours for neutralization is 0.01 hr/lb; and investment cost of neutralization equipment is \$20,510.

- Labor hours for manager (for bid preparation, etc.) is 1 hr/500 batteries.
- Batteries are sold to the recycler at \$0.03/lb.
- There are no site preparation costs.
- Materials and testing costs are \$0.05/gal.

Figure 7 shows a comparison of the total life cycle (10-yr) costs of options 1 through 4. Option 1 is the status quo and is always more expensive than options 2 and 3. It is more expensive than option 4 beyond 300 gal/yr. Wet recycling (option 2) results in net earnings rather than costs and is therefore the best option. Assuming that 25 percent (extreme limit) of the batteries are cracked, disposal of spent electrolyte from them and the wet recycle of uncracked batteries (option 3) is less expensive than draining and neutralization (option 4) until a generation rate of 2100 gal/yr. The actual number of cracked batteries may be much smaller than the assumed 25 percent and will lower the slope of the line corresponding to option 3.

Fort Sam Houston generates 950 gal/yr of spent electrolyte. At this rate, completely switching to wet recycling will result in NPV savings of \$97,311 (or \$9731/yr) and additional revenue of \$1210 in 10 years (or \$121/yr). Assuming that 25 percent of the batteries are cracked, wet recycling of uncracked batteries and disposal of acid would result in a net savings of \$73,866 (or \$7387 per year). Neutralization of the acid will require an investment of \$22,888 and an NPV savings in O&M costs of \$83,454. A SIR of 3.35 and a DPP of 3.5 years is expected.

Neutralization of acid is classified as a treatment activity under RCRA. Fort Sam Houston may have to obtain a Part B permit to implement it. Additionally, recycled lead-acid batteries are exempt from RCRA reporting requirements. From legal, waste minimization, and economics perspectives, wet recycling is the best minimization option for these batteries and is strongly recommended.

Antifreeze Solution

MPVMs are the primary generators of waste antifreeze solution. Since the antifreeze solution is not considered a hazardous waste, it is diluted with water and drained into a sewer at most Army installations. At Fort Sam Houston most of the antifreeze solution is collected and disposed of through DRMO. Recycling of this waste solution is possible as discussed in Chapter 5. It was considered as a minimization alternative and the results of the economic analysis are presented in this section.

Management options considered in this analysis are: (1) offsite disposal through DRMO (status quo); and (2) purchase of a Glyclean antifreeze reconditioning system and implementation of an onsite recycling program. Investment costs for the purchase of new equipment and startup materials in option 2 are assumed to all occur in the first year. A 10-yr economic life and midyear discounting rate of 10 percent is assumed for both options. The model's default values retained for this analysis include: site preparation and installation - 15 percent of total equipment costs; logistics and procurement - 7 percent of installed equipment costs; contingencies - 10 percent of installed equipment costs; labor rate (manager) - \$16.00 per hour; labor rate (laborer) - \$11.00 per hour; adjustments for leave - 18 percent of total man-hours; adjustments for fringe benefits - 36.2 percent of adjusted base

labor cost; number of work days in a year - 247; average maintenance - 5 percent of equipment costs; transportation of hazardous waste - \$0.04 per pound; and annual logistics and procurement - 1.6 percent of other O&M costs.

Some of the assumptions made in the economic analysis are:

- Disposal cost of antifreeze is \$1.22/gal.
- Labor hours for the manager (bids, etc.) is 1 hr/1000 gal; for laborers (drumming and transport) it is 1 hr/1000 gal.
- The cost of a Glyclean recycling system is \$2368; a 55-gal drum of Glyclean additives is \$1465; and 0.05 gal are needed per 1000 gal of antifreeze.
- The time required to recycle 100 gal of used antifreeze is 0.5 hr.
- New antifreeze costs \$8.45/gal (on GSA schedule).
- Recycled antifreeze is equivalent to a 50 percent mixture.
- A 50 percent dilution with water is used for the first year of purchase; no dilution is required in subsequent years.
- Liability cost for both disposal and reuse is \$0.01/gal.
- Escalation is 8 percent for disposal and 4 percent for others.
- Labor hours for onsite transport is 1 hr plus \$5.00 for every 100 gal.

Figure 8 compares the total life cycle (10-yr) costs of offsite disposal to onsite recycling with a Glyclean recycling system. Recycling antifreeze solution results in a considerable amount of savings at any generation rate greater than 100 gal/yr.

Fort Sam Houston generates approximately 1450 gal/yr of spent antifreeze solution. The NPV of the current practice of offsite disposal is \$64,388 (or \$6439 per year). The purchase and installation of a Glyclean reconditioning system and chemical additives requires a NPV investment of \$8882. The resultant NPV savings from switching to an onsite recycling and reuse program would be approximately \$3393 (or \$339 per year). The SIR and DPP computed for the conversion are 5.87 and approximately 2.58 years, respectively. Converting from the current disposal method to onsite recycling is strongly recommended.

Paint Thinner Waste

Paint thinner waste is generated from the cleaning of brushes, rollers, and pressurized spray equipment used to apply a variety of surface coatings to vehicles, aircraft, buildings, furniture, and other structures or equipment. Total thinner waste generation on Fort Sam Houston is estimated at 344 gal/yr. Of this volume, approximately 282 gal/yr are turned in to DRMO for offsite disposal as

hazardous waste from facilities that purchase their own thinner for use in their own cleaning equipment. The remaining 162 gal/yr is managed on contract with Safety Kleen, where the cleaning equipment is leased and the thinner recycled on a monthly basis. Management options chosen for economic comparison are: (1) onsite distillation through the purchase and use of a 5-gal batch still; (2) offsite disposal through DRMO; and (3) offsite, closed-loop recycling through Safety Kleen.

Investment costs for the purchase of new distillation equipment and startup materials in option 1 are assumed to all occur in the first year. A 10-yr economic life and midyear discounting rate of 10 percent is assumed for all three options. The model's default values retained for this analysis include: site preparation and installation - 15 percent of total equipment costs; logistics and procurement - 7 percent of installed equipment costs; contingencies - 10 percent of installed equipment costs; labor rate (manager) - \$16.00 per hour; labor rate (laborer) - \$11.00 per hour; adjustments for leave - 18 percent of total man hours; adjustments for fringe benefits - 36.2 percent of adjusted base labor cost; number of work days in a year - 247; average maintenance - 5 percent of equipment costs; transportation of hazardous waste - \$0.04 per pound; and annual logistics and procurement - 1.6 percent of other O&M costs.

Some of the other assumptions made in this economic analysis are given below.

- An annual escalation rate of 4 percent was applied to raw materials and replacement materials, maintenance and repair, other materials and supplies, and utilities.
- An escalation rate of 8 percent was assumed for offsite disposal costs, and 6 percent for contract recycling costs.
- Liability costs were assumed as follows: onsite distillation and reuse, \$0.03/gal; offsite disposal, \$0.08/gal; and contract recycle, \$0.01/gal.
- In the recycling process, it is assumed that 20 percent of the material is replaced with new material in each cycle. Ten percent of the material evaporates and 10 percent is disposed of with residue. Residue and thinner make up 20 percent of the original volume for disposal purposes.
- Annual repair and maintenance cost is 5.75 percent of the original cost of the equipment and is based on 2080 hours of use per year. If the equipment is used less, the costs are adjusted.
- Laboratory analytical costs are estimated as a percentage of labor costs. However, the minimum laboratory cost per sample may be substantially higher than the computed value for wastes generated in small volumes. A minimum of \$50.00 is assumed.
- Transportation and warehousing costs depend on the volume of waste handled.
- Costs of cooling water and electricity are assumed to be \$0.70/1000 gal and \$0.05/kWh, respectively.
- The disposal cost of thinner waste is \$1.00/gal (1989 price by DRMO).
- Purchase cost of new paint thinner is \$4.16/gal (GSA Schedule).

- Distillation stills are available with and without vacuum attachments. If the boiling point of the solvent is below 300 or 350 °F, a still without vacuum attachment is considered. For recovery of solvents with boiling points between 300 and 500 °F, a vacuum attachment is necessary. Most of the dope lacquer thinners (NSN 8010-00-160-5787) have a boiling point less than 300 °F.
- The GSA price for a 5-gal container of paint thinner is \$3.65/gal. If available in a 55-gal drum, the price could be even lower. For this analysis, a price of \$3.65/gal is assumed.
- The operation of small volume, batch-type distillation equipment, which includes loading, unloading, and proper containerization and temporary storage of hazardous still bottoms, is assumed to become the responsibility of personnel already assigned to the work area where the equipment will be installed. Based on the information provided by different still manufacturers, a direct labor charge of approximately 0.5 hr/5-gal batch of recycled thinner was computed for onsite distillation and included as a recurring O&M cost.
- Utility costs (electricity and water) for still operation can be determined from the power input to the still and the rate of cooling water used. The cost of power per gallon of solvent distilled is estimated at \$0.06 to \$0.12.
- Eighty percent of the cost of initial purchase of raw materials is included with the initial cost of equipment. The remaining 20 percent was included as an annual operations and maintenance cost.
- Cost of leasing equipment and supply/recycle of thinner obtained from Safety Kleen is \$75/batch. The volume of each batch is 7.5 gal. Liability costs associated with the contract, transportation, and ultimate disposal in this arrangement is assumed to be \$0.01/gal.

Net present values of total 10-year costs were calculated for each option for a number of annual generation rates ranging from 10 gal/yr to 500 gal/yr. Figure 9 shows the comparison between the NPVs for all the options.

There are no investment costs associated with options 2 and 3. Manufacturers of distillation equipment, such as Finish Engineering, Recyclene, and Progressive Recovery, Inc., were contacted for price quotes on small volume stills suitable for the recycling of paint thinner. Prices among the different manufacturers for similar size equipment are competitive with each other and listed in Table 51. The price of a 5-gal still from Finish Engineering is chosen for this analysis because of their current listing on GSA contract. The purchase of a 5-gal still and implementation of an onsite recycling program (option 1) is the least cost management option beyond waste generation rates of 200 gal/yr and less expensive than contract recycling (option 3) over the entire generation range examined in this analysis. Between generation rates of 10 gal/yr and 200 gal/yr, offsite disposal through DRMO (option 2) becomes the least cost management option.

The total life cycle costs for each management option at different generation rates are provided in Table 55. Table 56 shows a comparison of SIRs and DPPs computed for the three management options at different generation rates. The NPV of the O&M cost for maintaining a recycling contract with Safety Kleen is \$5722 (or \$572 per year). Even at this low generation rate, the purchase and operation of a 5-gal still is cost effective, providing a payback in 9.74 years. At a generation rate of

282 gal/yr, the NPV of the O&M cost for offsite disposal is \$12,157 (or \$1216 per year). The purchase and operation of a 5-gal still provides a payback in 8.37 years.

The existing management practices for paint thinner waste on Fort Sam Houston should both be discontinued and replaced by the purchase of a 5-gal still and implementation of an onsite recycling program. In doing so, a reduction in annual O&M costs, from savings in both the purchase of new thinner and in waste disposal, should result. Additional incentives include minimization of a hazardous waste stream and reduced liability. The investment cost that includes purchase of fresh thinner and a 5-gal still is expected to be \$4145. The NPV of the total life cycle O&M costs of this option is estimated to be \$8427 (or \$843 per year). Compared to offsite disposal, onsite distillation provides a SIR and DPP of 1.58 and 7.96 years, respectively.

Aqueous Paint Sludge Waste

Fort Sam Houston operates two paint booths that use water-wall type air pollution control (APC) systems to remove paint overspray from exhausted booth ventilation air. One booth is medium-sized and used by the DOL - Allied Trades Section, Building 2510. The second paint booth is smaller and located at DEH - Building and Grounds Division - Sign Shop, Building 4197. An economic analysis is presented in this section to compare the costs and benefits of converting the APC systems at both of these facilities to use dry filtration media. Such a conversion could completely eliminate the generation of noxious wastewater and gelatinous paint sludge currently discharged to the wastewater treatment plant.

Investment costs required for implementing the dry APC systems for both booths are assumed to all occur in the first year. A 10-yr economic life and midyear discounting rate of 10 percent is assumed for both options. The model's default values retained for this analysis include: site preparation and installation - 15 percent of total equipment costs; logistics and procurement - 7 percent of installed equipment costs; contingencies - 10 percent of installed equipment costs; labor rate (manager) - \$16.00 per hour; labor rate (laborer) - \$11.00 per hour; adjustments for leave - 18 percent of total man hours; adjustments for fringe benefits - 36.2 percent of adjusted base labor cost; number of work days in a year - 247; average maintenance - 5 percent of equipment costs; transportation of hazardous waste - \$0.04 per pound; and annual logistics and procurement - 1.6 percent of other (O&M) costs.

Some of the other major assumptions made in the economic analysis of the small paint booth conversion are:

- The booth is 6 ft wide, 9 ft deep, and 9 ft high.
- Solids content of the paints used is 40 percent.
- Transfer efficiency is 35 percent.
- Sump capacity is 280 gal, and water from the sump is drained and filtered at 4-week intervals.
- Eighty percent of the solids deposited in the sump is collected as sludge which contains 25 percent solids and 75 percent liquid (mostly water).

- Sludge is drummed and shipped as a hazardous waste.
- The liquid is discharged to a wastewater treatment plant.
- Capacity of the airduct fan is 3 hp.
- The water curtain is 6 ft high and 6 ft wide.
- Capacity of the water pump is 5 hp.
- Frequency of use is 1/2 a shift per day in a 5-day week.
- Five gal of paint are used per day.
- Volume of replacement water to the sump is 3500 gal, and the volume of wastewater is also 3500 gal.
- The volume of sludge generated is 26 gal in 4 weeks: (solids deposited in sump per day = 0.4 gal; recovery at 80 percent in 4 weeks = $8 \times 0.8 = 6.4$ gal; volume of sludge [containing 25 percent solids] = $6.4 \times 4 = 26$ gal in 4 weeks).
- A fiberglass cartridge filter system is used; the cost to install the cartridge is \$280/linear ft.
- The filter capacity is 0.02 gal of paint/sq ft; the filter replacement cost is \$0.20/sq ft.
- The linear flow rate after conversion is 125 ft/min (volume flow rate = cross-sectional area of booth $\times$ 125 = $6 \times 9 \times 125 = 6750$ sq ft).
- The clean flow rate through the fiberglass filter is 150 sq ft.
- The area of the cartridge is 45 sq ft ($6750/150 = 45$).
- To ensure a sufficiently low pressure drop, a surface area of 50 sq ft is considered. Therefore, the cost of the 5 ft $\times$ 10 ft filter face = $5 \text{ ft} \times \$280/\text{ft} = \$1400$.
- The quantity of solids to be collected on the filter is 1 gal.
- The overspray rate is 0.39 gal of solids per day.
- Filters are replaced twice per week.
- The fan in the duct may be downsized from 3 to 2 hp (considered an even exchange; no additional investment).
- Filter replacement labor time is 1 hr/week.

- Labor hours for sump draining, cleaning, and drumming is 52 hr/yr.
- The cost of electricity is \$0.05/kWh.
- The cost of sludge disposal is \$300/55-gal drum (number of drums of sludge per year = $(52 \times 26) / [4 \times 55] = 6$; disposal cost = \$1800 per year) and the cost of each drum is \$20.
- The cost of water is \$3.00/1000 gal.
- Electricity used by the wet booths is 6214 kWh/yr.
- Escalation rates for disposal - 8 percent; and others - 4 percent.
- Filter replacement costs are \$1040/yr.
- The disposal cost of dry filters is negligible.
- Electricity used by the dry booth is 1552 kWh/yr.

Some of the assumptions made in the economic analysis of the medium-size (cross-draft) paint booth conversion are:

- The booth is 17 ft wide, 35 ft deep, and 15 ft high. The water curtain is 10 ft high and occupies the entire width of the back wall of the booth.
- The sump capacity is 750 gal.
- Solids content of the paints used is 40 percent (3.2 gal/day).
- The transfer efficiency is 45 percent.
- Water from the sump is drained and filtered every 6 weeks.
- Eighty percent of the solids captured and deposited in the sump are collected as sludge which contains 30 percent solids and 70 percent liquid (mostly water).
- The sludge is drummed and shipped as a hazardous waste.
- Liquid is discharged to a wastewater treatment plant.
- Two airduct fans (3 hp) are used.
- Two water pumps (5 hp) are used.
- Frequency of use is 1 shift per day in a 5-day week.

- Volume of replacement water to the sump is 6000 gal and the volume of wastewater generated is 6000 gal.
- Eight gallons of paint are used per day.
- Paint solids lost to the water is 55 percent ($0.55 \times 3.2 = 1.8$ gal/day).
- The volume of sludge generated is 144 gal in 6 weeks: (solids deposited in sump per day = 1.8 gal; recovery at 80 percent in 6 weeks = $1.8 \times 6 \times 0.8 = 8.64$ gal; volume of sludge [containing 30 percent solids] = $8.64 \times 5 / 0.3 = 144$ gal in 6 weeks).
- The cost of flocculating agents added to the sump is \$15/week.
- A manually-deployed honeycombed paper filter system is used for the dry booth. The cost to install the filters is \$250/linear ft. The filter capacity is 0.1 gal paint/sq ft. Filter replacement cost is \$0.30/sq ft.
- The linear flow rate after conversion is 125 ft/min.
- The cross-sectional area of the booth is 255 sq ft.
- The volumetric flow rate through the booth is 31,875 cu ft/min.
- The clean flow rate through the fiberglass filter is 200 sq ft/min.
- The area of the filter surface required is 160 sq ft ($31,875/200 = 160$).
- Dimensions of the filter face are 10 ft high and 16 ft wide. The cost of installation is \$4000.
- The quantity of solids to be collected on the filter before replacement is 16 gal.
- The overspray rate is 1.8 gal of solids per day.
- The fan in the duct may be downsized to 5 hp (considered an even exchange - no additional investment).
- Filter replacement labor time is 2 hr/month.
- Labor hours for sump draining, cleaning, and drumming is 52 hr/yr.
- The cost of electricity is \$0.05 per kWh.
- The cost of sludge disposal is \$300/55-gal drum, (number of drums of sludge per year = $[52 \times 144] / [6 \times 55] = 22.7$; disposal cost = \$6810 per year) and the cost of each drum is \$20.
- The cost of water is \$0.70/1000 gal and the cost of wastewater treatment is \$3.00/1000 gal.

- The cost of other materials and supplies (drums and chemicals) is \$1240.
- Electricity used by wet booths per day is 38,800 kWh/yr.
- Escalation rates are 8 percent for disposal and 4 percent for others.
- Filter replacement costs are \$1664/yr.
- Disposal cost of dry filters is negligible.
- Electricity used by the dry booth is 15,517 kWh/yr.

Table 58 lists the life-cycle (10-yr) costs of small and medium-sized wet and dry booths. The table also provides results of the detailed comparison of the SIR and DPP for each case.

Converting the APC system at the small paint booth used at DEH results in a NPV savings of \$11,629 (or \$1163 per year). Investing \$1562 to retrofit the existing water-wall at this facility to use dry filtration devices provides a SIR of 7.44 and DPP of approximately 2.45 years. Conversion of the medium-sized booth at the DOL - Allied Trades Section requires an investment of \$4290 and would result in an estimated NPV savings of \$69,661 (or \$6966 per year) compared to the operating costs of the existing APC system. The SIR and DPP for converting the medium-sized booth are 16.24 and approximately 1.58 years, respectively. Converting the water wall APC systems at both DEH and the DOL to use dry filtration type systems is recommended.

Table 50
Savings to Investment Ratios and Discounted Payback
Periods for a Fast Lubricating Oil Change System

Number of Vehicles	SIR	DPP
100	0.38	> 10
250	0.39	> 10
500	0.39	> 10
1000	0.39	> 10
5000	0.39	> 10

Table 51
Savings to Investment Ratios and Discounted Payback
Periods for a Fast Lubricating Oil Change System
for 1000 Vehicles

Number of Oil Changes	SIR	DPP
2	0.39	> 10
4	0.79	> 10
5	0.98	> 10
6	1.17	9.99

Table 52
Purchase Cost of Distillation Stills (in 1989 dollars)

Manufacturer	Model	Capacity (gal)	Price (\$)	
			no vacuum attachment	vacuum attachment
Finish Engineering	LS-Jr	5	2770	4338
	LS-15IID	15	10,128	13,361
	LS-55IID	55	20,123	24,609
Recyclene	R-2	5	2995	
	RS-20	20-25	11,900	
Progressive Recovery, Inc.	SC-25	15	7290	12,865
	SC-50	35	11,300	16,895

Table 53

**Total Life Cycle Costs of Cleaning Solvent
Waste Options at Varied Generation Rates**

Generation Rate gal/yr	Onsite Distillation			Cont. Recyc. (LE) O&M \$	Disposal O&M \$	Cont. Recyc. (OE) O&M \$
	Inv. \$	O&M \$	Total \$			
5940	45,331	70,536	115,867	123,711	143,448	136,919
1538	34,873	18,785	53,658	33,632	37,142	37,180
7478	50,598	89,018	139,616	155,184	180,582	174,099

Table 54

**Comparison of Options for Cleaning Solvent
Waste at Various Generation Rates**

Generation Rate gal/yr	Options Compared	NPV Sav. \$	NPV Inv. \$	SIR	DPP years
5940	Onsite dist. vs. cont. recyc. (LE)	48,561	45,331	1.17	> 10
1538	Cont. recyc. (LE) vs. offsite disp.	3509	-	-	-
7478	Onsite dist. vs. cont. recyc. (LE)	60,377	50,598	1.31	9.42

Table 55

**Total Life Cycle Costs of Options for Paint
Thinner Waste at Varied Generation Rates**

Generation Rate gal/yr	Onsite Distillation			Contract Recycling O&M \$	Disposal O&M \$
	Inv. \$	O&M \$	Total \$		
62	3359	1638	5097	5722	2497
282	3972	6249	10,221	23,504	12,157
344	4145	8247	12,492	29,318	14,812

Table 56
Comparison of Options for Paint Thinner
Waste at Various Generation Rates

Generation Rate gal/yr	Options Compared	NPV Sav. \$	NPV Inv. \$	SIR	DPP years
62	Onsite dist vs. contract recycling	4084	3359	1.22	9.74
282	Onsite dist vs. offsite disposal	5908	3972	1.49	8.37
344	Onsite dist vs. offsite disposal	6565	4145	1.58	7.96

Table 57
Comparison of the Life Cycle Costs and SIR and DPP
Calculations for Small and Medium-sized Operations
of Wet and Dry Paint Booths

	Inv. (\$)	O&M (\$)	Total (\$)	SIR	DPP
<u>Small</u>					
Wet-wall booth	0	25,036	25,036		
Dry booth	1562	13,407	14,969	7.44	2.45
<u>Medium</u>					
Wet-wall booth	0	88,701	88,701		
Dry booth	4290	19,040	23,330	15.45	1.58

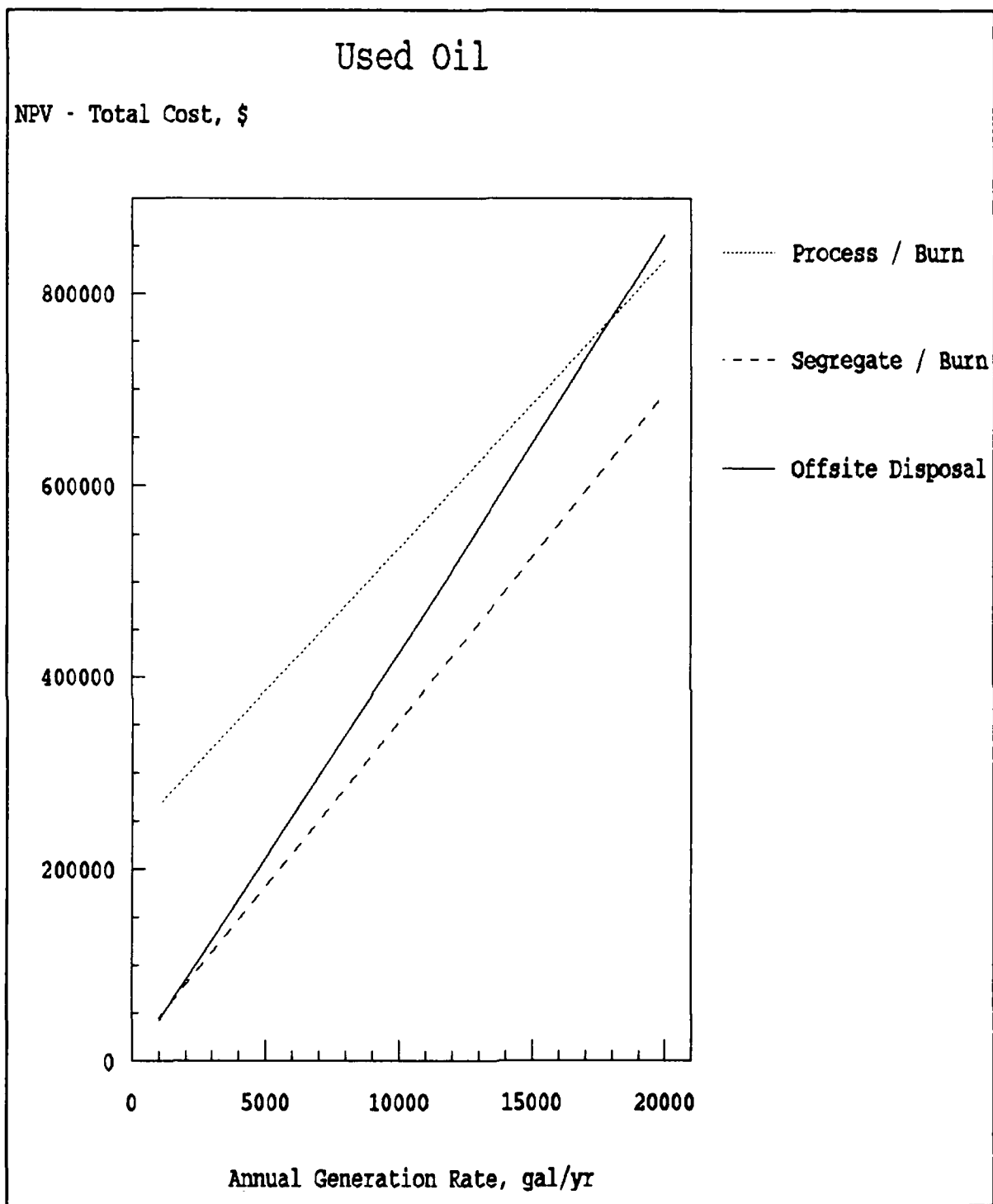


Figure 5. Comparison of the net present value for minimization of used oil wastes. (Offsite disposal defines the status quo.)

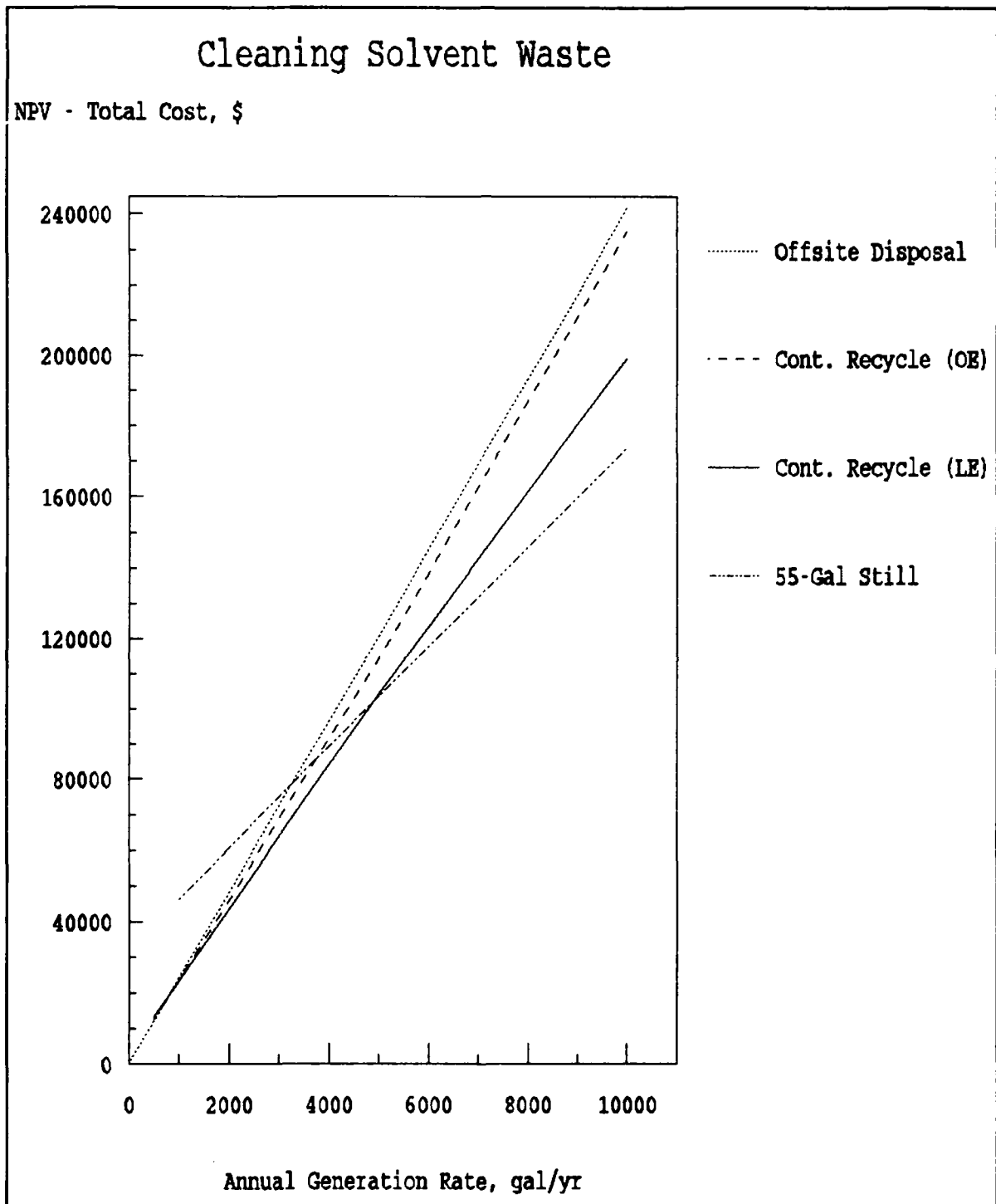


Figure 6. Comparison of the net present values for cleaning solvent waste minimization options. (Contract recycling defines the status quo.)

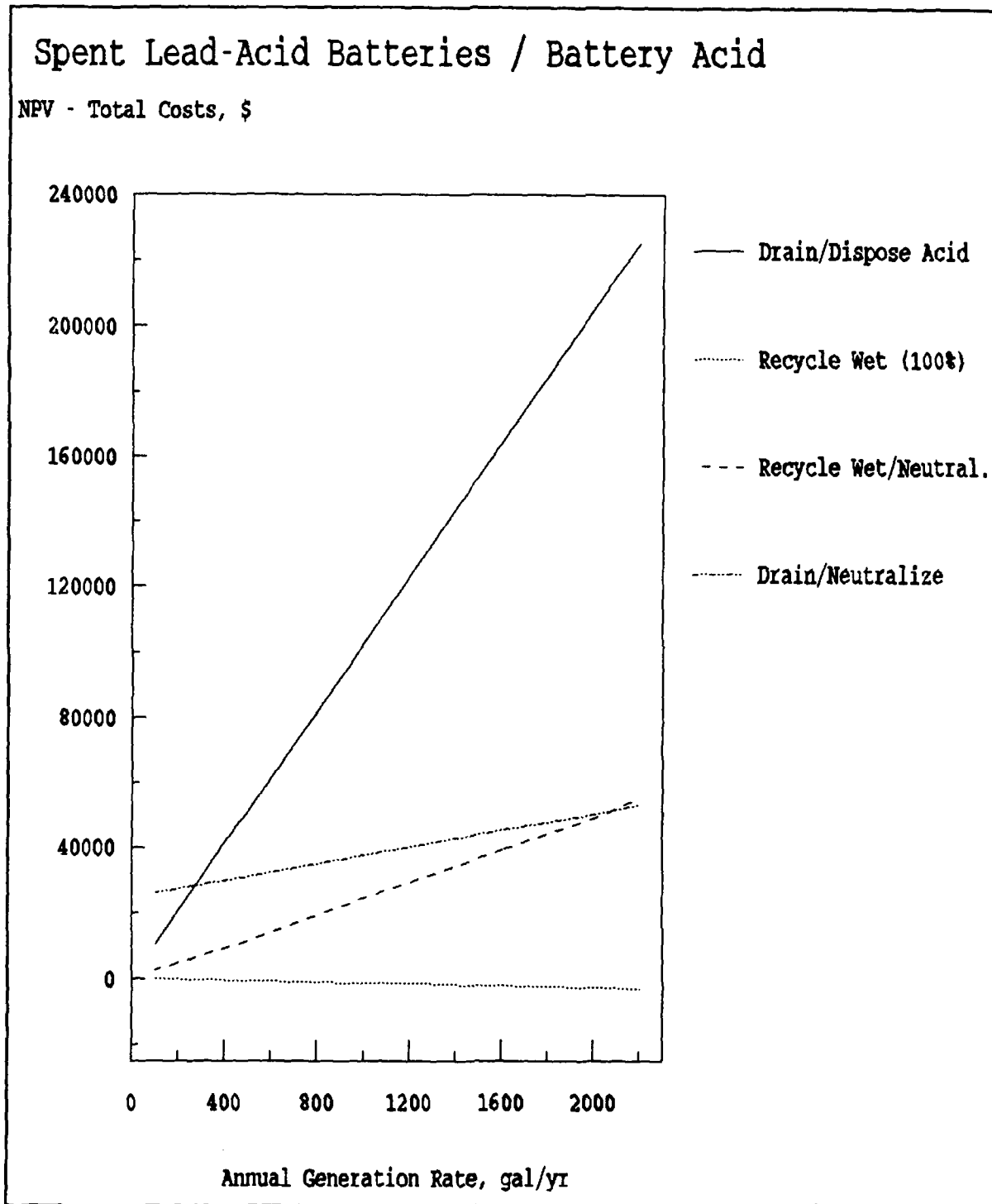


Figure 7. Comparison of the net present values of options for minimizing battery acid waste. (Draining and disposal through DRMO defines the status quo.)

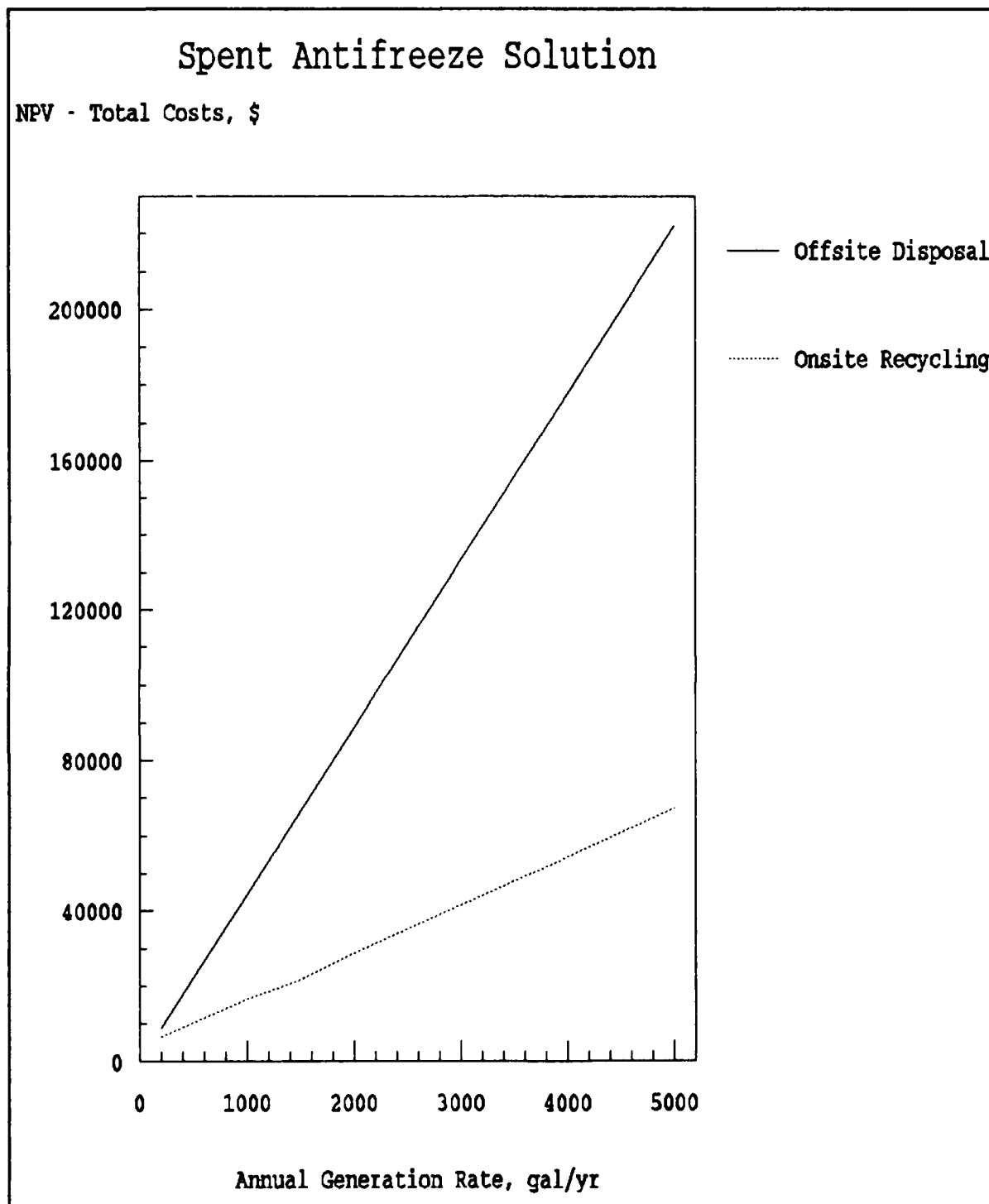


Figure 8. Comparison of the net present value of an option for minimizing waste antifreeze solution. (Offsite disposal defines the status quo.)

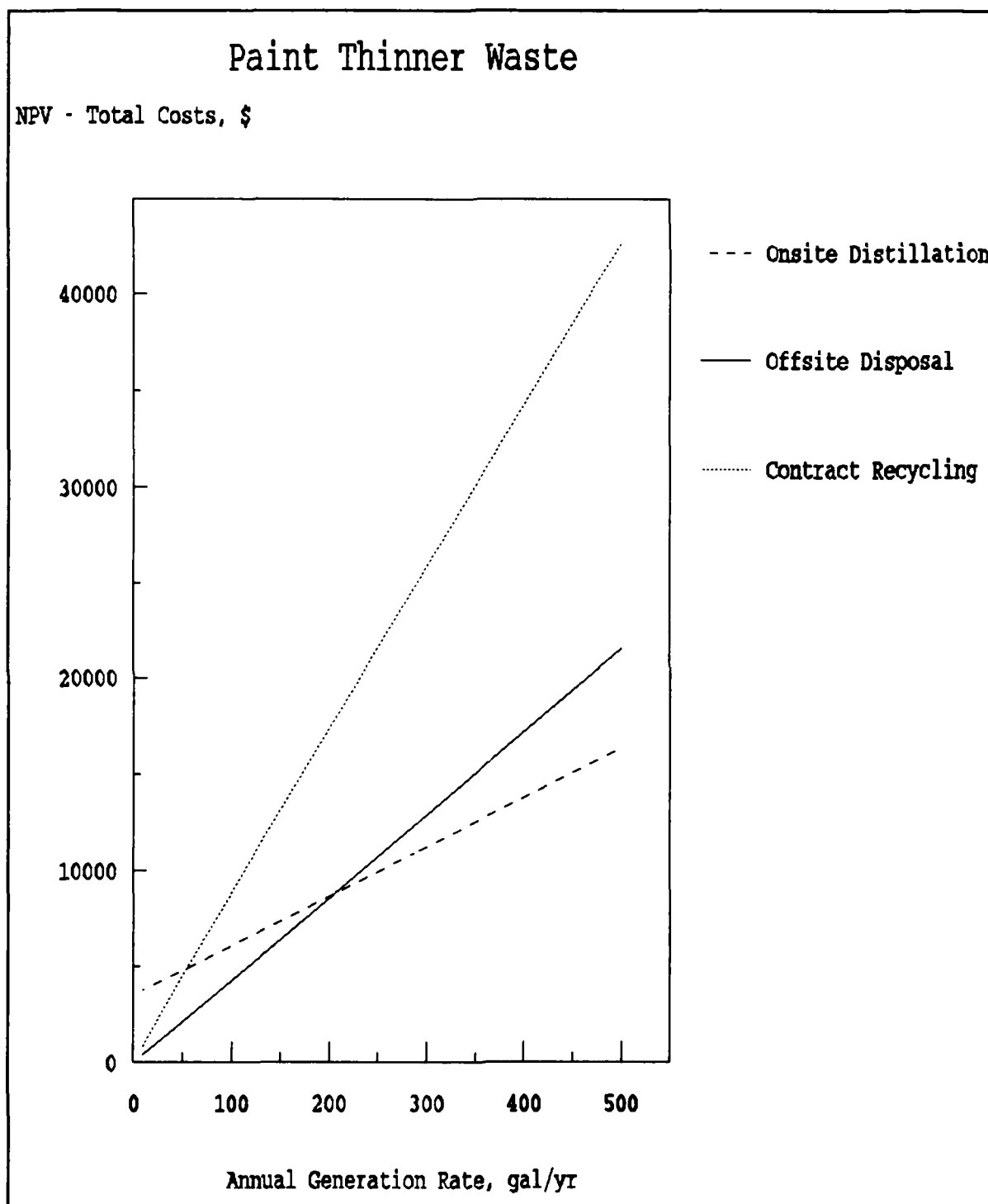


Figure 9. Comparison of the net present value of options for minimizing paint thinner waste. (Contract recycling defines the status quo.)

13 SUMMARY AND RECOMMENDATIONS

Summary

All Army installations that are generators or small quantity generators (according to RCRA definitions) are required to implement programs to reduce hazardous waste generation. Waste minimization is a method of preventing pollution with the primary focus on reducing waste generation. A number of benefits are accrued by implementing a waste minimization program. The benefits can be classified into the following four categories: economic, regulatory compliance, reduced liability, and positive public image/community relations.

Minimization of a particular waste can best be achieved by an appropriate combination of source reduction, recycling onsite/offsite, and treatment techniques. Source reduction is on the top of USEPA's hierarchy of waste management priorities. It is followed by recycling, waste separation and concentration, waste exchange, energy/material recovery, waste incineration/treatment, and, finally, ultimate disposal. A number of waste minimization techniques have been discussed in this report pertaining to wastes generated from: motor pools/vehicle maintenance facilities; aviation maintenance facilities; industrial maintenance, small arms shops; paint shops; printing, photography, arts/crafts shops; hospitals, clinics, and laboratories; and other miscellaneous sources on an Army installation.

Fort Sam Houston is a hospital/medical installation with few tenants. It is regulated by the USEPA and the State of Texas as a small quantity generator. An effective hazardous waste tracking program has been established. Thus, the installation is capable of determining when, what type, and how much waste has been turned in for interim storage before disposal through the DRMO at Kelly Air Force Base.

The installation generates very few major wastes (used oil, cleaning solvent, lead-acid batteries/battery acid, antifreeze, and paint thinner) and small quantities of other wastes. Analysis of annual waste disposal data indicates that motor pools and vehicle maintenance facilities are the largest source of wastes, followed by paint shops; photography, printing, and arts/crafts shops; hospitals, clinics, and laboratories; industrial maintenance, small arms shops; aviation maintenance facilities; electrical maintenance; and power production and heating cooling plants. This does not include the weight of the 180 vehicle and 1980 lithium batteries reported turned in for disposal. Also, this analysis does not include PCB transformer wastes.

Used oil is the largest quantity waste generated at a rate of 88,303 lb/yr. It is followed by nonhalogenated solvent wastes (53,887 lb/yr); spent antifreeze (12,975 lb/yr); corrosives (12,873 lb/yr - excluding boiler blowdown); halogenated solvents (5968 lb/yr); spent paint thinners (2403 lb/yr); contaminated fuels (2095 lb/yr); other paint wastes (1234 lb/yr); used alcohols (32 lb/yr); and miscellaneous wastes (17,089 lb/yr).

Used oil, cleaning solvent, battery acid, spent antifreeze, paint thinner, and paint sludge were considered for detailed technical and economic evaluation. The options examined include current practices (offsite disposal, burning, etc.), onsite distillation, onsite filtration/recycling, contract recycling, segregation/processing, and process equipment modification. Most of the other wastes (e.g., contaminated fuels) can be minimized by implementation of simple source reduction techniques (better operating practices), and/or elementary treatment (neutralization for acids and bases from laboratories).

Recommendations

A program to train military and civilian employees to handle hazardous material and manage hazardous wastes must be implemented to ensure compliance with 40 CFR 264.16.

A waste analysis program to characterize and define all (air, water, liquid, and solid) wastes from all the generators should be developed to ensure compliance with Federal and State of Texas laws.

Environmental Office personnel must conduct monthly inspections, minimization audits, and periodic training classes in recognition/handling/storage of hazardous materials and wastes. A comprehensive survey of waste generation and management helps develop inventories of quantities of hazardous materials used and wastes generated per month (or quarter, or year). These inventories must be updated periodically to reflect changes and disbanding of certain activities.

A HM and HW tracking (manifest) system should be implemented. Tracking HM from the supply warehouse to generators and HW from the generators to final storage before disposal, will provide a mass balance and improve minimization opportunities. This program will be an extension of the waste tracking program currently in place.

All generators must develop an inventory system and maintain proper records of materials procured and wastes generated from each of the activities. These records must be subject to regular inspections by the supervisors and EMO personnel.

All the above recommendations and many others are included in the HAZMIN plan (Appendix A). The implementation of the plan must begin immediately; the plan should be updated annually.

Plan Implementation

Careful planning and a systematic approach are required to implement a successful waste minimization program. Three key elements (policy, commitment, and responsibility) are necessary for a strong program foundation.

The Commander must prepare a formal, written policy on waste minimization and pollution control, including its philosophy, objectives, and proper practices. Such a policy must be publicized in the installation newsletters and distributed to all military and civilian employees. An example of a policy statement is provided in Appendix D.

The installation command hierarchy and the commanders of tenant activities must adopt and support the policy statement. They should also willingly commit resources necessary to launch and support the waste minimization program.

A leader (such as the Chief, EMO) should be appointed to oversee, direct, and assume all responsibility for the program. Supervisors and other employees of waste generating activities must be committed to the program for it to be effective. To encourage such a commitment, the Commanders and supervisors must implement motivational techniques. They must set goals for achieving waste/emissions reduction and provide incentives and awards for implementation of waste minimization ideas.

All waste generators must immediately implement HAZMIN options that require little or no capital investment (e.g., procedural or administrative changes) as discussed in Chapters 5 through 11.

These options are generally characterized as "better operating practices," a subcategory of source reduction that does not require detailed technical and economic evaluation. Better operating practices are methods that achieve source reduction by:¹⁵¹ (1) segregation (e.g., eliminate mixing of hazardous and nonhazardous wastes to improve their recyclability); (2) improved material handling and inventory practices (e.g., avoid accumulation of expired shelf-life materials, avoid spills, etc.); (3) preventive maintenance (e.g., prevent leaks and spills); (4) production scheduling (e.g., minimize quantities of unused raw materials and batch-generated wastes); and (5) minor operational changes. Implementation of "better operating practices" usually requires only minimal employee training and changes to standing operating procedures/practices (SOPs).

The current practice of contract recycling of cleaning solvent should be continued for the existing users. The contract should be extended (at a cost of \$3363/yr and a savings in disposal costs of \$3714) to include other users of parts cleaning solvents. The feasible options for minimization of used oil, cleaning solvent waste, spent battery acid, waste antifreeze solution, paint thinner waste, and paint sludge must be funded and implemented. Burning used oil is recommended after implementation of proper segregation practices and periodic testing and laboratory analyses. An air pollution permit for burning will also have to be obtained. Annual savings of \$14,629 can be expected.

Wet recycling of lead-acid batteries is recommended as a replacement to the current practice of draining and disposing of spent electrolyte. A savings of \$9731/yr and an additional revenue of \$121/yr can be expected. One hundred percent of the battery acid wastes can thus be eliminated.

A large quantity of waste antifreeze solution is turned in for disposal; most installations allow it to go down the drain. This initiative is commendable. Spent antifreeze, however, can be recycled as discussed in Chapter 5. An investment of \$8882 is required to purchase and install a Glyclean recycling system. With an annual savings of \$5211, compared to offsite disposal, a payback period of 2.58 years is expected.

For paint thinner waste, it is recommended that a 5-gal distillation still be purchased at a total investment cost of \$4145 and an annual operating cost of \$8247. The estimated payback period is expected to be 8 years.

To eliminate the paint sludge waste generated, and to stop the possibly illegal practice of allowing the paint booth waters to drain untreated into the sewers, it is recommended that Fort Sam Houston convert the wet-wall paint booths to dry booths. Conversion of the small paint booth requires an investment of \$1562, resulting in annual savings of \$1163 with a payback period of 2.5 years. The investment cost for the large paint booth is \$4290, with an annual savings of \$6966 and a payback period of 1.6 years.

The Fort Sam Houston Hazardous Waste Management Board, chaired by the Garrison Commander, must adopt the HAZMIN plan and establish policies and procedures required for the plan implementation. The expected implementation date is 31 September 1990.

After implementation of HAZMIN techniques at the generating activities, progress must be monitored and results recorded. The quantities of wastes generated before and after implementation of the techniques must be monitored and the achievements in waste minimization (e.g., percent minimized) documented. Waste minimization of 40 percent and "hazardous" waste minimization of 80 percent are expected.

¹⁵¹ National Association of Manufacturers, *Waste Minimization: Manufacturers' Strategies for Success* (ENSR Consulting and Engineering, 1989).

A waste minimization program never ends. Preventing waste generation and thereby reducing the pollution of air, land, and water must be a continuous quest. The goal of such a program must be to reduce wastes to the maximum extent possible. All waste generating processes must be continuously assessed and reassessed to account for changes in economic status (e.g., increase in disposal costs), changes in design of production processes, maintenance procedures, and/or technical/technological breakthroughs.

METRIC CONVERSION TABLE

1 Btu	=	0.293 W
1 gallon	=	3.785 liters
1 in.	=	25.4 mm
1 mi	=	1.6 km
1 pound	=	0.37 kilogram
1 psi	=	6.89 kPa
1 ton	=	0.9 MT
°C	=	5 (°F - 32)/9

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APPENDIX A:

FORT SAM HOUSTON HAZMIN PLAN

- 1 BACKGROUND The Hazardous and Solid Wastes Amendments (HSWA)¹ to the Resource Conservation and Recovery Act (RCRA),² passed in 1984, requires the generators of hazardous wastes to certify that they have a waste minimization program. Every waste shipment manifest is accompanied with the following declaration, in compliance with Section 3002 (b) of HSWA:

"The generator of the hazardous waste has a program in place to reduce the volume and toxicity of such waste to the degree determined by the generator to be economically practicable;....."

Therefore, all facilities that meet the RCRA definitions of Generator (> 1000 Kg/month) and Small Quantity Generator (100 to 1000 Kg/month) of hazardous waste (HW) have to implement waste minimization programs.

HSWA [Section 3002(a)] also requires the generators of hazardous wastes to submit a biennial report, including documentation on efforts to reduce the volume and toxicity of wastes generated. Facilities that treat, store, or dispose of hazardous wastes are required [by HSWA, Section 3005(h)] to submit annual reports accompanied with similar declarations on waste minimization.

In the broadest sense, hazardous waste minimization (HAZMIN) may be defined as the process of reducing the net outflow of hazardous waste effluents from a given source (or generating process). Minimization would include any source reductions in the generation of hazardous wastes as well as any recycling activities that would result in either a reduction in the total volume or quantity of hazardous wastes, or a reduction in the toxicity of hazardous wastes produced, or both, as long as it is consistent with the national goal of minimizing present and future threats to the environment.³ HAZMIN, therefore, can be achieved by:

Source Reduction - which refers to reduction or elimination of waste generation at the source, usually within a process. It also implies any action taken to reduce the amount of waste leaving a process;

Recycling Onsite/Offsite - which is the use or reuse of a waste as an effective substitute for a commercial product, or as an ingredient or feedstock in a process. Recycling also implies the reclamation of useful constituent fractions from

¹Public Law 98-616, *Hazardous and Solid Waste Amendments*, 1984.

²Public Law 94-480, *Resource Conservation and Recovery Act*, 1976.

³*Minimization of Hazardous Waste. Executive Summary and Fact Sheet*, EPA/530/SW-86/033A (EPA, Office of Solid Waste, Washington, D.C., 1986).

within a waste or removal of contaminants allowing it to be reused; and/or

Treatment - which is eliminating hazardous characteristics of a waste making it nonhazardous to human health and environment.

For any particular waste, the minimization options must be evaluated in the hierarchy of source reduction first, followed by recycling (including recovery and reuse), and, finally, treatment. Some small amount of residue may always remain (e.g., ash) which will require "ultimate" disposal (e.g., landfill burial). Although attempts have been made to clearly define the three HAZMIN categories, there may be overlap for certain specific techniques. Maximum waste reduction is usually achieved by using the best combination of suitable techniques from all three categories.

Recognizing the liabilities of improper disposal and the advantages of waste minimization, the Joint Logistics Commanders set a DOD wide goal of 50 percent reduction in hazardous waste generation by 1992, based on the baseline generation in 1985. The Department of the Army has adopted this goal and established a policy applicable to all Active Army, Reserve, and National Guard installations.⁴

- 2 PURPOSE The purpose of the Fort Sam Houston Installation HAZMIN plan is to provide a specific plan of action to reduce the quantities and toxicities of HW generated within the installation boundaries.
- 3 SCOPE The scope of the plan extends to all the HW regulated under the RCRA, the HSWA, and the State of Texas Hazardous and Solid Waste Regulations.

4 GOALS

4.1 Department of Army (DA) HAZMIN Goals

<u>Process, Operation, or Condition</u>	<u>Percent HW Reduction Desired by 1992</u>
Cleaning/degreasing	40
Transportation vehicle maintainance	30
Fueling operations	30
Battery shop operations	50
Painting	50
Sand blasting	60

⁴Office of the Assistant Chief of Engineers, "Hazardous Waste Minimization (HAZMIN) Policy," Department of the Army, 1989, 15 pages.

Metalworking	15
Graphic Arts	40
Electrical maintenance	60
Waste treatment sludges	60

4.2 Fort Sam Houston HAZMIN Goals

Same as DA goals.

4.3 HAZMIN Reduction Estimation

Percent HW reduction for any calendar year (CY) =

$$\frac{(\text{Baseline Year HW Generation} - \text{CY HW Generation}) * 100}{\text{Baseline Year HW Generation}}$$

5 PROGRAM MANAGEMENT

- 5.1 Fort Sam Houston will manage the HAZMIN program according to AR 200-1 and AR 420-47. The installation's Hazardous Waste Management Board (HWMB) shall review and adopt this plan, and establish other policies and procedures for its implementation. The HWMB is chaired by the Garrison Commander and consists of the following members:

Garrison Commander
 Civilian Executive Assistant
 Director of Engineering and Housing
 Director of Logistics
 Chief, Environmental and Energy Management Division
 Chief, Defense Reutilization and Marketing Office
 Installation Safety Officer
 BAMC, Director of Logistics
 BAMC, Chief of Preventive Medicine (Industrial Hygiene)
 BAMC, Chief of Health Physics
 AHS, Chief of Logistics Division
 Staff Judge Advocate

- 5.2 The following activities at Fort Sam Houston are generators of hazardous waste, used oil, and miscellaneous toxic wastes:

Motor Pools/Vehicle Maintenance Facilities
 Aviation Maintenance Facilities
 Hospitals, Clinics, and Laboratories
 Paint Shops
 Photography and Printing Operations
 Industrial Maintenance, Small Arms Shops, etc.
 Other Generators

6 TRAINING

6.1 Personnel Training

A training program will be developed by the Chief of the Environmental Management Office (EMO) for personnel involved in handling hazardous materials and managing hazardous wastes to ensure compliance with 40 CFR 264.16.

6.2 Training Content, Schedules, and Techniques

Personnel from HW generating activities must be given supervised on-the-job training as well as formal courses. The formal course must be designed similar to the program offered by the U.S. Army Environmental Hygiene Agency, or the U.S. Army Logistics Management Center. Followup refresher courses must be taught by the Environmental Personnel from the DEH environmental and energy management division.

The objective of a formal (or refresher) course must be to provide each student with the abilities to:⁵

1. Recognize, identify, and classify hazardous materials,
2. Take actions necessary to prevent hazardous chemical incidents, protect personnel health, and prevent damage to the environment,
3. Properly package, label, store, handle, and transport hazardous materials and hazardous waste,
4. Take immediate action in response to hazardous materials spills or other emergencies, and
5. Properly manage the resources under his/her control to prevent violation of applicable laws, regulations, and policies.

6.3 Implementation of Training Program. The Chief of the Training Division (Directorate of Plans, Training, Mobilization, and Security) will direct a training program designed by the Chief, EMO. All new and/or reassigned personnel will not work in positions dealing with hazardous materials/wastes unless they have completed the appropriate program within 6 months of the date of employment or reassignment. All supervisors will review the training status of their personnel annually.

6.4 Records

6.4.1 The Personnel Directorate (of Fort Sam Houston and tenant activities) will maintain records pertaining to job experience and the training completion requirements. The records must include description of the type/nature of initial and continuing training each person receives.

6.4.2 Fort Sam Houston will maintain records of all current personnel until closure of the tenant activity or the entire base. Training records of past employees must be kept for at least 3 years after the date of last employment.

⁵ *Defense Hazardous Materials Handling Course (DHMHC)*, U.S. Army Logistics Management Center (ALMC), Fort Lee, Virginia.

7 HAZMIN ACTIONS

7.1 General Actions

- 7.1.1 Command Initiatives:** For the HAZMIN program to be successful, the Garrison Commander and the chain of command for all the generators, tenants, and troops should make a commitment to all the goals and establish specific goals at the generator (or activity) level.

The installation commander will develop an environmental policy statement emphasizing pollution minimization and assign direct responsibility to all personnel as protectors of the environment in their day-to-day work. All personnel will be notified (e.g., through the installation newspaper) regarding the command commitment and goals.

Personnel incentives (such as awards, commendation, etc.) must be provided to encourage new HAZMIN ideas and to reward implementation of successful HAZMIN projects.

- 7.1.2** The installation must solicit cooperation with the host community (San Antonio) for success of HAZMIN projects.
- 7.1.3** Participation is required among appropriate personnel from: Directorate of Logistics (DOL) and Tenants' Logistics Directorates - responsible for supply/procurement, transportation; Directorate of Engineering and Housing (DEH) - responsible for interim and long term storage, compliance with federal/state environmental laws, and pollution control guidance; and Defense Reutilization and Marketing Office (DRMO) - responsible for proper disposal; in implementation, programming, and budgeting HAZMIN programs.
- 7.1.4** A hazardous material (HM) and hazardous waste (HW) tracking (manifest) program will be implemented at Fort Sam Houston (including all the tenants). Tracking HM from the supply warehouse to generators, and HW from the generators to final storage before disposal, will provide a mass balance and improve minimization opportunities. This program will be an extension of the existing waste tracking program currently in place; which was developed by the EEMD.
- 7.1.5** HAZMIN programs will be incorporated into the agenda of the Environmental (and Hazardous Waste) Management Board Meetings. Proper coverage must be provided in the installation newspaper to ensure wide acceptance among personnel.
- 7.1.6** Chief, EMO, Installation Safety Officer, and Industrial Hygienist will combine their resources to develop a training program for personnel in hazardous materials/waste handling and emergency response (according to Section 6) which is required by law.
- 7.1.7** Chief, EMO, will develop a waste analysis program to characterize and define all (air, water, liquid, and solid) waste streams from all the generators to ensure compliance with Federal and State laws.
- 7.1.8** DRMO and the Chief, EMO, will examine the use of waste exchange programs as a proper recycle methodology for some of the hazardous wastes.
- 7.1.9** The EMO Hazardous Waste Program Manager will conduct monthly inspections, minimization audits, and periodic training classes in recognition/handling/storage of hazardous materials and wastes.

7.2 Generator Actions

- 7.2.1 All generators must program for disposal of hazardous wastes following the decentralization of funding beginning in Fiscal 1990.
- 7.2.2 All generators will appoint environmental (hazardous waste) managers who would be responsible for minimizing generation (of air emissions, water pollution, and solid wastes), proper interim storage, and turn in of hazardous wastes.
- 7.2.3 The environmental (or Hazardous Waste) manager should interface with the EMO Hazardous Waste Program Manager in all matters pertaining to waste management and minimization. Individuals appointed to this duty will devote more time than is customary for a typical "extra duty."
- 7.2.4 All environmental managers will maintain proper records (logbooks) of materials procured and wastes generated from each activity and report on a monthly basis to the EMO.
- 7.2.5 All generators must, with the help of EMO, completely characterize (in terms of composition, periodicity of generation, why and how generated, etc.) all the waste streams, document, and provide relevant data when requested by the EMO.
- 7.2.6 All generators will include HAZMIN requirements as specified by the EMO in their mission standing operating procedures (SOPs).

7.3 Current HAZMIN Projects

- 7.3.1 Cleaning Solvent - Recycle Onsite/Offsite - Contract Recycling. A used solvent recycling program has been designed to collect and recycle used cleaning solvent (petroleum naphtha) used in motor pools, vehicle/aviation maintenance facilities, and other parts cleaning activities. Source reduction (e.g., better operating practices, testing, etc.) must be implemented by all generators to reduce the quantities used. Use of a substitute (e.g., Citrikleen) must also be explored.

From the solvent use rate of 7480 gal/yr, it is determined that onsite distillation (using a 55-gal batch still) is more economical than the current closed-loop (Safety Kleen)⁶ contract recycling for minimizing cleaning solvent wastes.

Estimated Costs: Investment - \$50,598; Annual O&M - \$8902

Estimated Payback Period: 9.42 years

However, some of the practical aspects of disbanding current operations, purchasing new equipment, the logistics of setting up and operating a recycling center, and transportation of spent solvent to the central location and recycled solvent back to the users, etc., makes the change to onsite distillation undesirable. The current practice of Safety Kleen contract recycling used by some of the generators (producing 5940 gal/yr) should be continued and extended to include other generators (who dispose of 1538 gal/yr and currently have their own solvent cleaning tanks).

⁶Safety Kleen, Inc., is a commercial solvent recycling contractor.

Estimated Costs: Annual O&M - \$3363

Estimated Annual Savings: \$351

The existing Safety Kleen contract may have to be modified to substitute the solvent (flash point 105 °F) being delivered with a nonignitable solvent (flash point > 140 °F). The solvent waste in such a case is a nonhazardous waste and is exempt from reporting requirements.

Estimated Waste Reduction (Recycling Alone): 0 percent

Estimated Waste Reduction (Source Reduction and Recycling): 40 percent

Estimated "Hazardous" Waste Reduction: 100 percent

- 7.3.2 Xylene - Recycle Onsite/Offsite - Distillation. A small distillation still is operated at the BAMC Department of Pathology to recover xylene from waste xylene. It is also used to recycle ethyl alcohol. The still bottoms are turned in for disposal as a hazardous waste. Approximately 1331 lb/yr of xylene still bottoms are generated. This practice should be continued and other source reduction measures implemented to reduce the quantity of xylene used (e.g., use of Histoclear as a substitute).

Estimated Waste Reduction (Recycling Alone): 0 percent

Estimated Waste Reduction (Source Reduction and Recycling): 40 percent

Estimated "Hazardous" Waste Reduction: 40 percent

7.4 Future HAZMIN Projects

- 7.4.1 Used Oil - Treatment - Burning. Used oil is currently accumulated by all the generators and turned in for disposal. About 12,600 gal/yr of used oil is generated and disposed of at a cost of \$53,802/yr.

Burning of used oil in one of the installation boilers is recommended as an alternative to disposal. Proper segregation of waste oil is required at all the generators. Chlorine detection kits (e.g., CLOR-D-TECT™1000 and CLOR-D-TECT™Q4000)⁷ must be used to detect the level of chlorinated solvent contamination of oil at the generators before the oil is transported to the boiler for burning. If oil samples contain chloride, a complete laboratory analysis is required to determine the flash point and the total halogens and heavy metals (As, Cd, Cr, Pb) content. If the halogen content is less than 1000 ppm and the heavy metals are within specifications, the oil can be blended and burned. An air pollution permit may have to be obtained.

Estimated Costs: Annual O&M - \$44,213

Estimated Annual Savings: \$9589

⁷CLOR-D-TECT is a trademark of the Dexsil Corporation [1 Hamden Park Drive, Hamden, CT 06517, (203) 288-3509]. CLOR-D-TECT 1000 is a go-no-go kit for determining if used oil is contaminated with chlorinated solvents. CLOR-D-TECT Q4000 is a quantitative test for determination of chloride (0 to 4000 ppm) in used oil.

Estimated Waste Reduction (Treatment Alone): 0 percent

Estimated Waste Reduction (Source Reduction and Treatment): 30 percent

Estimated "Hazardous" Waste Reduction: 0 percent

- 7.4.2 Spent Lead-Acid Batteries/Battery Acid - Source Reduction - No Draining/Sale. The current practice is to drain the lead-acid batteries and drum and dispose of the spent acid. About 1287 gal/yr of acid is generated and disposed of at an annual cost of \$13,189.

Lead-acid batteries (sealed and unsealed) must be accumulated at the generators (e.g., motor pools) on pallets. These batteries, when bound securely to the pallets, can be recycled. If the batteries are being recycled, they are exempt from RCRA reporting requirements and do not require the reporting and manifesting paperwork required for other hazardous wastes.

Estimated Costs: Annual O&M - \$121 (revenue)

Estimated Annual Savings: \$9731

Estimated Waste Reduction (Source Reduction/Recycling): 100 percent

Estimated "Hazardous" Waste Reduction: 100 percent

- 7.4.3 Used Antifreeze Solution - Onsite Recycling. Used antifreeze solution generated at the rate of 1450 gal/yr by the vehicle maintenance facilities is accumulated in 55-gal drums and disposed of at a cost of \$888/yr. It is commendable that only a few generators who generated small quantities of used antifreeze allow it to drain into the storm sewer. Although antifreeze is not a hazardous waste, it is difficult to treat and can cause an upset at the sewage treatment plant. Because the price of new antifreeze has more than doubled in the past two years (\$4.00 to \$8.45/gal), a technology (Glyclean filtration system) for recycling the 50 percent antifreeze solution is recommended.

Estimated Waste Reduction (Recycling Alone): 100 percent

Estimated Waste Reduction (Source Reduction and Recycling): 100 percent

Estimated "Hazardous" Waste Reduction: 0 percent

- 7.4.4 Paint Thinner/Residue - Recycle Onsite/Offsite - Distillation. The paint shop belonging to the Allied Trades Section (of the Directorate of Logistics) should purchase a 5-gal distillation still for recycling paint thinner wastes and discontinue the Safety Kleen contract recycling process. Thinner wastes generated elsewhere on the installation should be brought to the DOL shop and distilled. The still bottoms have to be disposed of as hazardous waste. Permit requirements, if any, will be reviewed by the environmental office before installation and operation of the still.

Estimated Costs: Investment - \$4145; Annual O&M - \$825

Estimated Annual Savings: \$963

Estimated Payback Period: 8 years

Estimated Waste Reduction (Recycling Alone): 80 percent

Estimated Waste Reduction (Source Reduction and Recycling): 90 percent

Estimated "Hazardous" Waste Reduction: 90 percent

- 7.4.5 Aqueous Wastes/Paint Sludge - Source Reduction - Dry Paint Booths. Fort Sam Houston has two wet-wall paint booths. A small paint booth is operated at DEH and a medium-sized cross-draft booth is operated at DOL Allied Trades Shop. Conversion to dry booths will completely eliminate the problem of wastewater and sludge generation. The current operating costs are estimated to be \$2504 and \$8870/yr for the small and the medium booths, respectively.

Estimated Costs (Small Booth): Investment - \$1562; Annual O&M - \$1341

Estimated Annual Savings (Small Booth): \$1163

Estimated Payback Period (Small Booth): 2.5 years

Estimated Costs (Medium Booth): Investment - \$4290; Annual O&M - \$1904

Estimated Annual Savings (Medium Booth): \$6966

Estimated Payback Period (Medium Booth): 1.6 years

Estimated Waste Reduction (Source Reduction): 100 percent

Estimated "Hazardous" Waste Reduction: 100 percent

- 7.4.6 Other Wastes - Source Reduction. Implement "better operating practices" and other appropriate minimization techniques.

Estimated Waste Reduction: 20 percent

Estimated "Hazardous" Waste Reduction: 10 percent

7.5 Overall Estimate of Expected Waste Reduction

Expected Waste Reduction: 40 percent

Expected "Hazardous" Waste Reduction: 77 percent

8 REFERENCES

- 8.1 Fort Sam Houston waste generation data is given in Tables A1 and A2.
- 8.2 The calculations for the "overall" estimated waste reduction (in section 7.5) are presented in Table A3.

9 IMPLEMENTATION

Estimated Implementation Date: September 30, 1991.

10 RESPONSIBILITIES

- 10.1 The duties and responsibilities of persons directly responsible for implementation of this plan and success of the HAZMIN program are described in this section. The following personnel will form the HAZMIN committee that will oversee implementation of this plan and keep it revised and updated in the future.

Job Title

HAZMIN Activity

Chief, Environmental
Management Office

Overview of the entire program; chair the committee.

Hazardous Waste Program
Manager, EMO

Establish a hazardous materials/waste training program; establish waste analysis contract; establish waste inventory and inspection program; establish a HW/HM tracking program; coordinate with Safety Officer, Fire Chief, DRMO and all the environmental coordinators.

Safety Officer

Establish a chemical inventory program; flag and control purchase of hazardous materials; coordinate with the environmental engineer regarding maintaining and updating inventory.

Chief, Defense Reutilization and
Marketing Office

Establish proper waste turn-in procedures; waste contract management; explore offsite reclamation and waste exchange options.

Chief, DEH Operations Division

Inventory control of materials and wastes; vehicle/equipment maintenance, painting and laboratory wastes minimization; pesticides management; PCB transformer inventory management.

Chief, DEH Fire Prevention and
Protection Division

Coordinate with safety office; inventory flammable/toxic materials; SARA Title III compliance.

Chief, DOL Transportation Division	Inventory control of materials and wastes; vehicle maintenance; wastes minimization.
Chief, DOL Maintenance Division	Inventory control of materials and wastes; painting, machining, and weapons cleaning wastes minimization.
Chief, DOL Supply and Services	Flag and control procurement of hazardous materials; coordinate with Safety and EMO; establish chemical usage inventory and demand history by each generator.
DEH, Supply Division	Flag and control procurement of hazardous materials; coordinate with Safety and EMO; establish chemical usage inventory and demand history by each generator.
Chief, BAMC Materiel Branch	Flag and control procurement of hazardous materials; coordinate with Safety and EMO; establish chemical usage inventory and demand history by each laboratory and generator.
Chief, DPCA Arts and Crafts and Auto Crafts	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
Chief, DPCA Training and Audiovisual Support Center	Inventory control of materials and wastes; photographic and printing wastes minimization.
Industrial Hygienist, Brooke Army Medical Center	Establish inventory of hazardous materials/wastes; establish waste generators monitoring program; coordinate minimization and proper disposal practices (infectious, hazardous, and radioactive wastes) with environmental office.
Environmental (or Hazardous Waste) Managers	As discussed in Section 10.4.

- 10.2 Responsibilities of all HAZMIN Committee Members (except Chief, EMO)
 - 10.2.1 Identify and prioritize goals necessary for achieving the goals outlined in this plan.
 - 10.2.2 Provide information on HAZMIN techniques to the actual generators of hazardous waste.
 - 10.2.3 Organize a team to conduct annual HAZMIN assessments (or audits) to determine sources, types, and quantities of hazardous materials used and hazardous wastes generated.
 - 10.2.4 Report on the status of the HAZMIN program to the Chief, EMO on a regular basis.
 - 10.2.5 Assist the Chief, EMO in preparing an annual HAZMIN status report.
- 10.3 Responsibilities of the Chief, Environmental Management Office.
 - 10.3.1 Oversee and provide resources (including technological assistance) to conduct the annual HAZMIN assessments. Report the state of the HAZMIN program to the commander.
 - 10.3.2 Revise and update this plan annually.
 - 10.3.3 Prepare a HAZMIN status report when requested by HQFORSCOM or HQDA.
 - 10.3.4 Program funds necessary to accomplish HAZMIN goals.
 - 10.3.5 Chair the HAZMIN Committee.
 - 10.3.6 Conceive, develop, and implement HAZMIN techniques consistent with this plan.
- 10.4 Responsibilities of Environmental (or Hazardous Waste) Managers.
 - 10.4.1 Establish goals for minimizing all forms of environmental pollution (air, water, solid, and hazardous waste).
 - 10.4.2 Obtain training (organized by EMO) on all the applicable environmental laws and train all subordinate personnel.
 - 10.4.3 Implement "better operating practices" through: inventory control (maintaining logbooks for materials procured and pollution generated); segregation of wastes; spill and leak prevention; and scheduling frequent preventive maintenance of equipment.
 - 10.4.4 Examine and implement the use of substitute nonhazardous or less hazardous materials in place of hazardous materials.
 - 10.4.5 Examine and implement "process changes" such as: process modifications; equipment modifications; and changes in operation settings, to reduce the quantities of pollution generated.
 - 10.4.6 Examine and implement technologies for recycling, reuse, or treatment of wastes. Information about technologies and equipment suppliers can be obtained from environmental personnel at EMO.

Table A1
Fort Sam Houston Waste Generation Summary

Waste Generating Operations or Conditions	Waste Category	lb/yr	lb/yr/unit	Waste Stream Unit
Motor Pools and Vehicle Maintenance Facilities	1	12,873	9513	Sulfuric Acid
			3360	Caustic Radiator Wash
	2	12,975	15,975	Ethylene Glycol
			18,560	Petroleum Naphtha
	3	21,330	2310	PD-680-II
			460	MEK
			4068	Methylene Chloride
	6	85,205	77,689	Motor Oil
			6938	Transmission Oil
			578	Hydraulic Oil
	7	1050		Diesel
				Mogas
	8	302	302	Paint Related Material
	9	175	175	Paint Thinner
	10	180 veh. bat.	180 veh. bat.	Dead Batteries (vehicle)
Aviation Maintenance Facilities	3	5547	5547	Degreasing Solvent
	6	630	210	Turbine Oil
			420	Hydraulic Oil
	7	660	660	JP-4
Photography, Print, and Reproduction Facilities	3	285	285	Cleaning Solvent
	5	1425	155	Methylene Chloride
			1270	Perchloroethylene
	10	11,628	4280	Photo Fixer
			6920	Photo Developer
			360	Electrostatic Solution
			68	Electrostatic Developer

Table A1 (Cont'd)

Waste Generating Operations or Conditions	Waste Categories	lb/yr	lb/yr/unit	Waste Stream Units
Vehicle Painting Facilities and Maintenance Paint Shops	3	8316	8316	Petroleum Naphtha
	8	932	360	Old, Unused Paint
			192	Spent Paint Filters
			380	Waste Paint Sludge
Industrial Maintenance, Small Arms Repair, and Special Equipment Shops	9			
		2112	2112	Paint Thinner
	3	6577	2880	Petroleum Naphtha
	4		3697	Spent Degreasing Solvent
	10	465	465	1, 1, 1 Trichloroethane
Power Production, Heating/Cooling Facilities		30	30	Abrasive Blasting Media
	1			
	3	18,250	18,250	Caustic Boiler Blowdown
	6	2880	2880	Petroleum Naphtha
	7	2450	2450	Lubrication Oil
Electrical Maintenance/Electric Motor Repair Facilities		385	385	Contaminated Diesel
	3			
		6625	6625	Petroleum Naphtha
	9	116	116	Varnish Thinner
	6	18	18	Turbine Oil

Table A1 (Cont'd)

Waste Generating Operations or Conditions	Waste Category	lb/yr	lb/yr/unit	Waste Stream Unit
Hospitals, Clinics, and Laboratories	3	2327	25	Acetylene
			1331	Xylene
			968	Toluene
			1	Carbon Disulfide
			2	MEK
	4	10	8	Carbon Tetrachloride
			2	1, 1, 1 Trichloroethane
	5	32	25	Ethyl Alcohol
			8	Methanol
	10	5,131	3	Potassium Cyanide
4910			Formalin	
218			Mercury	
Hazardous Waste Storage Facility	10	300	300	PCB Contaminated Soil
Miscellaneous	10	1980 Li Batteries	1980 Li Batteries	Lithium Batteries

Waste Categories: 1. Spent acids or bases (corrosives); 2. Spent antifreeze solution; 3. Spent degreasing solvents (nonhalogenated); 4. Spent degreasing solvents (halogenated); 5. Used alcohols; 6. Used oils; 7. Contaminated fuels; 8. Waste paint related material; 9. Spent thinners; 10. Miscellaneous wastes - smaller volumes.

Table A2
Total Waste Generation Rates By Waste Categories

Waste Generation Summary Table											
Generator	Total	1	2	3	4	5	6	7	8	9	10
Motor Pool	137,978	12,873	12,975	21,330	4068		85,205	1050	302	175	180 veh. bat.
Aviation Maintenance	6837			5547			630	660			
Photography	13,338			285	1425						11,628
Paint Shops	11,360			8316					932	2112	
Industrial Maintenance	7072			6577	465						30
Heating/Cooling	23,965	18,250		2880			2450	385			
Electrical Maintenance	6759			6625						116	
Hospitals	7500			2327	10	32					5131
Waste Storage Facility	300									300	
Miscellaneous	1980 Li bat.										1980 Li bat.
Total	215,109	31,123	12,975	53,887	5968	32	88,303	2095	1234	2430	17,089

Table A3
Calculation of the Overall Waste Reduction Factors

Waste	Quantity lb/yr (gal/yr)	Est. Red.	Est. "HW" Red.
Cleaning Solvent	57,567 (7478)	0.40	1.00
Xylene	1331	0.40	0.40
Used Oil	88,303 (12,600)	0.30	0.00
Battery Acid	9513 (950)	1.00	1.00
Antifreeze	12,975 (1450)	1.00	0.00
Paint Thinner	2403 (344)	0.80	0.90
Paint Sludge Solids	4390* (439)	1.00	1.00
Other Wastes	24,467**	0.10	0.10
Weighted Average		0.40	0.77***

*Not included in Tables A1 and A2. Estimated from the wet-wall paint booth usage rate. The quantity of wastewater generated is approximately 1464 gal/yr.

**Does not include boiler blowdown of 18,250 lb/yr.

***Since used oil and antifreeze are not "hazardous wastes," they have been excluded from this calculation.

APPENDIX B:

HAZMIN PROTOCOL AND SURVEY FORMS

HAZMIN Protocol

Goals

1. Define current status of waste generation and management practices.
2. Identify and evaluate new waste minimization alternatives.
3. Identify support for existing alternatives/activities.
4. Identify areas/activities requiring further research and development.

Approach

- I. Review information available at the installation.
- II. Talk to several groups of individuals.
- III. Develop a list of waste streams and rank them.
- IV. Develop information on each waste stream.
- V. Identify minimization options for each waste stream.
- VI. Evaluate and rate options (preliminary or first screen) for each waste stream.
- VII. Conduct detailed technical and economic feasibility analysis of select minimization options for high priority waste streams.

HAZMIN Protocol

I. Review information available at the installation.

The information reviewed by the survey team includes:

1. Installation policies/programs on waste minimization, if any.
2. Hazardous waste manifests, annual (and biennial) reports, and other RCRA information since 1985.
3. State and local regulations that are more stringent than federal regulations.
4. Environmental audit/review reports.
5. Emission inventories.
6. Permit and/or permit applications, and any regulatory violations.
7. Contracts with waste management firms.
8. Waste assays and/or tests.
9. Materials purchase orders, purchase records.
10. Maps, organizational charts, list of activities associated with different buildings.
11. Production/maintenance schedules.
12. Operator data logs, batch sheets.
13. Operation manuals, process descriptions - standard operating procedures (SOPs).
14. Process flow diagrams (PFDs) and facilities layout.
15. Heat and material balances for production processes and pollution control systems.
16. Safety procedures for handling hazardous materials.

Products:

1. List of information sources.
2. Waste stream list.
3. Survey agenda or checklist detailing what is to be accomplished.
4. List of questions that need to be resolved.
5. List of information that needs to be gathered.

HAZMIN Protocol

II. Talk to several groups of individuals.

Identify appropriate individuals to interview among:

1. Environmental personnel
 - who compile USEPA/State reports
 - who compile DRMO reports
2. Waste generators
 - supervisors
 - shop foremen and production employees
3. Hazardous waste managers
 - operators of onsite treatment, storage, and disposal (TSD) facilities
 - transporters of waste from generation points to TSD facilities
4. Individuals responsible for purchasing/acquisition of hazardous materials (for possible substitution alternatives, costs of purchase, etc.)
5. Individuals with broad HAZMIN responsibilities
 - finance and accounting
 - construction/renovation of facilities
 - higher levels of management
 - legal advisors

HAZMIN Protocol

III. Develop a list of waste streams and rank them.

Develop a waste generation inventory based on reports, permits, and observation. Inventory must be representative of "normal" operations.

Ranking criteria:

1. Composition
2. Quantity (volume or mass generated per year and unit of production)
3. Degree of hazard (toxicity, flammability, corrosivity, etc.)
4. Method and cost of disposal
5. Potential for minimization and recycling
6. Compliance status (in or out)
7. Potential liability (past spills or accidents; proximity to water)
8. Degree of acceptability of changes at the installation
9. Installation personnel preference for options.

Products:

1. Waste description with rationale for selection
2. Description of facilities, processes, and waste streams.

HAZMIN Protocol

IV. Develop information on each waste stream.

The following information must be developed on each waste stream based on observation and available reports:

1. Waste characterization
 - chemical/physical analysis
 - reason for hazardous nature
2. Waste source
3. Baseline generation
4. Present method of TSD and associated costs
5. Past/present minimization efforts and associated costs

Some points to be reviewed in the above determination are:

- actual point of generation
- details about subsequent handling/mixing
- "hazardous" versus nonhazardous determination
- physical and chemical characteristics
- quantities by waste treatability category
- potential variations in the rate of production, maintenance, etc.
- potential for contamination or upset
- true costs for management, onsite and offsite including tax, fringe, and overhead for labor, cost of space; vehicle insurance, maintenance, fuel, etc.

HAZMIN Protocol

V. Identify minimization options for each waste stream.

Follow USEPA guidelines on waste minimization. The categories arranged in a hierarchical order are:

1. Source reduction
 - a. product/material substitution
 - b. source control
 - i. input material changes (e.g., dilution, purification)
 - ii. technology changes (e.g., process changes, layout changes, etc.)
 - iii. procedural/institutional changes
2. Recycle/reuse
 - a. onsite
 - b. offsite
3. Waste separation and concentration
4. Waste exchange
5. Energy/material recovery
6. Waste incineration/treatment
7. Treatment
8. Ultimate disposal.

HAZMIN Protocol

VI. Evaluate and rate options (preliminary or first screen) for each waste stream.

Some considerations for a preliminary evaluation and rating of minimization options for each waste stream are:

1. Waste reduction effectiveness (i.e. reduction of waste quantity and/or toxicity)
2. Extent of current use in the facility
3. Industrial precedent
4. Technical soundness
5. Cost (preliminary capital and operating cost evaluation)
6. Effect on product quality
7. Effect on operations
8. Implementation period
9. Resources availability and requirement.

HAZMIN Protocol

VII. Detailed technical and economic feasibility analysis of select minimization options for high priority waste streams.

The following aspects must be considered in the final detailed analysis:

1. Technical soundness and commercial availability
2. Evaluation of detailed life cycle costs of all the options for each waste stream
3. Detailed comparison of costs of the current practices with alternative options to obtain savings to investment ratios and discounted payback periods
4. Implementation period.

HAZMIN Survey Forms

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Motor Pools & Vehicle Maintenance Facilities

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

<u>Waste Stream</u>	<u>Generation Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)	<u>Material Input</u>	<u>Usage Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)
Spent cleaning solvent		Cleaning solvent	
Carburetor cleaner		Carburetor cleaner	
Waste oil		Engine oil	
Antifreeze solution		Antifreeze	
Lead-acid batteries		Lead-acid batteries	
Battery acid		Battery acid	
Aqueous detergent or caustic wastes (engine/radiator washing)		Caustic/detergent	
Detergent solution from floor wash		Detergent floor wash	
Oily dirt with heavy metals			
Spent sorbent (Dry-Sweep)		Sorbent	
Contaminated fuel (mogas/diesel)		Fuel: diesel mogas	
Dirty rags		Rags	
Solvent tank-bottom sludges			
Contaminated water			
Other fluids (transmission, brake, etc.)		Other fluids (transmission, brake, etc.)	
Mixed wastes			
Hazardous faulty parts (e.g., brake pads)			
Miscellaneous (specify)		Miscellaneous (specify)	

Installation _____ Date _____ POC _____
 Phone _____

WASTE STREAM/MATERIALS USAGE: Aviation Maintenance Facilities

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

<u>Waste Stream</u>	<u>Generation Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)	<u>Material Input</u>	<u>Usage Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)
Spent cleaning solvent		Cleaning solvent	
MEK degreaser & cleaner		Methyl ethyl ketone	
Calibrating fluid (specify)		Calibrating fluid (specify)	
Paint stripper (specify)		Paint stripper (specify)	
Paint thinner (specify)		Paint thinner (specify)	
Filters (paint booth)		Filters (paint booth)	
Used paint cans			
Waste engine oil		Engine oil	
Deicer solution		Deicer	
Nickel-cadmium batteries		Nickel-cadmium batteries	
NICAD battery electrolyte		Battery electrolyte (potassium hydroxide)	
Aqueous detergent or caustic wastes (engine washing)		Caustic/detergent (engine washing)	
Detergent solution from floor wash		Detergent floor wash	
Oily dirt with heavy metals			
Spent sorbent (Dry-Sweep)		Sorbent	
Contaminated fuel (Avgas)		Fuel (Avgas)	
Dirty rags		Rags	
Solvent tank-bottom sludges			
Contaminated water			
Miscellaneous (specify)		Miscellaneous (specify)	

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Industrial Maintenance, Small Arms Shops, etc.

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

Waste Stream

Generation Rate

(indicate units: gal/yr
lb/yr, pints/mo, etc.)

Degreasing solvent (trichloroethylene)
Degreasing solvent (1,1,1-trichloroethane)
Degreasing solvent (others)

Paint thinners (specify)
Surface cleaners (specify)
Paint wastes
Waste oil
Hydraulic/cutting fluids
Corrosive chemicals (caustic soda)
Corrosive chemicals (phosphoric acid)
Corrosive chemicals (chromic acid)
Corrosive chemicals (phosphate solution)
Corrosive chemicals (others, specify)
Tank bottoms (specify)
Paint/sand blasting wastes
Steam cleaning compound (alkali wastes)
Radioactive wastes
Batteries (lead-acid, NICAD)

Battery electrolyte (specify)
Miscellaneous (specify)

Material Input

Usage Rate

(indicate units: gal/yr
lb/yr, pints/mo, etc.)

Trichloroethylene
1,1,1-trichloroethane
Degreasing solvent (others, specify)

Paint thinners (specify)
Surface cleaners (specify)

Lubricating oil
Hydraulic & cutting fluids
Caustic soda
Phosphoric acid
Chromic acid
Phosphate
Corrosive chemicals (others, specify)

Alkali
Radioactive sources
Batteries: Lead-acid
Nickel-cadmium
Battery electrolyte (specify)
Miscellaneous (specify)

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Paint Shops

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

<u>Waste Stream</u>	<u>Generation Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)	<u>Material Input</u>	<u>Usage Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)
Old/used paint cans			
Old/used paint			
Paint thinners (specify)		Paint thinners (specify)	
Paint strippers (specify)		Paint strippers (specify)	
Caustic wastes		Caustic soda	
Detergent solution from floor wash		Detergent floor wash	
Oily dirt with heavy metals			
Spent sorbent (Dry-Sweep)		Sorbent	
Dirty rags		Rags	
Solvent tank-bottom sludges			
Contaminated water			
Filters from paint booths		Filters (paint booths)	
Sludges from water-wall booths			
Miscellaneous (specify)		Miscellaneous (specify)	

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Hospitals, Clinics, and Laboratories

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

Waste Stream

Generation Rate

(indicate units: gal/yr
lb/yr, pints/mo, etc.)

Pathological wastes (specify)

Medical infectious wastes (specify)

Pharmaceutical wastes (specify)

Chemical wastes (specify)

Radioactive wastes (specify)

Photographic wastes (specify)

Miscellaneous (specify)

Material Input

Usage Rate

(indicate units: gal/yr
lb/yr, pints/mo, etc.)

Laboratory chemicals (xylene)
Laboratory chemicals (mercury)
Laboratory chemicals (others, specify)

Photographic chemicals (specify)

Miscellaneous (specify)

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Photography, Printing, Arts/Crafts Shops, etc.

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

Waste Stream

Generation Rate

(indicate units: gal/yr
lb/yr, pints/mo, etc.)

Material Input

Usage Rate

(indicate units: gal/yr
lb/yr, pints/mo, etc.)

Solvents (specify)

Solvents (specify)

Inks (specify)

Inks (specify)

Photographic chemical wastes (specify)

Photographic chemicals (specify)

Printing chemical wastes (specify)

Printing chemicals (specify)

Bath dumps

Paint wastes

Paint/sand blasting wastes

Other dry wastes

Miscellaneous (specify)

Miscellaneous (specify)

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Heating and Cooling Plants

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

Waste Stream

Generation Rate

(indicate units: gal/yr
lb/yr, pinta/mo, etc.)

Contaminated fuel oil

Combustible chemicals (cyclohexylamine)

Combustible chemicals (other, specify)

Corrosive chemicals (caustic soda/potash)

Corrosive chemicals (other, specify)

Boiler blowdown

Toxic emissions

Ash

Miscellaneous (specify)

Material Input

Usage Rate

(indicate units: gal/yr
lb/yr, pinta/mo, etc.)

Waste oil

Fuel oil

Natural gas

Combustible chemicals (cyclohexylamine)

Combustible chemicals (others, specify)

Corrosive chemicals (caustic soda/potash)

Corrosive chemicals (other, specify)

Miscellaneous (specify)

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Laundry and Drycleaning Facilities

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

<u>Waste Stream</u>	<u>Generation Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)	<u>Material Input</u>	<u>Usage Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)
Corrosive chemicals (caustic soda)		Corrosive chemicals (caustic soda)	
Corrosive chemicals (others, specify)		Corrosive chemicals (others, specify)	
Drycleaning compound (perchloroethylene)		Perchloroethylene	
Drycleaning compound (others, specify)		Drycleaning compound (others, specify)	
Equipment filters		Filters	
Contaminated water			
Other dry wastes (specify)			
Miscellaneous (specify)		Miscellaneous (specify)	

Installation _____ Date _____ POC _____
Phone _____

WASTE STREAM/MATERIALS USAGE: Miscellaneous Generators

Generator (Unit Name) _____ Building _____ DODAAC _____ UIC _____

<u>Waste Stream</u>	<u>Generation Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)	<u>Material Input</u>	<u>Usage Rate</u> (indicate units: gal/yr lb/yr, pints/mo, etc.)
Wet chemical wastes (specify)		Wet Chemicals (specify)	
Dry chemical wastes (specify)		Dry Chemicals (specify)	
Off-shelf-life chemicals			
Used chemicals (pesticides, etc.)			
Batteries (specify)		Batteries (specify)	
Battery electrolyte (specify)		Battery electrolyte (specify)	
Contaminated soil			
Demilitarized ammunition			
Decontaminating agents (STB, DS2, etc.)			
Hazardous empty containers (drums etc.)			
Contaminated equipment (PCB transformers etc.)			
Contaminated water		Water	
Sludge from water treatment		Water treated	
Leachate into groundwater			
Infectious wastes			
Ordnance			
Fire fighting foam		Fire fighting foam	
Miscellaneous (specify)		Miscellaneous (specify)	

APPENDIX C:

FORT SAM HOUSTON - LIST OF TENANTS

Main Organizational Tenants/Activities

1. Headquarters, U.S. Army Health Services Command (HSC)
2. U.S. Air Force, Brooke Army Medical Center (BAMC)
3. Academy of Health Sciences (AHS)
4. U.S. Army, Fifth Recruiting Brigade

Military Units Tenants/Activities

5. Alamo Exchange Region
6. American Red Cross
7. Armed Forces Police
8. Army Frequency Coordinator
9. Defense Investigative Service
10. Defense Mapping Agency Hydrographic/Topographic Center (TOPO)
11. Defense Mapping Agency Inter-American Geodetic Survey
12. Defense Property Disposal Agency
13. Fort Worth District, Corps of Engineers
14. Fort Sam Houston Commissary
15. Fort Sam Houston Military Intelligence Detachment
16. Fort Sam Houston Field Office Third Region USACIDC
17. Midwest Commissary Region
18. Navy Detachment
19. Navy Personnel Support Activity
20. Post Exchange Section

21. San Antonio Goldminers
22. Special Security Detachment
23. St. Mary's University ROTC
24. Trinity University ROTC
25. Training and Doctrine Command
26. University of Texas at San Antonio ROTC
27. U.S. Army Audit Agency, Southwestern Region
28. U.S. Army Institute of Surgical Research (Burn Center)
29. U.S. Army Physical Evaluation Board
30. U.S. Army Veterinarian Food Inspector Office
31. U.S. Marine Corps
32. 137th Ordnance Detachment
33. 546th Ordnance Detachment

Reserve Units & National Guard

34. U.S. Army Reserve Center
35. Headquarters, 90th Army Reserve Command (ARCOM)
36. 807th Medical Brigade
37. 5450 RTU
38. 416th Engineer Command
39. Army Reserve Training Center 2, 3
40. Texas Army National Guard
41. Texas State Guard

LIST OF ABBREVIATIONS

AAFES	Army and Air Force Exchange Service
AFB	Air Force Base
AFFF	Aqueous Film Forming Foam
AHS	Academy of Health Sciences
AMF	Aviation Maintenance Facility
AOAP	Army Oil Analysis Program
AQCR	Air Quality Control Region
ARCOM	U.S. Army Reserve Command
BAMC	Brooke Army Medical Center
BOD	Biochemical Oxygen Demand
C4	Combat Casualty Care Course
CARC	Chemical Agent Resistant Coating
CFR	Code of Federal Regulations
DEH	Directorate of Engineering and Housing
DERA	Defense Environmental Restoration Account
DESR	Defense Environmental Status Report
DLA	Defense Logistics Agency
DMA	Defense Mapping Agency
DOD	Department of Defense
DOHS	State of California, Department of Health Services
DOIM	Defense Office of Information Management
DOL	Directorate of Logistics
DOT	U.S. Department of Transportation
DPCA	Directorate of Personnel and Community Affairs
DPP	Discounted Payback Period

DFTMSEC	Directorate of Plans, Training, Mobilization, and Security
DRMO	Defense Reutilization and Marketing Office
EMO	Environmental Management Office
ETIS	Environmental Technical Information Service
FLOCS	Fast Lubricating Oil Change System
FORSCOM	U.S. Army Forces Command
FSH	Fort Sam Houston
FUSA	Fifth U.S. Army
HAZMIN	Hazardous Waste Minimization
HCL	Hospitals, Clinics, and Laboratories
HCP	Heating/Cooling Plants
HMTC	Hazardous Materials Technical Center
HSC	Health Services Command
HSWA	Hazardous and Solid Waste Amendments
HW	Hazardous Waste
HWMB	Hazardous Waste Management Board
IMSS	Industrial Maintenance, Small Arms Shop
INSCOM	U.S. Army Intelligence and Security Command
ISC	U.S. Army Information Systems Command
ISCP	Installation Spill Contingency Plan
ISR	Institute of Surgical Research
JLC	Joint Logistics Commanders
LPI	Leak Potential Index
MEDDAC	Medical Department Activity
MPVM	Motor Pools and Vehicle Maintenance Facility
MSDS	Material Safety Data Sheet

MWSA	Medical Waste Sanctions Act
NAAQS	National Ambient Air Quality Standard
NIPER	National Institute for Petroleum and Energy Research
NPDES	National Pollution Discharge Elimination System
NPV	Net Present Value
NSA	National Security Agency
O&M	Operations and Maintenance
OB/OD	Open Burning/Open Detonation
PECI	Productivity Enhancing Capital Investment
PEP	Propellants, Explosives, and Pyrotechnics
PMB	Plastic Media Blasting
POL	Petroleum, Oils, and Lubricants
PPAS	Photography, Printing, and Arts/Crafts Shop
PS	Paint Shop
PX	Post Exchange
RCRA	Resource Conservation and Recovery Act
SIR	Savings-to-Investment Ratio
SPCC	Spill Prevention Control and Countermeasures
SQG	Small Quantity Generator
USARCSW	U.S. Army Fifth Recruiting Brigade
TACB	Texas Air Quality Control Board
TASC	Training and Audiovisual Support Center
TMP	Transportation Motor Pool
TOPO	Defense Mapping Agency, Hydrographic/Topographic Center
TSDF	Treatment, Storage, and Disposal Facilities
TSS	Total Suspended Solids

USACERL	U.S. Army Construction Engineering Research Laboratory
USAEHA	U.S. Army Environmental Hygiene Agency
USARECS	U.S. Army Reserve Equipment Concentration Site
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USE	Used Solvent Elimination
USEPA	U.S. Environmental Protection Agency
UST	Underground Storage Tanks

DISTRIBUTION

Chief of Engineers

ATTN: CEHEC-IM-LP (2)

ATTN: CEHEC-IM-LH (2)

ATTN: CERD-L

HQ FORSCOM (6)

ATTN: FCEN/CDE/E

Fort Belvoir, VA 22060

ATTN: CECC-R

TRADOC

ATTN: DEH

Commander, U.S. Army Environmental Hygiene Agency

ATTN: HSHB-ME-SH

HQ USATHAMA

Aberdeen Proving Ground, MD

Defense Technical Info. Center 22314

ATTN: DDA (2)

17

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