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NASA LANGLEY RESEARCH CENTER AND THE TIDEWATER INTERAGENCY POLLUTION PREVENTION PROGRAM

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ABSTRACT

National Aeronautics and Space Administration (NASA)'s Langley Research Center (LaRC) is an 807-acre research center devoted to aeronautics and space research. LaRC has initiated a broad-based pollution prevention program guided by a Pollution Prevention Program Plan and implemented through specific projects. Developed under an interagency agreement with EPA's Risk Reduction Engineering Laboratory, the Program Plan contains an environmental baseline, opportunities for pollution prevention, and establishes a framework to plan, implement and monitor specific prioritized pollution prevention projects.

Over twenty specific source reduction or recycling projects have been initiated since 1991. Recycling activities and use of conservation measures have reduced the use of various freon chlorofluorocarbons, ozone depleting substances (ODCs), by 84 percent in 1993 compared with 1990 figures. In addition, improved silver recovery procedures reduced the amount of photographic laboratory waste by 70 percent, or 11,982 pounds, during 1993. Total hazardous waste, excluding abrasive blasting debris generated by specific remediation projects, has been reduced by 25 percent, or about 50,000 pounds, in 1993 compared to 1992.

By implementing their pollution prevention program, NASA LaRC is contributing to the success of the Tidewater Interagency Pollution Prevention Program (TIPPP). TIPPP is a pollution prevention demonstration program designed to integrate pollution prevention concepts and practices at Federal installations in the Tidewater, Virginia area. Other participants include Langley Air Force Base, the U.S. Army Transportation Center at Fort Eustis, Naval Base Norfolk, and the Environmental Protection Agency. In addition to featuring NASA LaRC's Pollution Prevention Program, this report describes the pollution prevention and recycling accomplishments of TIPPP participants.

CONTENTS

		Page
Disclaimer		ii
Abstract		iii
Tables		v
Figures		v
Acknowledgements		vi
Chapter 1.	Introduction	1
	NASA Langley Research Center	1
	The Tidewater Interagency Pollution Prevention Program	1
Chapter 2.	NASA Langley Research Center	4
	The LaRC Pollution Prevention Program	6
	NASA LaRC Pollution Prevention Activities	7
Chapter 3.	Fort Eustis/Fort Story	20
	Accomplishments	20
Chapter 4.	Langley Air Force Base	23
	Accomplishments	23
Chapter 5.	Naval Base Norfolk	25
	Accomplishments	25
Chapter 6.	EPA Risk Reduction Engineering Laboratory	28
	The Pollution Prevention Research Branch	28
	The Waste Reduction Evaluation at Federal Sites Program	28
Chapter 7.	Conclusions	30
Appendix A - TIPPP Pollution Prevention Opportunity Assessment Reports		32
Appendix B - Pollution Prevention Fact Sheets		179

TABLES

		Page
1	Waste Oil and Hazardous Waste Disposal 1993	4
2	Air Emissions from NASA Langley Research Center	5
3	Pollution Prevention Opportunity for Photoprocessing Activities	14

FIGURES

		Page
1	NASA LaRC Hazardous Waste Disposal 1990-1993	6

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CHAPTER 1

INTRODUCTION

NASA LANGLEY RESEARCH CENTER

National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) has emerged as a leader in multi-media pollution prevention. LaRC staff have developed and are implementing a comprehensive pollution prevention program to minimize the environmental impacts associated with their primary mission of aeronautical and space research. This program demonstrates a commitment to preserve and protect the environment by moving away from a strictly compliance-oriented environmental program to a more proactive pollution prevention-oriented approach.

LaRC has been undertaking pollution prevention projects for years. Earlier projects, such as redesigning the electroplating tanks, set the stage for a more comprehensive Center-wide pollution prevention effort by demonstrating the benefits and feasibility of pollution prevention technologies. LaRC's Pollution Prevention Program was officially initiated in September, 1992. This date marks the completion of the Center's comprehensive Pollution Prevention Program Plan. The Plan is the corner stone in LaRC's Pollution Prevention Program. Individual projects and initiatives are planned and implemented within the framework provided by the Program Plan.

TIPPP is a pollution prevention demonstration program that focuses on Federal installations in the Tidewater, Virginia area. TIPPP is designed to integrate pollution prevention concepts and practices into the operational activities and processes of these installations. LaRC is continuing to accomplish goals set forth by the TIPPP.

THE TIDEWATER INTERAGENCY POLLUTION PREVENTION PROGRAM

TIPPP is an innovative Federal cooperative effort that began in 1990. In April 1990, EPA and Department of Defense (DoD) signed a Cooperative Agreement to promote environmental compliance at military facilities in the Chesapeake Bay watershed. This agreement, in support of efforts related to the restoration of the Chesapeake Bay, committed the two agencies to incorporate pollution prevention into programs and activities at bay installations. LAFB, Fort Eustis, and Naval Base Norfolk were then selected to participate in this demonstration program. Following the initial agreement, NASA joined the effort by including the LaRC.

In addition, EPA's Office of Federal Facilities Enforcement (OFFE), Risk Reduction Engineering Laboratory, and Region III, along with the Commonwealth of Virginia and DoD's Office of the Deputy Assistant Secretary of Defense (Environment) work together to implement pollution prevention projects at these installations. The Air Force Air Combat Command is the lead Federal agency in TIPPP and plays the role of the Coordinator.

On August 6, 1992, EPA, DoD, NASA, Air Force, Army, and Navy signed an additional agreement, the Memorandum of Understanding (MOU) that established TIPPP as a cooperative demonstration program designed to support various pollution prevention efforts to:

- Reduce solid and hazardous wastes generated at the participating facilities;
- Improve the energy efficiency of the installations;
- Test the use of alternate, environmentally protective materials that still meet research and military specifications;
- Improve procurement practices and inventory controls; and
- Reduce nonpoint source environmental problems.

TIPPP is intended to augment existing pollution prevention efforts, as well as to initiate new projects and promote information transfer at each participating installation. Under TIPPP, the participating installations develop and implement pollution prevention practices to reduce the wastes, emissions, and adverse environmental impacts of their facilities. Each installation will develop a customized pollution prevention program to address its specific problems and support its individual needs. These program plans will target processes within four sectors: (1) energy production/usage, (2) industrial processes, (3) residential wastes, and (4) natural resource conservation and land management.

TIPPP is comprised of five components, which are performed by installation personnel and supported by EPA, DoD, and NASA.

- *Planning* - Develop the TIPPP program plan, which is based on two levels of planning: (1) a comprehensive community-wide pollution prevention program plan, and (2) four installation-specific program plans. Each installation has developed their own site-specific plan, with support from EPA. The purpose of both the community-wide plans and the installation-specific plans is to provide a 3- to 5-year strategy for identifying, implementing, and institutionalizing pollution prevention techniques.
- *Opportunity Assessments* - Conduct pollution prevention opportunity assessments (PPOAs) for operations that produce wastes and/or adversely affect the environment. EPA assisted TIPPP members by conducting the initial nine PPOAs. The results of these PPOAs are included in Appendix A.
- *Outreach* - Educate the communities on pollution prevention and recycling concepts. All participants are developing training and outreach programs for their constituents.
- *Research and Development* - Provide DoD and NASA with a demonstration program for various prevention concepts, techniques, and strategies. EPA, DoD, and NASA will identify research efforts and demonstration projects that might be presented at a participating installation. In addition, as research topics are identified through installation assessments, they plan to support specific research and implementation projects.
- *Technical Transfer* - Provide documentation of test cases for pollution prevention that can be transferred to other facilities through such mechanisms as EPA's Pollution Prevention Information Clearinghouse (PPIC) and the Federal Agency Mini-Exchange (FAME). Under this program, the participants will develop case studies and document all results for specific projects so that they may be transferred to other Federal facilities and communities. Nine pollution prevention fact sheets were completed during the initial PPOAs. These fact sheets have been distributed to other Federal installation and are available in Appendix B of this report.

Since its inception, TIPPP has made significant strides in achieving its pollution prevention goals through the efforts of the participating installations. In fact, TIPPP is taking the lead in pollution prevention by demonstrating ways to integrate pollution prevention into the activities of a community. Each participant has contributed to the success of TIPPP through its own accomplishments.

This document focuses on the accomplishments of the NASA LaRC Pollution Prevention Program. Chapter 2 describes the NASA LaRC pollution prevention program and highlights specific program initiatives and projects. Progress in pollution prevention by the other TIPPP installations include Fort Eustis-Fort Story, Langley Air Force Base (LAFB), Naval Base Norfolk and EPA's Risk Reduction Engineering Laboratory (RREL) is the subject of the remaining chapters.

CHAPTER 2

NASA LANGLEY RESEARCH CENTER

LaRC is an 807-acre research center located in Hampton, Virginia. At LaRC, a facility dedicated to aeronautical and space research, NASA conducts innovative research programs to advance our knowledge, further the state-of-the-art in aircraft design, and to develop advanced transportation systems and space station technologies. Approximately 60 percent of the research performed at LaRC is in aeronautics. Aeronautical research is conducted to improve today's aircraft as well as developing new technology for the future. LaRC performs aeronautical research using a variety of wind tunnels, which operate under various atmospheric conditions, test media, temperatures, and Mach speeds. About 6,000 people are employed at LaRC, of which 3,100 are civil servants and 2,900 are contractor and university personnel.

Activities at LaRC with potential to adversely impact the environment and generate wastes include large-scale physics and chemistry research, engineering and design testing programs and the upkeep, operation, and maintenance of the Center's equipment and facilities. Center activities involve the use of approximately 6,000 different chemicals and materials. An overview of estimated waste quantities requiring disposal for 1993 is presented in Table 1. Estimated atmospheric emissions for 1992 are presented in Table 2.

TABLE 1. WASTE OIL AND HAZARDOUS WASTE DISPOSAL 1993

Waste	Quantity (lbs)	Percent of Total
Used Oils	76,000	42
Metallic Hydroxide Sludge and Liquid Waste from Printed Circuit Board Mfg.	36,777	20
Solvent	30,895	17
Contaminated Oil	9,172	5
Aqueous Cleaning Solution/Sludge	8,349	5
Photoprocessing Chemical Solution Waste	5,193	3
Contaminated Aircraft Fuel	5,644	3
Mixed Hazardous Waste or Chem Waste	3,468	2
Out-of-date Chemicals	2,837	1.6
Batteries	1,529	0.1
Metal bearing waste from Laboratory Research	167	<0.1
TOTAL	180,031	100*

* Does not equal 100% due to rounding.

Source: NASA LaRC Office of Environmental Engineering, March, 1994

TABLE 2. AIR EMISSIONS FROM NASA LANGLEY RESEARCH CENTER

Constituent	Emissions (tons/year)
Total Hazardous Air Pollutants	6.21
Total VOC	22.28
Total ODC	36.32
Carbon Monoxide	10.9
Lead	0.01
Nitrogen Oxides (as NO_2)	62.03
Sulfur Oxides (as SO_2)	31.18
Ozone	0.031
Pm10	6.02

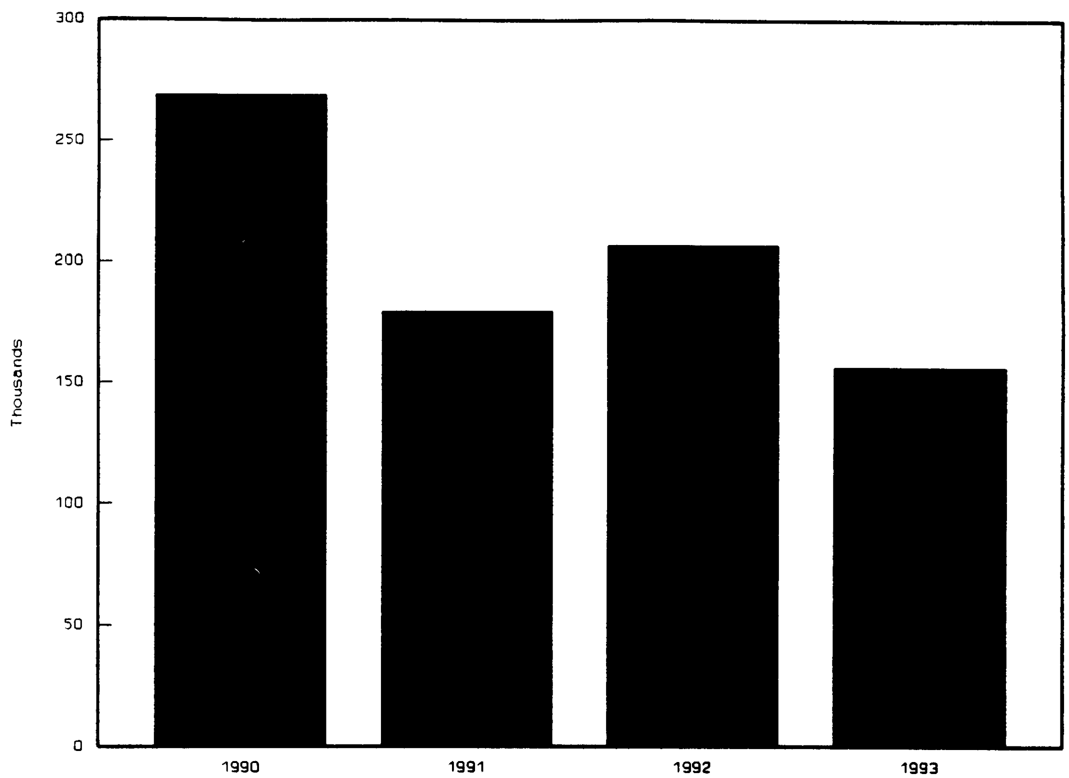
Source: Air Emissions Inventory, Ebasco, Services Inc. 1993

In recent years, LaRC has initiated large-scale, proactive environmental protection programs. Recognizing the far-reaching benefits of pollution prevention, LaRC has emerged as a leader in using pollution prevention projects to minimize waste, reduce costs, and limit potential liabilities. LaRC's pollution prevention program emphasizes source reduction and recycling and recognizes that the elimination of pollutants at the source is generally less risky and more cost effective than waste treatment and disposal. The program will also assist the Center in meeting the requirements of Executive Order 12856 *(Federal Compliance With Right-To-Know and Pollution Prevention Requirements)*. Executive Order 12856 subjects each Federal agency to the reporting requirements established by the Emergency Planning and Community Right-to-Know Act. Additionally, each Federal agency is required to plan for and implement pollution prevention in order to reduce the generation of toxic chemical emissions and wastes by 50 percent by 1999 based on a baseline year of 1994.

LaRC has conducted several notable pollution prevention activities. For instance, LaRC's continued recycling activities and use of conservation measures have reduced the use of chlorofluorocarbon, an ozone depleting substance, by 44 percent or 19,305 pounds in 1992 compared with 1989 figures. In addition, improved silver recovery procedures reduced the amount of photographic laboratory waste by 28 percent, or 6,141 pounds, during 1992. Total hazardous waste, excluding abrasive blasting debris generated by specific projects, has been reduced by 23 percent, or about 60,000 pounds, in 1992 compared to 1990. The Center is also installing a natural gas-fired boiler to reduce the use of inefficient oil-fired units and lower air emissions. When the oil-fired units are operating, a low sulfur fuel ($\leq$0.5 percent sulfur) will be used, lessening the emission of SO_x. The central focus of LaRC's pollution prevention activities since September 1992, however, is its Center-wide Pollution Prevention Program.

In addition to pollution prevention successes, activities at the Center vary from year to year causing fluctuations in waste generation patterns. Overall, the amount of hazardous waste the Center must dispose of each year is on a general downward trend as shown in Figure 1. Because of this fluctuation, it is important for the Center's programs to focus on long-term benefits of its pollution prevention program.

Figure 1. NASA LaRC hazardous waste disposal (1990-1993).



* Hazardous waste disposed excluding non-recurring remediation wastes.
Source: NASA LaRC Office of Environmental Engineering, March 1994

THE LaRC POLLUTION PREVENTION PROGRAM

The LaRC Pollution Prevention Program is comprised of a Program Plan implemented through individual projects and support initiatives under the direction of the Office of Environmental Engineering of the Safety, Environment and Mission Assurance Office.

Through its Pollution Prevention Program, LaRC is committed to proactive environmental stewardship in the course of meeting its mission. Specific Program goals are to:

- Systematically reduce and eliminate the use of hazardous materials, and the generation of hazardous and solid waste and other emissions to the environment.
- Adopt a comprehensive approach to environmental management that considers all environmental media collectively.
- Integrate pollution prevention into environmental compliance programs.
- Develop pollution prevention partnerships with other Federal facilities and organizations.

- Instill a pollution prevention ethic throughout the entire Center community and all mission areas.
- Acquire world-class pollution prevention technologies for distribution throughout NASA.

As a first step toward meeting the overall goals, LaRC developed a comprehensive pollution prevention program plan. Completed in September 1992, the Program Plan covers three general sectors: (1) energy production and usage, (2) industrial and commercial processes or operations, and (3) natural resource conservation/land management.

Specifically, the Program Plan:

- Developed a baseline of LaRC's most significant chemical uses, activities, wastestreams and environmental issues;
- Established criteria for ranking pollution prevention opportunities;
- Identified more than 50 pollution prevention opportunities, ranging from a chemical materials management system to cardboard recycling;
- Developed an implementation plan for the Center;
- Described a pollution prevention opportunity assessment of a major photoprocessing operation; and
- Created a Recycling Program Plan and an Affirmative Procurement Plan for the Center.

The Program Plan provides the framework within which to identify, plan, implement, monitor, and evaluate specific pollution prevention projects or initiatives. The Program Plan will be updated periodically to identify new pollution prevention opportunities and to assess the performance of existing pollution prevention techniques. Individual pollution prevention projects and initiatives conducted under the Program Plan are described in the following sections.

NASA LaRC POLLUTION PREVENTION ACTIVITIES

LaRC staff are conducting various prevention activities to reduce the broad range of wastes and emissions generated at the facility. A major thrust is to eliminate hazardous waste generation and to reduce the corresponding management costs. The major sources of the wastes listed in Tables 1 and 2 were targeted for reduction. This includes projects to reduce oil wastes, wastes from electroplating operations, photoprocessing wastes, and solvents. Another program focus is to eliminate the use of ozone depleting compounds (ODCs).

The Program is a collection of short- and long-term projects and initiatives designed to accomplish the Program Plan goals. The projects described in this report are in various stages of completion; some have been implemented while other are still in the planning phase. It is expected that as projects are completed new projects will be initiated. This next section begins by describing four foundation projects. Following this discussion is a summary of specific action projects. Many of these projects were initiated prior to completion of the NASA Langley Pollution Prevention Program Plan. Additionally, some of the projects implemented have a net economic cost or long payback period. These projects were undertaken despite their poor economic justification because of their ability to reduce waste, lower environmental liability, or respond to worker concerns.

Foundation Projects

Foundation projects are helping to build the organizational and physical infrastructure required to support a pollution prevention program. Foundation projects underway include developing a chemical material tracking system, constructing a pollution prevention building, conducting training, and outreach and communication. Each of these projects is briefly described.

Materials Tracking System--

LaRC researchers utilize thousands of different chemicals at the Center's many laboratories and material testing facilities. Each laboratory generates a relatively small quantity of waste. However, wastes from chemical laboratories collectively represent approximately 10 percent of the wastes listed in Table 1.

Reducing laboratory wastes presents challenges. Laboratory wastes are characterized by a myriad of different chemicals and chemical mixtures generated in small quantities from many different individual laboratories. The nature of research and development work requires specific chemicals, thus making chemical substitution impossible in many cases. The small quantities of a particular waste chemical or chemical mixture also makes recycling impractical, as does the need for certifiable chemical grades.

The strategy chosen to reduce laboratory waste was to improve chemical utilization by setting up a Center-wide chemical materials tracking system. The system objectives are to improve chemical material use and reduce chemical wastes. The tracking system will also help the Center comply with Executive Order 12856.

Specifically, the system will:

- Help alleviate environmental problems and costs caused by inadequate tracking of chemical materials (e.g., improper handling of chemicals, purchasing materials already on-hand, chemical shelf life expiration);

- Provide information necessary to comply with Emergency Planning and Community Right-to-Know Act (EPCRA) reporting requirements;

- Assist the Center in meeting the pollution prevention requirements of Executive Order 12856 by identifying opportunities to reduce or eliminate the use of toxic chemicals;

- Provide various LaRC staff with adequate access and reporting capabilities so they know what on-site organizations and locations have specific chemical materials on hand; and

- Provide chemical materials usage statistics by specific organizations and locations.

Implementing the chemical material tracking system will allow LaRC to track the types and quantities of chemicals entering the Center and where they are utilized. Roughly 75 percent of the identified benefits can be achieved simply by accounting for the types and quantities of chemicals entering LaRC. The remainder of the benefits can be realized by tracking the chemical materials on hand at the facility and knowing where they go as they change hands or locations. The tracking system is expected to be operational in early 1995.

Pollution Prevention Support Building--

A support building is being designed to house pollution prevention related equipment and materials. The building will house an electrolytic silver recovery unit for centralized silver recovery from photoprocessing wastes, used oil management equipment and a drum crusher. The building was designed with flexibility in mind and includes the necessary utilities (e.g., compressed air lines, water, electricity) to accommodate different types of equipment as the need arises. Outside covered storage areas have been designed to be used to temporarily store materials such as glass or other recyclable materials.

Pollution Prevention and Environmental Awareness Training--

The Office of Environmental Engineering (OEE) is developing a series of training sessions for environmental coordinators scheduled to begin in mid-1994 and continuing briefings for senior management. The overall objective is to strengthen the pollution prevention program by enlisting the support of staff throughout the Center.

The training program for environmental coordinators will consist of a series of presentations to raise environmental awareness and introduce pollution prevention ideas. The sessions will familiarize environmental coordinators with pollution prevention concepts and techniques and encourage them to implement pollution prevention at their job-sites.

The primary objective of the senior management briefings is to introduce top management to the concepts of pollution prevention. It includes sessions on potential legal requirements for environmental compliance and how pollution prevention can exceed compliance requirements, thus reducing potential liability. The anticipated result is to institutionalize senior management commitment for the Pollution Prevention Program.

Communications and Outreach--

A crucial element of the NASA LaRC Pollution Prevention Program is the environmental education, communication, and outreach necessary to heighten Center staff awareness of environmental issues. The role of pollution prevention, such that broad-scaled implementation of the Program can occur and work practices that adversely impact the environment can be avoided, is clearly presented. Another important component of the Program is to publicize accomplishments, both at the Center and externally.

Among Center staff and contractors, educational and promotional communications would enhance opportunities for expanded participation in, and ultimate success of, the Pollution Prevention Program. It is envisioned that as pollution prevention projects are initiated, documented, and publicized as successes, the staff will begin to understand prevention concepts as well as the benefits of pollution prevention. This increased awareness should in turn result in expanding interest in the Program. If LaRC employees are unaware of protective environmental practices and the importance of such practices, they are less likely to understand the need for pollution prevention programs.

With regard to an external audience, it is envisioned that LaRC pollution prevention experience and successes could be transferred to other Federal facilities, such as TIPPP participants. Also, LaRC pollution prevention activities can potentially serve as a model for other NASA facilities, especially in cases where there are great similarities among the missions of the NASA facilities.

A Communications and Outreach Strategy was developed. Informal focus groups were convened in early 1994 to solicit additional input on how best to maximize employee participation in and external awareness of the Program. Specific communications and outreach activities recommended in the Strategy have been initiated. Display posters are being developed which describe pollution prevention and the LaRC Pollution Prevention Program. A series of fact-sheets to be distributed to employees and reproduced in the

LaRC newsletter have been developed. Additional activities planned for FY 1995 include, flyers, educational presentations, and seminars. External outreach effort under consideration include active staff participation in appropriate forums, conferences and seminars to publicize NASA LaRC pollution prevention technologies and activities.

Action Projects

Ongoing efforts focus on reducing ODCs and the high volume wastes identified in Table 1. LaRC staff is undertaking action projects to implement the findings from earlier studies or address opportunities identified during Program Plan development or subsequent investigations. These projects range from recycling municipal solid waste and eliminating the use of organic solvents, to filtering and reusing antifreeze. A brief summary of representative projects follow. Each summary discusses the project background, approach and benefits. Implementation issues, economic data, and project schedule are also examined. These projects are loosely grouped based on the type of waste to be prevented.

Oil Analysis To Reduce Waste Oil Generation--

LaRC's Operations Support Division (OSD) is responsible for the maintenance and repair of the hundreds of motors, compressors, vacuum pumps and other equipment required to run the Center's test facilities and infrastructure. Used oil generated from equipment repair or scheduled equipment maintenance is one of the Center's largest volume wastestream. Previous maintenance procedures resulted in oil changes based on hours of operation or a specified time interval.

OSD staff has been using oil analysis as a tool to reduce the frequency of oil changes. Oil samples from equipment containing greater than 100 gallons of lubricating oil are now taken semi-annually and sent to an outside laboratory for analysis. Based on the laboratory results the oil is either changed or left in the system. The laboratory results are also used for predictive maintenance purposes to identify equipment wear.

Replacing oil based on the oil's properties rather than on a schedule (e.g., every 100 hours or every year) reduces oil waste generation. Savings include avoided disposal costs ($100 per 55-gallon drum if the oil is contaminated), the cost of replacement oil, and the labor required to change the oil. These savings can be substantial, given the size of some of the equipment. For example, the motors used to power LaRC's National Transonic Facility contain 5,000 gallons of oil. Cost savings are not documented to date. OEE is working with OSD to document future cost savings.

The cost of the off-site laboratory used to analyze oil samples is approximately $23,328 per year. This is based on approximately 54 samples per month at $36 per sample.

OSD staff have been very pleased with the oil analysis program. LaRC staff are considering expanding the program to include equipment containing less than 100 gallons of lubricating oil. Currently, the oil is routinely changed every 12 months for such equipment. The oil analysis program may also be applied in the future to the LaRC vehicle fleet.

OSD will be using a portable oil analyzer in the near future. The oil analyzer (OilView Computational Systems, Incorporated) is a portable oil analyzer designed for in-shop use by maintenance staff. The system provides immediate lubricant condition screening analysis. Test results will be used to determine which oil samples require off-site laboratory analysis. The cost of the portable oil analyzer system (software and analyzer) is $8,635.

The analyzer and software measures lubricant condition as a function of the time-rate-of-change of the electrical impedance and capacitance of a small fluid sample. Tests are performed by filling the sample bottle with a representative sample of the lubricant to be analyzed and fastening the sample to the analyzer. The analyzer connects to an IBM PC-compatible computer. The software is loaded directly from DOS. Numerical test results present five parameters: corrosion index, contaminant index, ferromagnetic index, large contaminant indicator, and large ferromagnetic indicator. If the oil is within accepted limits, it will not be changed. If the portable oil analyzer test results show unacceptable contaminant levels, a sample of the oil will be sent to the off-site laboratory for more detailed analysis.

Used Oil Filter Recycling--

LaRC's Vehicle Maintenance Shop routinely changes oil for approximately seven hundred government vehicles. Previously, the Vehicle Maintenance Shop would drain the excess oil from filters into a 55-gallon waste oil drum before disposing of the filters in the trash. The Vehicle Maintenance Shop began collecting used oil filters for recycling in May, 1993. Three drums of used oil filters are generated annually.

If not recycled, drained used oil filters would otherwise be included with NASA's solid waste, which is sent to the Hampton Roads Refuse Incineration Facility. The Center incurs a net cost from sending oil filters out to be recycled. Shipping a 55-gallon drum of drained oil filters costs $88.00. Disposing of the drained filters as solid waste is relatively inexpensive. In the eight months since the recycling program was implemented the Vehicle Maintenance Shop has already collected two drums of used oil filters. The Vehicle Maintenance Shop is very enthusiastic about this and its other waste reduction projects.

Substitute Reusable Absorbent Pads for Single-Use and Speedi-Dry Absorbent Pads--

Currently, LaRC's National Transonic Facility (NTF) and the Vehicle Maintenance Shop purchase approximately 3,200 pounds of speedi-dry per year and 863 single-use absorbent pads, socks, and pillows per year. At the NTF, the absorbent materials are used primarily to absorb oils that have leaked from wind tunnel motors. The Vehicle Maintenance Shop uses absorbents for drips and spills during oil and fluid changes. The speedi-dry absorbents cost the facilities $286 per year. The absorbent pads cost $1,374 per year. The Center disposed of 18 drums of used absorbents at a cost of $2,040. An unquantified amount of soiled absorbent material is disposed of as solid waste and burned in the waste-to-energy facility located at the Center.

According to the manufacturer, when the pads become saturated with oil they can be wrung out to remove up to 90 percent of the oil. The NTF and the Vehicle Maintenance Shop are testing reusable absorbent pads to see how well they perform. OEE has purchased reusable absorbent pads and two wringer units, one for each facility. Each facility will replace its absorbent pads and Speedi Dry with the reusable absorbent pads. The pads can be reused up to ten times. The wringer unit sits atop a disposal drum which collects the oils as they are squeezed from the pads. The pads can be collected in a drum for later use or immediately be replaced to absorb more liquids. The oil will be collected and sent off-site for energy recovery.

Wringing and reuse should reduce purchases of absorbent pads and Speedi Dry absorbent. It should also lessen the amount of waste absorbent pads and speedi-dry absorbent materials. The reduced volume of waste absorbent materials should decrease disposal costs. Additionally, the oils removed from the absorbent pads may be collected for energy recovery.

Reusable absorbent pads should be economically and environmentally beneficial to NASA. In these two facilities alone, a cost savings of approximately $2,281 will be realized from the use of reusable absorbent pads. The capital investment for the wringer units will be recovered in about six months.

The NTF staff report that the reusable pads performed poorly when used to absorb leaks. The pads did not show good wicking properties. Oil soaked up by one of the pad's panels migrated to a seam and leaked from the pad. NTF staff believe the reusable pads will be better suited for soaking up large spills where the pads can be wrung out and immediately reused to soak up the spill.

Vehicle Maintenance Shop staff have not used the reusable pads. They report that the large reusable pads are ill-suited for the small leaks and drips typical of Vehicle Maintenance Shop operations. Vehicle Maintenance Shop staff use paper towels to wipe up the drips and leaks.

OEE staff are planning to remove the wringer and reusable pads from the Vehicle Maintenance Shop and place them in one of OSD facilities for a trial basis. Wringer units and absorbent pads have been in the NTF and Vehicle Maintenance Shop since January, 1994.

Electroplating Waste Reduction--

The 1270 complex manufactures prototype printed circuit boards for use in spacecraft and aircraft instrumentation and testing. Current printed circuit board manufacturing involves processing copper clad glass laminate material through a series of chemical tanks to clean and prepare the laminate for electroplating and etching. Printed circuit board manufacturing is one of the major waste generating operations at LaRC. The Hampton Roads Sanitation District (HRSD) permit requires the 1270 complex to pretreat all rinsewater generated from the fabrication processes currently being performed. The rinsewater pretreatment facility (Building 1270C) is currently certified to pretreat rinse material generated by the 1270 complex processing. Building 1270C currently pretreats an average of 5,000 gallons of rinsewater a week using 600 pounds of seed material and generates one cubic yard of metal hydroxide sludge. The management and staff at the 1270 complex are actively working on ways to eliminate or reduce process wastes. Two recent projects are to install a deionization unit to allow for closed-loop recycling of rinsewater and redesigning process bath tanks to reduce raw material use. Both projects are described below.

Procurement and Installation of a Deionization/Water Recycling System--

A deionization/water recycling system was purchased and installed in the 1270 complex. The system will ultimately allow treated water to be reused as rinsewater in the 1270 complex processes. An additional benefit is the volume reduction of wastewater treatment sludge. The saturated by-product of the new deionization system will then be processed by the pretreatment system (Bldg. 1270C) on the fifth day.

It is expected that this project will reduce the amount of seed purchased and sludge generated as well a reducing the associated costs. After the system is up and running the Electronics Technology Branch will try using the purified water from the system as rinsewater. The capital cost of the new system is $20,000. It has been estimated that the avoided costs will be $19,868, based on reduced sludge generation and seed material costs.

The new system should pay for itself in less than one year based solely on reduced waste volume. The cost savings from reusing treated wastewater as rinsewater has not been estimated.

When the system is operational, it will need to be certified by HRSD for operation. The system will require a considerable amount of time to workout operational logistics and optimize the system to achieve full efficiency (75 percent reduction in sludge output; 80 percent reduction in seed material used). Recycling of pretreated water will be considered when the new system is operating at maximum efficiency.

Testing of the new system is currently in progress. The system was installed in January, 1994. Certification by HRSD should be completed by May 1994. The system should reach maximum efficiency or or before January 1996, at this point, water recycling will be considered.

Electroplating Tank Size Reduction--

In the past, these tanks required 156 gallons of chemical concentrate per year for proper solution chemistry of the printed circuit board operation. The process tanks used in the printed circuit board manufacturing were in need of replacement due to rising maintenance costs and upgrades to meet customer requirements. When the new equipment was ordered, consideration was given to minimizing the size of the thirteen tanks. This was accomplished by soliciting customer requirements and by determining the maximum chemical-loading-rate requirements of the various chemistries being used. After determining load rates and customer requirements, recommended tank specifications were 19 percent smaller, in most cases, and in some cases 50 percent smaller. The new tanks were operational in March of 1991.

The benefits of this project included reduced chemical supply costs, reduced waste generation, and reduced labor costs to process wastes. Chemical costs savings due to tank size reductions are $652 per year. Reduced waste generation and reduced labor costs to process wastes have not been quantified. There have been no problems with production, performance, or product quality with the new tank designs.

Implementation of Photolab Pollution Prevention Assessment--

As part of the Pollution Prevention Program Plan, a Pollution Prevention Opportunity Assessment (PPOA) of the Center's photolab and other similar activities that generate silver bearing wastes was performed. The PPOA recommended several pollution prevention options to improve photolab operations.

- Modify quality assurance operations to reduce waste generation.
- Install a water meter in order to monitor water usage to establish baseline information.
- Minimize water usage and reuse rinsewater when possible.
- Return packaging materials to manufacturer.
- Install solution level alarms on waste photographic solution storage containers to prevent waste solution from overflowing and draining into the floor drain.
- Minimize evaporation losses of photographic solutions.

The photolab, Bldg. 1155, is a major generator of silver-bearing wastewater. In 1992, the lab began implementing silver recovery procedures. Previously, the waste solutions had to be disposed as hazardous waste. A new procedure to remove the silver from the waste photographic solutions was implemented using the metal replacement canister method. Extensive testing was done to ensure that silver in the effluent from the canisters would meet discharge permit levels. The used canisters are sent to property disposal, which ships them to Defense Reutilization and Marketing Organization for sale to metal recovery companies. These new procedures have reduced hazardous waste disposal and recovered material for recycling.

The photolab has begun implementation by installing a water meter to establish baseline water usage. This baseline will help to document actual or potential cost savings from any pollution prevention opportunities involving water usage. The photolab will begin implementation of the other recommended opportunities involving water usage after applicable information has been available for one year.

Implementation of the photolab PPOA will significantly reduce the amount of hazardous waste generated and waste disposal costs. Additional benefits include reduced operating and raw material costs, reduced waste management labor, and reduced liability.

Implementation of the first of these will save an estimated $35,000 per year. Table 3 lists each pollution prevention opportunity with its potential impact, anticipated cost savings, and implementation cost. A first-order economic analysis of each opportunity was provided in the PPOA.

Although no schedule for implementation has been established, OEE continues to work with photolab personnel to implement one or more of these projects.

TABLE 3. POLLUTION PREVENTION OPPORTUNITIES FOR PHOTOPROCESSING ACTIVITIES

Opportunity	Potential Impact	Anticipated Cost Savings ($/yr)	Implementation Cost ($)
Modify General Processing Procedures	Reduced paper, chemical, water use, and silver recovery processing	35,000	Minimal
Install a water meter in order to monitor water usage	Establish baseline information for future pollution prevention options	None but will allow OEE to monitor water usage to quantify water reductions	1,856
Minimize water usage and reuse rinsewater when possible	Reduced water usage	Unquantifiable without water meter	Minimal
Return packaging materials to manufacturer	Reduced solid wastestream	No direct cost reduction but will contribute to the Center recycling program	194
Install solution level alarms on waste photographic solution storage containers	Reduce potential for overflows of untreated photographic solutions into floor drains	No direct cost reduction but will reduce possibly liability costs	260
Minimize evaporation losses	Reduced replenisher use	Unquantifiable	Minimal

Centralized Silver Recovery Unit--

Photoprocessing and x-ray operations are located at ten facilities, Bldgs. 1148, 1149, 1163, 1202, 1205, 1238, 1256, 1268, 1270, and 1296, throughout LaRC in addition to the main photolab, Bldg. 1155. Photoprocessing facilities are used to develop photos used in LaRC publications and for special events. X-ray processing is used for various research projects and for medical diagnosis. The operations performed include batch mixing of photochemicals, plate-making, negative and x-ray development. Wastes generated from LaRC photoshops include silver-bearing liquid wastes. Liquid wastes from x-ray and photo developing operations are hazardous because of the high silver content. The goal of this project is to recover silver from photoprocessing wastes and reduce waste disposal costs by eliminating off-site hazardous waste shipments of silver-bearing liquids.

A centralized silver recovery unit will be set up for operation in the new pollution prevention support building by late 1994. The equipment will be used to recover silver from all silver-bearing waste-generating operations, except the main photolab, which has its own recovery system. OEE will develop an implementation plan and standard operating procedures for the centralized silver recovery unit.

Implementation of this project will ensure uniform management of all silver recovery activities. Silver flake will be recovered from the waste solutions. Disposal of silver-bearing liquids as hazardous wastes will be reduced by approximately 1,200 gallons and the resulting disposal costs will be lessened by approximately $3,000. The economic benefits to NASA from implementation of this project will vary depending on the efficiency of the electrolytic silver unit. If the unit can remove enough silver to meet regulatory requirements, the economic benefits will be higher than if the unit must be operated in series with secondary metal replacement cartridges to meet regulatory requirements. Revenue from the recovered silver is not included in the analysis because of the uncertainty of recoverable quantities and silver price fluctuations.

OEE must obtain a permit modification to discharge effluent from the centralized silver recovery unit to the HRSD system. In addition, before mixing solutions from different facilities, compatibility of solutions should be tested (e.g., bleach fixers cannot be mixed with regular fixer) to insure proper and safe operation. The pollution prevention support building is scheduled to be completed in 1994. The equipment will be installed soon thereafter. Some trial runs are expected to confirm the operational efficiency of the recovery system.

Termination and Restriction of ODC Class 1 Compound Usage--

CFCs have been the solvent of choice NASA-wide to clean wind tunnel components such as valves and piping. NASA has established a written policy to phase out the use of CFCs and other ODCs in response to the Montreal Protocol and the CAA Amendments of 1990. NASA has established a goal of eliminating non-essential uses of chlorofluorocarbons and methyl chloroform [1-1-1 trichloroethane (TCA)]. As a result, NASA LaRC has already begun terminating from the supply system Class 1 - ODCs as defined by the 1990 CAA Amendments. The Langley Research Center CFC/Halon Materials Requirement Report, issued annually, called for discontinuing the use of TCA at the end of the second calendar quarter of 1993. Accordingly, supply is only issuing TCA until the Center's current supply is exhausted. In November 1993, the Center targeted electrical contact cleaners containing TCA for replacement in stock supply. In addition to terminating TCA from the supply system, NASA LaRC has restricted the use of CFC 22, CFC 11, CFC 113, and CFC 12 for use as refrigerants only.

The LaRC OEE staff worked with the facility staff to systematically replace ODCs with alternatives such as aqueous cleaners. The LaRC staff is striving to eliminate all use of ODCs. An ongoing effort is to identify an alternative to CFC-113, which is used to verify the cleanliness of parts after they have been cleaned. The verification process involves placing the cleaned parts to be tested in a beaker. Approximately 100 ml of CFC-113 is poured over the cleaned parts. The CFC-113 solution is distilled and the amount of volatile and non-volatile residue are determined. The use of CFC-113 for verification is a NASA-wide specification. Alternative verification processes and solvents are being researched by NASA and LaRC staff.

Aqueous cleaners have been found to be a viable substitute for many operations. Several projects to reduce and eliminate the use of ODCs are described below.

Aqueous Cleaner Replaces Trichlorotrifluoroethane for Cleaning Oxygen Systems--

Oxygen system parts and components from wind tunnels were cleaned with trichlorotrifluoroethane (CFC-113). LaRC operating specifications required the use of CFC-113 for cleaning oxygen systems. Approximately 825 gallons of CFC-113 were used annually to clean the oxygen systems.

The LaRC staff decided to replace CFC-113 with alkaline detergents. They tested a number of different commercial alkaline detergents using them with high-purity deionized water in an ultrasonic cleaner. The goal of the project was to find a detergent that could clean as effectively or more effectively than CFC-113. The initial project was performed in a laboratory using small components contaminated with a known amount of contaminant. The contaminant used was chosen because it is extremely difficult to remove. Using various detergents with deionized water and ultrasonics, LaRC staff determined the detergents with the best cleaning performance were Selig 101 and Brulin 815GD. After the laboratory test stage, a scale-up test was started. In this project, different alkaline cleaners, including the two mentioned previously, are being used in the actual cleaning environment.

Aqueous cleaning has replaced the use of CFC-113 in 99 percent of the cleaning operations. Cleanliness verification results show the aqueous cleaning is effective and meets cleanliness standards. Savings are estimated at $15,000 in raw material cost as of 1993. Projected savings are greater as the cost of CFC-113 continues to increase rapidly due to the declining commercial production and availability of CFCs in response to statutory mandates. Tests are still being conducted to evaluate other cleaners to improve cleaning efficiency. A related effort was to rewrite the LaRC operating specifications to allow non-CFC cleaning.

Aqueous Cleaning Replaces Freon-113 for National Transonic Facility Cryogenic System Parts--

The NTF houses a large wind tunnel used for aeronautic investigations of the boundary layer between Mach and sub-Mach speeds. Aqueous cleaning replaced the use of CFC-113 to clean small metal parts used in cryogenic systems in the NTF wind tunnel. The annual consumption of 70 to 130 gallons of CFC-113 has been eliminated by switching to an aqueous detergent. Parts are cleaned in an ultrasonic vapor degreaser manufactured by Blackstone. There was no equipment modification required to switch from using CFC-113 to aqueous cleaning. There were no increased costs associated with the change.

The detergent adequately cleans the parts. However, there has been a problem with excessive foaming. The NTF staff are experimenting with other detergents to find one that does not foam as much and still cleans the parts adequately.

Switching to aqueous cleaners at the NTF has resulted in a substantial cost savings by eliminating CFC-113 use. Annual expenditures for CFC-113 used for cleaning the wind tunnel components was approximately $18,000 in 1991.

Switching to aqueous cleaning generates a new wastestream. The wastewater from the cleaning unit is collected, tested, and discharged to the sanitary sewer. In the past the dirty CFC-113 not lost by evaporation was collected, recycled, and reused.

Non-CFC Cleaning of Flight Hardware--

CFCs, especially CFC-113, are currently being used as the wash and rinse solvents to precision clean flight hardware. Precision-cleaning removes particles by ultrasonification and removes organic contamination by dissolution.

This project involved testing the cleaning efficiencies of ten different cleaners in order to find a solvent to replace CFCs. The ability of each solvent to clean flight hardware was determined by measuring the amount of non-volatile residue. Isopropyl alcohol cleaned better than all other solvents tested. Aqueous solvents were unacceptable because they left a residue on the parts being cleaned. In many cases the parts were dirtier than when they began. Isopropyl alcohol cleaned parts better than CFC-113. The lab has converted one ultrasonic tank to allow the use of isopropyl alcohol and a deionized water rinse.

The lab has decided, however, to continue to use CFC-113 until the phase-out date. A deionized water blanket in the CFC-113 tank has substantially reduced CFC-113 loss from evaporation. The Center is planning to purchase an agitation cleaning system which can use a variety of solvents including alcohols, aqueous solutions or water (Martin Marietta Jet Clean PC100) for additional testing.

Aqueous Parts Washing in the Aircraft Landing Dynamic Facility, the Vehicle Maintenance Shop, Engineering and Fabrication Building, and the Boiler Plant--

Degreasing parts and equipment is done at a number of buildings within the Center. During the Program Plan development, thirty-two facilities using solvent-based cleaners were identified. Traditionally, parts both metal and non-metal (e.g., teflon or plastic), were cleaned using degreasers containing solvents. Staff cleaned parts in various washer tanks containing solvents such as xylene, methylene chloride, or petroleum naphtha.

A Program goal is the total elimination of the use of solvents for cleaning purposes. The conversion from organic solvent degreasers was prompted by a number of factors. Organic degreasers used at the Center must be managed as hazardous materials because of their flammability and/or toxicity. Organic solvents also generate hazardous wastes and volatile organic compound (VOC) emissions. Workers at one facility also expressed concern over potential health risks from being exposed to the solvent.

Aqueous cleaning has replaced solvent cleaning at four locations which previously used organic solvents. The locations include the engineering and fabrication building, the machine shop, Aircraft Landing Dynamics Facility, and the Vehicle Maintenance Shop. Four different biodegradable aqueous cleaners are in use; Big Blue, Natural Blue, Formula 088, and Citraclean. The aqueous cleaners are used in the existing parts washer tanks, equipment, and tanks at three of the locations. At the Vehicle Maintenance Shop two aqueous parts washer machines (Better Engineering Model 200P and Impulse Model) were installed at a cost of $11,692.

The primary advantage of using an aqueous cleaning system is that it reduces the occupational hazard, waste management costs, and environmental liability associated with solvent parts cleaning. Approximately 3,500 pounds of hazardous waste and 2,000 pounds of VOC emissions have been reduced annually by changing to aqueous cleaners. Approximately $1,000 in direct waste disposal costs have been avoided annually. Raw material costs have also been reduced since the aqueous cleaners are typically less expensive than the solvent cleaners.

The switch to aqueous cleaners has been successful. Aqueous cleaners effectively remove oil, grease, soil, and other contaminants from parts. Cleaning parts with aqueous cleaners takes approximately one-third longer compared to using the solvent degreasers. However, this has not slowed down work, since the technicians soak the parts in the tank prior to cleaning. There have been some problems with rusting, however; at one facility the inside of the parts washer tank lid rusted. The Vehicle Maintenance Shop, which switched to aqueous cleaning in October 1993, experienced some start-up problems. Initial results of using a terpene-based cleaner were not acceptable. The cleaner caused flash rusting of the parts to be cleaned, piping, and spray nozzles in the parts washer equipment. The terpene-based cleaner also emulsified the oil so that it was not removed by the oil skimmer. Workers also complained of the strong odor given off by the cleaner. The Vehicle Maintenance Shop staff have since switched to an alkaline aqueous cleaner that does not cause rusting, has no objectionable odors, and cleans sufficiently.

The parts cleaners in use at the four facilities are not connected to drains. The cleaning solutions are reused, therefore, have no associated disposal costs. Makeup water and fresh detergent are added to the solution as needed. The sludge in the tank bottoms have not required disposal. Once the sludge builds up to a level where cleaning the machine is required, the sludge waste will have to be tested to determine the correct disposal method.

Electronic Document Transfer To Eliminate Paper Use–

The NASA LaRC technical library provides a service whereby researchers can request and obtain copies of articles, journals, and other publications. The library staff locates the publication, photocopies the material, and sends the researcher a paper copy of the requested materials. The library uses an estimated 20 reams of paper per week to photocopy requested publications.

The library is investigating the use of electronic transfer methods to replace the paper copies. Under the new system, documents will be scanned and sent electronically via LaRC Net (the local area network) to the researcher.

Advantages of electronic document transfer include eliminating the use of paper and corresponding paper purchase costs, and reducing paper waste. An additional benefits is the reduced storage space for new journals and publications can be purchased in digital form such as a CD ROM. Once the publication is scanned or transferred into a digital file, it can be stored in a fraction of the space needed for a hard-copy document. This will eliminate the need to store hard copies of the publication. Documents stored on diskette or CD ROM have much longer shelf-life than hard-copy documents, many of which are now falling apart due to age.

There is some concern that the new system will not be appropriate for transferring documents containing technical or engineering drawings. It may not be possible to accurately scan engineering drawings and other technical graphics. These types of documents may still need to be stored and transferred using paper copies.

The current software under consideration can only process (scan, convert by software, transfer to a diskette, or sent across the Local Area Network) one page at a time. This is unacceptable since the library staff typically copy multi-page documents. The labor required to wait while each page is processed is judged to be prohibitively expensive. The software is reportedly being upgraded so that the processing will be faster. The project is scheduled to identify and purchase the required hardware and software by late 1994.

Gas Cylinder Management and Recycling–

NASA LaRC annually purchases and rents several hundred compressed gas cylinders that are used for research and maintenance purposes. There are three ownership categories of compressed gas cylinders used at the Center:

1. Stock cylinders are government-owned cylinders that are issued by supply to LaRC personnel. Empty cylinders are returned to supply and then transported off-site to be refilled by a local vendor.

2. Rental cylinders are cylinders that are owned by a vendor but the contents (i.e., the gas) are purchased by NASA for use in various applications. The vendor charges NASA a daily rental for use of the cylinder and keeping the cylinder on-site.

3. Government-owned cylinders are cylinders that have been purchased from vendors. These cylinders vary in size but many of them are disposable cylinders. The disposable cylinders are designed for single use and not meant to be refilled. Government-owned cylinders do not include stock cylinders.

Many cylinders are kept on-site for several years and personnel lose track of the location of the cylinders. In addition, as personnel retire and the cylinders tags fade, knowledge of the contents and purposes of the cylinders are lost. A repercussion of this situation is that the Center must dispose of the cylinders at great expense. On the average, the cost for disposal of a gas cylinder as hazardous waste is about $300, but can vary significantly depending on the contents of the cylinder. In contrast, it costs approximately $27 to return a cylinder to a vendor or $75 to prepare and ship a cylinder to the Defense Reutilization and Marketing Organization (DRMO) for sale as scrap metal. Between 1993 and 1994, the Center disposed of, or returned to vendors, approximately 200 cylinders for a combined cost of $28,000.

The Center began working to improve cylinder management by first determining exactly how gas cylinders are currently managed and tracked. Rental cylinders were returned to vendors when empty. Government-owned cylinders were prepared for delivery to the DRMO by emptying the cylinder, removing the valves, and drilling holes in the cylinder. Stock cylinders are refilled by a vendor under contract to NASA LaRC.

After much investigation and discussions with many gas cylinder vendors, the Center found that many of the vendors will accept empty cylinders made by their company, even if the Center had purchased the cylinder. The gas cylinder vendors will not reimburse the Center for the cylinder but the Center avoids any cost associated with hazardous waste disposal. The Center's new policy for gas cylinders is to return all "returnable" cylinders (rentals and government-owned) to vendors instead of disposing of them as hazardous waste. Non-returnable government-owned and stock cylinders that are past their service life will be prepared for delivery to the DRMO for sale as excess government property.

The next step is to track gas cylinders in order to avoid future problems. Gas cylinders pose a unique problem from a materials tracking perspective since cylinders are often sent off-site to be refilled by local vendors and then returned to the Center. Although each cylinder has a unique serial number, this does not suffice for tracking and reporting requirements since each time a cylinder is refilled it may be used by a different organization. Additionally, for reporting requirements any tracking system will need to account for the usage of the gas in the cylinder, rather than just the cylinder itself. Given this, NASA is determining whether gas cylinders can be tracked using the Center-wide Chemical Materials Tracking System or whether a separate tracking system is required. The Center is reviewing a gas cylinder tracking program called Cyltrack from OMWARE Inc. for this purpose.

Implementing this project will reduce the number of cylinders disposed of as hazardous waste and the resulting disposal costs. Tracking of gas cylinders and their content will reduce the number of cylinders that have to undergo costly testing to identify their contents. Tracking of gas cylinders will also increase the material usage rates of gases in the cylinders. An intangible benefit of cylinder tracking is reduced liability to NASA for disposal of hazardous waste.

CHAPTER 3

FORT EUSTIS • FORT STORY

Fort Eustis and Fort Story, a sub-installation of Fort Eustis since 1962, are the home of the U.S. Army Transportation Center, 1 of 16 Training and Doctrine Command (TRADOC) installations. Fort Eustis, which has been owned and occupied by the U.S. Army since 1918, covers 9,000 acres of land, ranging from tidal wetland to bottomland forest. Fort Story, located 50 miles southeast of Fort Eustis on the Atlantic shoreline, has been a military installation since 1914.

ACCOMPLISHMENTS

Through TIPPP, Fort Eustis and Fort Story have conducted several pollution prevention activities, including the efforts summarized below.

Pollution Prevention Program Plan

In February 1993, Fort Eustis developed a facility-wide Pollution Prevention Program Plan. This plan is a blueprint for using pollution prevention techniques to reduce waste generation and environmental impacts caused by post operations.

Green Commissary Project

Fort Eustis developed and constructed a display for the entrance of its commissary that discusses the topic of "reduce, reuse, and recycle". It includes numerous publications from EPA on waste reduction, recycling, and other current environmental information. Fort Eustis also conducted two employee training classes on pollution prevention.

As part of the "Green" Commissaries TIPPP program, the Fort Eustis commissary was chosen to participate in a demonstration project being conducted to show how commissaries can "go green" and still maintain profitability. The commissary has initiated a comprehensive pollution prevention program that evaluates all aspects of its operations and ways to accomplish them in a more environmentally sound manner. Through the PPOA that has already been conducted and further environmental training, the commissary will significantly reduce its waste production and prevent pollution from being generated in the first place.

EcoLogic '93

Fort Eustis held its first-ever environmental fair on April 23, 1993 called EcoLogic '93. It supported the Army's environmental strategy and provided an opportunity to present environmental information to military and civilian personnel on Fort Eustis and to the surrounding communities. Over forty exhibitors participated and the response to the event was overwhelmingly positive.

Environmental Watch

Fort Eustis developed a quarterly publication that is distributed post-wide to keep everyone informed on pollution prevention and other environmental issues.

Environmental Stewardship Proclamation Ceremony

In support of the Army Environmental Stewardship Campaign, an Environmental Stewardship Proclamation Ceremony was held at Fort Eustis on November 19, 1992. During the ceremony, the Commanding General signed a proclamation affirming the Transportation Center's intentions to integrate environmental protection with the installation's mission.

Commander's Environmental Excellence Awards Program

Fort Eustis developed the Commander's Environmental Excellence Awards Program as an incentive to encourage personnel to document and tout their successes in environmental management and training and awareness programs. This program recognizes successful environmental initiatives with a quarterly award presented by the Commanding General. The first award was presented on Earth Day 1993.

1992 TRADOC Pollution Prevention and Recycling Award

To meet Army recycling goals, Fort Eustis established a recycling program which has been highly successful. From March 1990 to November 1992, for example, the following materials were recycled:

- More than 2 million pounds of paper
- More than 3 million pounds of metal
- More than 925,000 pounds of cardboard
- More than 316,000 pounds of glass
- More than 147,000 pounds of aluminum cans

In recognition of its success, the recycling program was given the 1992 TRADOC Pollution Prevention and Recycling Award and has been awarded the Department of Army's Pollution Prevention and Recycling Award for 1993.

Environmental Awareness Program

As part of its pollution prevention efforts, Fort Eustis has established an ongoing environmental awareness program. The program has sponsored many activities, included are:

- Various demonstrations for parts washers and non-hazardous solvents and lubricants, material substitutes, and other equipment to reduce hazardous wastes;

- Pollution prevention training classes for the Transportation Officer' Basic Course and the Transportation Officer's Advanced Course;
- An Environmental Day in October 1992 sponsored by the 24th Battalion; and
- A Household Hazardous Waste Forum, co-sponsored by the city of Newport News.

CHAPTER 4

LANGLEY AIR FORCE BASE

LAFB, located in Hampton, Virginia, comprises approximately 2,900 acres and is home to more than 9,000 military and approximately 3,000 civilian employees. The host unit at LAFB, the 1st Fighter Wing, is charged with the mission of maintaining combat capability for rapid global deployment to conduct air superiority operations. To accomplish this mission, the 1st Fighter Wing flies the F-15 Eagle, UH-1N helicopters and C-21 aircraft.

ACCOMPLISHMENTS

LAFB has conducted a variety of pollution prevention activities through TIPPP, as demonstrated in this chapter.

Pollution Prevention Management Plan

In 1991, LAFB developed a Pollution Prevention Management Plan that set forth the objectives of the installation for reducing pollution to the air, land, and water.

Plural Component Paint System

A plural component paint system was recently installed at the base. This system allows paint to be mixed in the exact quantities and packaged in units suitable for a specific job. Thinners required to clean the paint lines and equipment can be collected in separate containers for recycling. In addition, a high-volume, low-pressure spray gun will be installed to increase the efficiency of paint use. This new system will reduce the amount of hazardous materials entering and leaving the base and will reduce the amount of volatile organic compounds (VOCs) emitted.

Antifreeze Recycler

LAFB purchased an antifreeze recycling system to remove the metals, colloidal silica, and other harmful particulates in used antifreeze. The system will also restore corrosion inhibitors to the antifreeze, making it ready for immediate reuse. This process will significantly reduce the amount of hazardous material handled by the base.

Hazardous Waste Disposal Reporting System

LAFB has developed a computer-based reporting system to track hazardous waste disposal. This system identifies the waste associated with each operation, tracks the disposal of the waste, and provides other information required to make management decisions.

Household Chemical Pollution Prevention Program

Household chemicals are used throughout the base and resident housing for cleaning purposes. Often, facilities and residents have excess household chemicals that may inadvertently become part of the municipal solid wastestream. LAFB recently established a program which that allows facilities and residents to turn in excess household chemicals so that they may be re-issued for use, thereby avoiding disposal.

Solid Waste Management

Langley's recycling program is divided into areas that target different parts of the installation. The 1st Moral Welfare Recreation and Services Squadron recycles aluminum cans, office paper, and corrugated cardboard boxes for the administrative and industrial areas. The residential communities curbside recycling program recycles newspapers, corrugated cardboard boxes, brown paper grocery bags, glass bottles and jars, metal food and beverage cans, aluminum foil and foil products, metal aerosol cans, metal paint cans, and number 1- and 2-type plastic bottles and jars.

Environmental Awareness Programs

LAFB maintains an ongoing environmental awareness program that conducts numerous activities on-base and in the surrounding community. For example, the base sponsors an Earth-Week program each year. During Earth-Week, the base conducts educational and training programs, as well as poster and art contests to promote environmental awareness.

To publicize its efforts, LAFB uses various types of environmental awareness information sources including Federal and State EPA information publications, *Air Force Times*, the base newspaper, and closed-circuit television. By combining the efforts of the environmental programs with those of the public affairs, legal, and contracting offices, LAFB is more efficiently educating the base community on environmental issues.

Reuse of Jet Fuel at the Flight Line

The process of powering down an aircraft generates approximately one-quarter gallon of JP-5 fuel which is collected in a sump on the aircraft. Personnel at the flight line remove the fuel from the sump and deposit it into specially designed 125- or 660-gallon containers called bowsers. The recovered fuel in the bowser is tested for contamination and moisture content. If the test results show the fuel is within specifications the fuel is returned to the main fuel storage tank. The recovered fuel is mixed through the bulk storage filter banks prior to being used to refuel aircraft. This process recovers approximately 2,400 gallons of fuel annually. Cost savings are estimated at $1,848 in raw material ($0.77/gallon) and $432 in avoided waste disposal charges ($0.18/gallon).

CHAPTER 5

NAVAL BASE NORFOLK

Naval Base Norfolk, located in the Tidewater, Virginia, area, covers approximately 5,400 acres of land, hosts approximately 200 tenant commands, docks more than 100 ships, and employs more than 100,000 military and civilian personnel, qualifying it as the largest naval base in the U.S. Navy. The base is situated in the Chesapeake Bay watershed and is surrounded on three sides by water – the Elizabeth River, James River, and Willoughby Bay.

The mission of Naval Base Norfolk is to provide quality support to the tenant commands. Tenant commands are very diverse ranging from administrative to operational commands, such as Naval Station and Naval Air Station, to industrial commands, such as the Naval Aviation Depot and Shore Intermediate Maintenance Activity Norfolk. To carry out its mission, base personnel conduct a variety of operations, including paint stripping, painting, engine maintenance, cleaning, and other operational and repair work. These activities consume large quantities of chemicals and materials and generate many different types of hazardous and non-hazardous wastestreams.

ACCOMPLISHMENTS

Through TIPPP, Naval Base Norfolk has completed numerous pollution prevention activities which are highlighted in this section.

Household Hazardous Waste Program

Using the LAFB program as a model, Naval Base Norfolk established a household hazardous waste program in five family housing areas. By collecting and re-issuing household chemicals, this program helps to ensure complete use of the materials, avoiding their disposal.

Recycling Program

The recycling program at Naval Base Norfolk has been very successful since its establishment in the mid-1980s. Currently, the base recycles approximately 30 percent of its solid waste, which saved approximately $3.4 million in disposal costs in FY 1992. Norfolk's recycling program is ranked number one throughout the Navy and number three in the DoD.

Waste Minimization Plan

TIPPP was instrumental in helping to gain funding to prepare the Naval Aviation Depot Norfolk Waste Minimization Plan, which was finalized in June 1993. This plan includes environmental baseline information and several pollution prevention opportunities for the depot which generates significant quantities of wastes.

Environmental Awards

In recognition of its environmental excellence, the Naval Aviation Depot was awarded the Navy's Environmental Quality Award for a large industrial activity in FY 1992. In addition, two individuals from the depot received environmental awards in FY 1992 for their work in promoting the environment. John VanName, environmental engineer, received the Secretary of the Navy Individual Pollution Prevention Award for his work in waste minimization, and Kevin Summers, supervisory environmental engineer, was the runner-up for the Individual Environmental Quality Award.

PPOA Training

As part of its pollution prevention program, the base established a PPOA training program in FY 1992. Approximately 25 personnel have been trained in the opportunity assessment process. This training will be essential to the successful implementation of the Waste Minimization Plan.

Improvement of Paint Stripping and Painting Operations

Other environmental efforts in pollution prevention at Naval Base Norfolk include converting wet-spray paint booths to dry booths. This effort will reduce the quantity and toxicity of paint wastes, reduce emissions of VOCs, and increase the efficiency of using raw materials. Efforts to minimize blast grit in the cleaning and paint shops has also been implemented to further reduce waste generation.

Plating Waste Minimization

A recent waste minimization project for plating activities has significantly reduced heavy metal sludge-bearing waste containing chromium, cadmium, silver, and nickel. Using commonly available equipment, this project has reduced the quantity and toxicity of rinsewaters generated during plating, stripping, and cleaning processes and has greatly reduced the waste disposal costs associated with plating activities.

Hazardous Waste Minimization

Through its aggressive hazardous waste minimization program, Naval Base Norfolk has reduced its hazardous waste disposal requirement from 408,000 gallons in FY 1990 to 253,000 gallons in FY 1992. The primary focus of the program has been on training and education, and on single point hazardous material issue at the Naval Air Station Supply Department and Naval Supply Center Norfolk Paint Mart and Reutilization Store.

Aqueous Parts Washers

To reduce solvent use in the parts cleaning process, aqueous parts washers were installed aboard the *U.S.S. Theodore Roosevelt* and at the Shore Intermediate Maintenance Activity (SIMA) Norfolk. These parts washers use high-pressure water and water-based cleaners, rather than chemical solvents, to clean the equipment. The parts washers on the *U.S.S. Theodore Roosevelt* represent the first such systems aboard ship; Naval Base Norfolk is working with other ships to install additional systems. The installation of the parts washer at SIMA Norfolk resulted in the cancellation of the base's single largest Safety Kleen solvent contract which will eliminate solvents and the procurement and disposal of rags, immediately saving the base $24,000 a year. More than $100,000 can be saved in labor costs the first year. Many other commands at the base and surrounding area have been provided demonstrations of this technology and have procured or are in the process of procuring additional parts washers.

CHAPTER 6

EPA RISK REDUCTION ENGINEERING LABORATORY

HE POLLUTION PREVENTION RESEARCH BRANCH

The Pollution Prevention Research Branch (PPRB) of the Risk Reduction Engineering Laboratory (RREL) is charged with research, development and demonstration of promising pollution prevention techniques and technologies. In accordance with the Pollution Prevention Act of 1990, PPRB research efforts focus on Source Reduction, Reuse, and Recycling alternatives in the reduction of waste generated in any media.

As Federal environmental objectives are identified for the 1990's, Agency programs are being restructured to meet new requirements. Chief among these is the increased importance of pollution prevention in all Agency activities. Further, all Federal departments and services have been directed to develop pollution prevention opportunities in order to decrease the total environmental burden resulting from Government activities, and to provide opportunities in both the public and private sector to reduce environmental risks.

THE WASTE REDUCTION EVALUATIONS AT FEDERAL SITES PROGRAM

In keeping with the Agency's responsibility to advise and cooperate with other Federal departments on environmental risk reduction, the PPRB has managed a technical support effort known as the Waste Reduction Evaluations At Federal Sites (WREAFS) Program. WREAFS was established to conduct research, develop and demonstrate opportunities to reduce the generation of waste from Federal activities. The Pollution Prevention Program Plan for NASA-Langley Research Center was produced under the WREAFS Program via an interagency agreement between NASA-LaRC and RREL.
WREAFS has also conducted technology evaluations and pollution prevention opportunity assessments in support of the NASA-LaRC program. Separately, WREAFS continues to support pollution prevention research and development efforts at Ft. Eustis and Naval Base Norfolk.

Since 1988, WREAFS has funded work on other Federal sites and it has supported RD&D with Federal departments through Interagency Agreements (IAG). WREAFS has sponsored pollution prevention opportunity assessments, base-wide assessments, technology and product demonstrations, technology evaluations, technology and methodology development, technical assistance and technology transfer across the Federal community. WREAFS has conducted cooperative RD&D activities with the:

- National Aeronautics and Space Administration,
- Department of Defense,
- Department of Treasury,
- Department of Transportation,
- Department of Energy,
- Department of Interior,
- Department of Agriculture,

- Department of Veterans Affairs, and
- the U.S. Postal Service.

Through WREAFS, the EPA provides support to Federal facilities in researching, developing and demonstrating pollution prevention technologies and transferring lessons learned among the Federal community. Continuing efforts under WREAFS has expanded to include projects that combine pollution prevention and compliance aspects in a single technical effort. A new publication in this area, entitled, "Federal Facility Pollution Prevention: Tools for Compliance," is being published by the PPRB and will be available by Fall 1994.

CHAPTER 7

CONCLUSIONS

The NASA LaRC pollution prevention program is a comprehensive approach to environmental management. It covers hazardous and nonhazardous wastes and emissions to all environmental media. Beginning with an environmental baseline data and program plan LaRC systematically examined all Center operations and activities to identify opportunities for source reduction or recycling. After ranking the opportunities LaRC pursued specific projects that target the best opportunities. This includes large volume wastes such as waste oil, wastes with high costs such as electroplating sludge, air emission sources, e.g., ozone depleting compounds and organic solvents, and solid waste recycling. Additionally, a series of foundation projects, (chemical material tracking system, pollution prevention support building, training, and employee outreach and communication), seek to institutionalize pollution prevention throughout the LaRC community.

NASA LaRC's pollution prevention program has resulted in substantial benefits. Over 50,000 pounds of hazardous waste have been reduced, the use of ozone depleting compounds has been lessened by 44 percent, and over $50,000 in waste disposal costs are avoided annually. Additional benefits include improved worker health and safety, reduced environmental liability, and enhanced environmental compliance. There is also growing awareness among the LaRC community of the benefits of pollution prevention. Implementing the pollution prevention program has required personnel throughout the facility to change their viewpoint. LaRC environmental staff work closely with researchers and support personnel to design and implement projects. Cooperation and frequent communication between the environmental staff and the research and support personnel has resulted in wide acceptance, and success, of specific pollution prevention projects.

TIPPP has demonstrated the value of a model community approach to integrating pollution prevention into the daily operation of Federal facilities. The installation programs and projects have shown the worth of pollution prevention concepts in achieving better environmental quality and more efficient production and operation. TIPPP accomplishments have forged a new understanding of the role of pollution prevention in supporting the environmental mission of Federal facilities. The individual pollution prevention projects and initiatives have confirmed the benefits of pollution prevention, both immediate and long-term.

The monthly meetings among TIPPP participants established a formal channel for exchanging ideas and solving common problems. Installation programs, in turn, provide the common pool of information and understanding on techniques, technologies, and strategies that might prove successful in reducing waste from all participating installations. TIPPP has fostered a cooperative spirit among the installation environmental managers that has extended beyond pollution prevention. An example is the joint participation of Naval Base Norfolk and NASA Langley Research Center in Earth Day events.

TIPPP has provided a proving ground for various pollution prevention techniques. This enables the participants to minimize redundant efforts. Information on prevention techniques and technologies have been disseminated through publications such as the PPOA surveys contained in Appendix A and the fact sheets included in Appendix B. This information is available to other installations or communities that might wish to establish a pollution prevention effort.

A long-term goal of TIPPP was to create a pollution prevention effort that will continue to function long after the pilot program. This goal seems assured. TIPPP is the genesis for an informal network whereby environmental and pollution prevention information and ideas are shared among the different installations. Other Federal installations in the Tidewater area have become active participants. In particular, the Naval Weapons Station at Yorktown and the Department of Energy Continuous Electron Beam Accelerator Facility are the latest TIPPP participants.

APPENDIX A

TIPPP POLLUTION PREVENTION OPPORTUNITY ASSESSMENT REPORTS

A series of pollution prevention opportunity assessments were performed at TIPPP installations. The assessments were conducted as part of the U.S. Environmental Protection Agency's Waste Reduction Evaluations at Federal Sites (WREAFS) Program. The assessments took place during the early stages of TIPPP and were intended to provide a pool of information on pollution prevention technologies common to the installations. The waste generating operations chosen for study were found at two or more TIPPP installations. A mix of industrial and non-industrial operations were selected in order to demonstrate the range of pollution prevention opportunities.

Working within time and resource constraints, EPA decided to cover a wider range of operations in less detail rather than study a couple of operations in great detail. Consequently, the reports are a survey of pollution prevention opportunities rather than a comprehensive assessment. Each report describes the waste generating activity, lists the wastes generated, points out opportunities for pollution prevention, and describes source reduction or recycling options. The main difference is the lack of a rigorous economic or technical evaluation of specific options. A lack of readily available data also limited the analysis.

The information contained in the reports, while accurate in 1991 when the assessment were performed, may no longer be current. Many of the operations have changed during the past three years.

POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

BLASTING OPERATIONS
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

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SAIC Project No. 01-0832-03-1021-010

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INTRODUCTION

Depainting operations occur whenever an anti-corrosive coating on a large metal structure needs replacing. Such structures include buildings, bridges, ships, storage tanks, and other large objects containing exposed metal surfaces.

There are two objectives in a typical depainting operation. The first is to free the coated surface of old paint, rust, and scale. The second is to make sure an acceptable surface profile has been left behind, so that the new paint will demonstrate acceptable adherence.

Most depainting jobs are accomplished using some type of blasting technology. In this group of technologies, small hard abrasive particles are directed under high pressure towards the structural surface. The impact of the particles on the surface removes the unwanted paint and, at the same time, scores the structural surface, creating the needed profile. The blasting abrasive of choice has traditionally been sand, chosen because of its low cost and availability.

Blasting wastes consist of blasting debris and blasting abrasive. For the purposes of this report, blasting abrasive is defined as any material applied to a coated surface for the purpose of removing the coating, and blasting debris consists of paint chips, dust, and mill scale removed from the surface during the blasting operation. Paint chips may also contain lead, zinc, barium, and/or selenium in the coating formulation.

There are a number of drawbacks to traditional blasting technologies from a pollution prevention standpoint; these include:

- Generation of heavy dust clouds, which are hazardous to workers and can leave the worksite and contaminate surrounding areas
- Mixing of blasting waste and debris, which creates a sizable amount of hazardous waste.

Concerns about waste generation, site contamination, and rising raw material and disposal costs have lead to the creation and implementation of new technologies and approaches that attempt to alleviate these problems.

This report outlines several strategies for environmentally sound depainting technologies, focusing primarily on the recyclable steel grit system implemented by EG&G, the operations contractor for NASA Langley Research Center. Information on this application was obtained through conversations with Ray Anderson (EG&G's point of contact), technology descriptions provided by the company manufacturing the blasting equipment, and case studies describing results and costs associated with use of the technology. NASA (through its contractor) is already implementing many of the suggestions contained in this report; the entire strategy is presented as guidance for ways NASA and similar facilities can enhance their current approaches. This report also examines alternative technologies, both for blasting and for containment of blasting debris which may be preferable for certain applications, depending on institutional, cost, and operational parameters. The descriptions of processes and status of projects ARE as of September 1991, when the onsite assessment was conducted.

PROCESS REVIEW

NASA Langley Research Center's physical plant contains a number of structures that require periodic blasting and repainting, including numerous wind tunnels coated with lead-based paint. The depainting system and procedure used on one wind tunnel is the basis for this report. Other structures at the Center scheduled for depainting operations in the near future include a plenum shell and the exterior of another wind tunnel.

The Sixteen-foot Transonic Wind Tunnel is a closed-circuit, single-return continuous flow atmospheric tunnel used for force, movement, pressure, and flow visualization studies on propulsion-airframe integration models. It presents several challenges for a depainting operation due to the unusual architectural features (ribbing, re-bar, etc.) and geometry that comprise the structure's surface. EG&G's objective was to identify and implement a combination of blasting and containment technologies that would clean the structure's surface, impart a surface profile suitable for repainting purposes, and realize pollution prevention goals, all while maintaining a cost-effective operation. For the project, a decision was made to use a recyclable steel grit blasting system, coupled with a variant of negative pressure containment technology.

Technology Description

Complete Abrasive Blasting Systems, Inc. (Kent, Washington) provided EG&G with their SABAR model MS-4-25-1 recyclable steel grit blasting system. The system included a model MS-6a abrasive blast machine, with a working pressure of 125 psig, four abrasive blast outlets (of which two are available for use at any time), an induction vacuum recovery system, a model SPI-16 combination interceptor/classifier capable of processing a minimum of 3.5 tons of abrasive each hour, a 165 cubic foot capacity storage hopper operating under 29" Hg of pressure, a model 3400 blast lighting system, a dust collector for the vacuum exhaust, and a skid for easy transport of the equipment.

The system had a total abrasive bin capacity of 285 cubic feet. A total blast cycle (using two blast nozzles) required approximately 11 hours, while a total reclaim cycle (using one vacuum) took approximately 12 1/2 hours, depending on hose length, air pressure/volume, and operator effort. The system was designed to be accompanied by conventional containment (tarps).

The containment tarps used by the facility were made by Aero Canvas Product (Cincinnati, Ohio). Specifications for these tarps include construction of 22 ounces vinyl coated white nylon, heat sealed fabric seams, Number 4 solid brass spur grommets every two feet on the perimeter, and external and internal flaps/aprons.

Process Description

EG&G describes its blasting operations as a mirror image of a typical asbestos removal process. A modular floor was laid under the worksite and the containment tarps installed to prevent leakage of hazardous debris from the blasting area. Containment consisted of the tarps and the slight negative pressure induced by the operation of the recovery system, with makeup air being added to sustain the partial vacuum and protect workers. The negative pressure helped keep fugitive dusts from exiting the containment structure through seams in the tarps. Blasting system operators (wearing respirators and Tyvec™ suits) position themselves a short distance from the coated surface during actual blasting. It is estimated that although some small quantity of steel grit was lost to the waste stream during each blast cycle (expenditure of a full system load of grit), it would still be more than 100 blast cycles before addition of replacement grit is needed. At that rate, spent abrasive was a very small fraction of overall waste generation during the operation.

Collected blasting debris is stored in 55 gallon drums. Used Tyvec™ and polyethylene film are disposed of in one cubic yard "Waste Wranglers", which can hold approximately the same volume of waste as four 55 gallon drums, yet can be disposed much more cheaply ($225 per drum versus $500 per Waste Wrangler). However, the Waste Wrangler was not strong enough to hold the heavier blasting media and paint chips, and so was not available for general waste disposal.

After completing a shift, operators washed themselves and their respirators with the wastewater flowing to holding tanks. The water then passed through a filter to remove lead contamination before sewer discharge. It is estimated that the operation generated approximately 1,000 gallons per week of this wastewater. Areas surrounding the site were tested periodically for possible debris contamination.

After the blasting operation was completed, the blasting team vacuumed the floors and the tarps, repainted the structure, and then disassembled the containment.

Process Savings

Savings from the use of this system when used to clean the tunnel interior (as opposed to the exterior now being blasted) totaled $2,087,990 when compared to conventional sand blasting technology. This figure includes $134,870 in reduced abrasive purchases, $262,920 in drum costs, and $1,690,200 in disposal costs. Environmental benefits include a significant reduction in the volume of hazardous waste generated by the operation, due to the separation of spent abrasive from the debris waste stream [9].

Depainting Operation Pollution Prevention Case Study

The following case study [7] is an examination of the factors affecting hazardous waste generation during depainting operations. In it, a grit-based blasting system, similar to the one employed by EG&G is used to test different containment technologies. The study was conducted on a steel bridge structure for the State of Michigan Department of Transportation. Three different dry abrasive blast processes were evaluated for the amount of abrasive used, amount of hazardous waste generated, worker safety/environmental conditions, and cost differences.

The three processes were applied to three different sections of the bridge with identical conditions. These conditions included peeling paint (25 percent of surface), light to heavy rusting (10 percent of surface) and heavy corrosion (8 percent of surface in expansion areas).

Once a coating has been applied to a surface the volume of blasting debris generation is roughly the same regardless of which containment technology is used. Therefore, the real variable in blasting waste generation (and disposal costs) is spent media. One of purposes of this experiment, therefore, was to identify the blasting/containment technology or combination of technologies that produced the largest reductions in blasting media waste volume and disposal cost.

Experimental design

The test runs were conducted using three different combinations of waste containment technologies. The basic test setup (Design 1) incorporated a blast pot, blast nozzles and a four-sided enclosure with ground drop cloths (total containment). Design 2 added a dust collector and stronger ventilation, and Design 3 used a negative pressure total containment system with cyclone separation of grit and blast debris (the level of technology attained by EG&G). The variables studied were the use, disposal, and cost of blasting abrasives.

Results

The study summarized each of the three tests and rated them as poor, fair or excellent. Design 1 was rated as "poor" due to cost and labor intensity of maintaining a 100 percent enclosure. In addition, there was very high worker exposure to hazardous lead dust and paint solvent fumes. This translated to a production rate drop and increased abrasive usage causing more pre-cleaning of the steel prior to painting.

Design 2 was rated as "fair" and is similar to Design 1 in that the enclosure maintenance was extremely costly. The advantage of Design 2 was associated with worker safety, with the addition of a ventilation system. The major difference between Design 1 and Design 2 was the volume and disposal cost savings of the spent abrasive. Design 1 resulted in 11.8 tons of hazardous waste disposed for $2,183 versus 10.4 tons non-hazardous, plus 2 5-gallon pails hazardous for a total disposal cost of $330 for Design 2.

Design 3, which was the most technologically advanced, was rated as "excellent". The work area did not need extensive containment, there was no daily clean-up activities outside the work area and minor preparation (vacuuming) of the steel was needed prior to painting. The hazardous waste volume generation for Design 3 was less than one cubic foot resulting in a disposal cost of $35.

The costs per square foot for each of the three designs was calculated and are summarized in Table 1. It was determined that Design 3 generated the least volume of hazardous waste and was the least expensive option overall of the three designs tested.

Cleaning rates did not vary significantly among containment designs. The most progressive design reduced waste generation dramatically, due to the addition of abrasive recovery technology. This study shows that:

- The cost difference between more rather than less comprehensive containment is small when compared with overall waste disposal costs (plus more containment provides better protection against containment leaks).

- Removing abrasives from the waste stream can be the most cost effective containment technology, as well as the most important pollution prevention technique.

TABLE 1. POLLUTION PREVENTION TECHNOLOGY ASSESSMENT CASE STUDY

Pollution Prevention Technology	Cleaning rate (sq-ft/hr)	Abrasive Waste Generation	Cost (per sq-ft)
Design One: 4-sided enclosure w/ drop cloths	116	11.8 tons	$1.30
Design Two: 4-sided enclosure w/ drop cloths, dust collector, ventilation	127	10.4 tons	$0.67
Design Three: Total negative pressure containment enclosure, ventilation, recycling equipment	118	< 1 ft^3 (spent abrasives)	$0.06

The study shows that significant levels of pollution prevention can be achieved through the use of technologies already on the market.

ASSESSMENT

A review of EG&G's blasting operation at NASA Langley Research Center was done in September 1991. Data on material inputs and outputs are not available at this time. Worksheets in EPA's

Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003) requesting process data were distributed by the pollution prevention assessment team, but were not returned.

Pollution Prevention Activities

NASA and its contractor have already implemented a number of environmentally-sound blasting operation waste management techniques that are a significant improvement over conventional technologies. The most important of these are:

- Recycling of steel grit abrasive
- Cyclone separation technology
- Vacuum exhaust dust collection
- Negative pressure full containment (with makeup air)
- Site sampling and analysis
- Wastewater pretreatment

Pollution Prevention Options

This section presents information aimed at supplementing and enhancing NASA's current and future blasting operations to become even more effective at pollution prevention. Because the EG&G staff are already implementing some of these ideas, they may be redundancies in the report. This section presents a comprehensive approach and may examine alternatives already in use at Langley. It presents information on new technologies gleaned from a variety of different sources that are aimed at reducing hazardous waste streams from blasting operations as much as possible. Pollution prevention alternatives are presented as two main options: source reduction and material containment.

Source Reduction Opportunities

The first priority in any pollution prevention scheme is source reduction - the attenuation or elimination of both the hazardous elements and the overall volume of the given waste stream. In this case, source reduction techniques can theoretically be applied to three waste stream constituents: blasting abrasives, blasting debris volume, and heavy metals contained in the debris.

Blasting Abrasive - eliminating abrasives from the waste stream has both environmental and economic benefits: it reduces the volume of waste needing disposal, and thus reduces both disposal and replacement costs. The following process substitutions are commercially available:

- Steel grit with recycle (currently in use)
- Power tools
- Flash blasting
- Cavitation blasting
- Cryogenic cleaning

Blasting Debris Volume and Composition - since blasting debris consists of coatings that have already been formulated and applied, little can be done to reduce their toxic nature or overall volume. Of the heavy metals, lead is of primary concern in older coatings, though zinc, barium and selenium are being used in current formulations and will eventually enter the waste stream as well. NASA estimates that, even though lead paint is no longer being used in coating formulations, it will be 5-10 years before the last of the lead already applied enters the waste stream. Lead will therefore continue to be a constituent of concern for the foreseeable future, and its management will have to be taken into account during blasting operations.

However, planning for the future will help ensure that hazardous waste generation does not impact blasting operations indefinitely. Specifications for new coatings can be formulated to include pollution prevention goals as priority items. For instance, non-toxic anti-corrosives can be substituted for lead-based pigments with little or no loss in product performance. Similarly, coatings can be specified which accomplish the desired anti-corrosion objectives with as few coats as possible. Institutional barriers may have to be overcome to incorporate pollution prevention objectives into coating formulations, but internalization of waste disposal costs into projected cost/benefit analyses may help make necessary changes easier to implement.

Containment Technologies

Containment does not have any explicit pollution prevention characteristics, due to the fact that it does not prevent waste from being generated. Its main contribution comes from the pollution prevention attributes of the technologies: by preventing wastes from exiting the blasting site, they significantly reduce or eliminate contamination of the air, ground and water surrounding the site (fugitive emissions).

Containment can be realized primarily through material control technologies. Types of containment technologies currently available commercially include: conventional total containment; negative pressure containment enclosures (as currently used by EG&G); and localized containment.

Based on a cursory assessment of available technologies and project requirements, several source reduction and containment options were selected for feasibility analysis. The source reduction technologies include power tools and cryogenic cleaning. Containment technologies include negative pressure containment enclosures and localized containment.

FEASIBILITY

A feasibility analysis was conducted for each component of the pollution prevention options. A brief discussion of each option is presented below.

Power Tools

Technology Description - power tools are applied directly to the painted surface, removing the coating by reciprocating or rotating action. They have applications on any type of curved surface or structural material. Examples of power tools include needle guns and rotary peening machines.

- Needle guns have multiple reciprocating needles powered by a pneumatic piston. Needles are enclosed by vacuum shroud, and cutting debris is drawn towards the vacuum source for collection.[1]

- Rotary peening machines have tungsten carbide tipped flap assembly removes coatings in much the same way as steel shot does. Peening machines can also be outfitted with dust collectors.

Both types of tools remove the abrasive from the waste stream, thus reducing the volume of hazardous waste. Although more labor intensive than other alternatives, power tool technology offers lower waste handling and disposal costs (no media enters the waste stream), and thus may be cost effective if disposal costs are included in the decision-making process.

The following is a review of three power tool case studies, including data on cleaning rates, waste generation, and cost per square foot and is summarized in Table 2.

TABLE 2. CLEANING RATES, WASTE GENERATION, AND COST PER SQUARE FOOT FOR THREE POWER TOOL BLASTING PROJECTS

Case Study	Cleaning Rates (sq-ft/hr)	Waste Generation (per sq. ft off wall cleaned)	Cost per square foot
Case Study #1	80	220 gallons/8,600 sq. ft.	Not available
Case Study #2	14 - 18	3.2 gallons	$3.05
Case Study #3	60 - 100	.75 gallons/100 sq. ft.	$4.50

Case Study #1 - Two 4,300 square foot tanks in California were recently cleaned using needle gun technology. Four 55 gallon drums of hazardous waste were generated, and containment of the debris was characterized by an outside consultant as "near 100 percent".[1] The vendor estimates that conventional blasting would have generated about 55,000 pounds of waste (an estimated 95 percent reduction).[1]

Case Study #2 - a power tool performance test was performed on a bridge in North Carolina. One-half the bridge was sandblasted to SSPC-SP10, and on the other half power tools were used to remove the coating down to mill scale. Material - "I" beam with 16" web coating system 4.2 mils thick.(2)

Case Study #3 - power tools were used to clean a 60 foot diameter spherical tank. Material - 7 mil of coating, including a red lead primer.(2)

Cryogenic Cleaning

Technology Description - cryogenic technology uses frozen CO_2 (dry ice) in pellet or crystal form as the blasting media. The carbon dioxide reverts to gaseous form once the coating has been removed from the wall, thus eliminating abrasive wastes from the waste stream.

Cryogenic cleaning is perhaps the best technology reviewed in terms of source reduction. It does not harm the blasting surface, nor does it require a recycling system. Questions include its inability to sufficiently score surfaces for repainting, and its removal efficiency for hard coatings (epoxies, etc.).

Table 3 provides is a quantitative/qualitative review of available data regarding abrasive technologies, as compared to steel grit with recycling (Table 3).

Negative Pressure Containment Enclosures

Technology Description - a large vacuum pump induces a negative pressure gradient within the containment area, keeping the air virtually free of dust (a conventional baghouse system is used to filter particulates from the airstream). Blasting system operators wear air-supplied hoods while in the contained space.

Drawbacks include the need to make a significant additional capital investment in containment equipment, the danger of lead intoxication due to seam leakage. However, operator protective gear, such as respirators and Tyvec™ suits, can minimize the chance of such a situation arising.

TABLE 3. ASSESSMENT OF DEPAINTING TECHNOLOGY FOR
THE NASA LANGLEY RESEARCH CENTER
CURRENT TECHNOLOGY VS. POLLUTION PREVENTION OPTIONS

Criteria	Current Technology	Option #1	Option #2
Quantitative Data	Steel grit with recycling	Power tools	Dry ice
Cleaning rate (sq ft/hr)	150	14 - 100	70
Waste generation		.75 gal/100 sq ft	
Cost ($/ft^2)	$0.95	$3.05 - 4.50	$51/ft^2 ($CO_2$ only) [Schmidtz, ASAF]
Qualitative Data			
Comparability with existing containment procedures	Yes	Yes	No
Waste hazard reduction	No	No	No
Alternative's adverse environmental impacts	All media eventually winds up as waste	Cutting heads must be replaced; maintenance for tools	CO_2 is released to atmosphere

Localized Containment (Vacuum Blasting)

Technology Description - vacuum blasting allows the abrasive/debris mixture generated by blasting to be moved directly to a storage hopper for separation and/or disposal with no area cleanup or total containment costs incurred.[3] Vacuum blasting can be combined with continuous or non-continuous forms of recovery/reuse technology for enhanced pollution prevention.

Advantages of localized containment include maximized worker protection, minimized fugitive emissions, and blasting waste containment efficiencies of greater than 99 percent.

Drawbacks include the difficulty of keeping an effective vacuum seal on curved surfaces, and operator fatigue due to the effort required to keep the shroud in place against the structural surface. Worker education in vacuum shroud operation may help minimize leaks.[3]

Table 4 provides a quantitative/qualitative assessment of an alternative and current containment technologies.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

The blasting operations described in this report could be implemented at facilities which may have need of blasting operations. Localized containment technologies, although not feasible for use on the Transonic Wind Tunnel due to its unusual architecture, might possibly be implemented on job sites where the painted surface is more regular in shape. EG&G's operators can also prove to be a valuable asset in disseminating practical worksite experience with the new technologies to other worksites within the TIPPP program. As is the case with NASA Langley Research Center, a number of planning studies would have to be evaluated before the full feasibility of any technology described in this report could be evaluated.

TABLE 4. ASSESSMENT OF CONTAINMENT TECHNOLOGIES FOR THE NASA LANGLEY RESEARCH CENTER CURRENT VS. ALTERNATIVE

Criteria	Current	Alternative
Quantitative Data	Negative pressure containment enclosure	Localized Containment
Containment efficiency	Not Available	95 - 99%
Qualitative Data		
Compatibility with existing operating procedures	Yes	Yes
Waste hazard reduction	Good	Good
Treatment/disposal cost reduction	Good	Very Good
Safety hazard reduction	No	Yes
Effect on operation quality	Very Good	Very Good

MEASUREMENTS OF POLLUTION PREVENTION

Measuring the impacts of pollution prevention activities requires baseline data on wastes and their disposal costs, as well as installation, operation and maintenance, and labor and overhead costs for each blasting operation. Much of this background data were not available from the NASA Langley Research Center. Table 5 provides a list of facility information required to conduct a PPOA and the documents wherein the information is contained.

Before a final recommendation can be made about which of the technologies presented in the report best fits a specific worksite's needs, a complete facility database must be assembled and analyzed. In addition, criteria similar to those in Tables 3 and 4 should be used to evaluate the application of pollution prevention techniques.

IMPLEMENTATION

All of the technologies presented in this report are available commercially, and thus their application is limited only by the respective technologies. For instance, cryogenic cleaning has great potential because of its pollution prevention capabilities, but cannot be used where no previous surface profile exists. Localized containment, while possessing excellent pollution prevention characteristics, is difficult for the operator to hold in place, and difficult to use when the painted surface is not absolutely flat. Combinations of technologies may be used to overcome certain limitations, as evidenced by NASA experience.

Other initiatives, such as new coating re-formulation, may be hindered by organizational resistance to change. Technical obstacles such as specifications for longevity and corrosion protection exist. Also, the cost of any pollution prevention program may exceed a facility's ability to implement it, despite the certainty of overall program cost benefits due to reduced waste disposal and contamination costs.

TABLE 5. FACILITY INFORMATION FOR POLLUTION PREVENTION ASSESSMENTS

Information Required	Location
Design Information	Process flow diagrams
	Material/heat balances
	Operating manuals/process descriptions
	Equipment lists
	Equipment specifications and data sheets
	Piping and instrument diagram
	Plot and elevation plans
	Equipment layouts and work flow diagrams
Environmental Information	Hazardous waste manifests
	Emission inventories
	Biennial hazardous waste reports
	Waste analyses
	Environmental audit reports
	Permits and/or permit applications
Raw material	Material application diagrams
	Material safety data sheets
	Raw material inventory records
	Operator data logs
	Operating procedures
	Productions schedules
Economic Information	Waste treatment and disposal costs
	Utility and raw material costs
	Operating and maintenance costs
	Departmental cost accounting reports
Other Information	Company environmental policy statements
	Standard procedures
	Organizational charts

Finally, pre-existing contracts for materials or depainting systems may exist which preclude the implementation of superior technologies for the foreseeable future. The extent to which these barriers obstruct change will ultimately determine the success of blasting system pollution prevention operations at TIPPP installations.

RESEARCH DEVELOPMENT AND DEMONSTRATION (RD&D) NEEDS

In order to make definitive choices based on sound pollution prevention practice, and to provide the data necessary to make such choices in the future, NASA Langley Research Center should undertake a number of RD&D studies. These would involve taking test stretches of typical structures and materials at the Center and subjecting them to the various depainting technologies described above. Parameters such as cleaning rate, overall waste generation, containment, and cost could then be compared under conditions unique to the Center.

New technologies are constantly being made available that may be preferable for some applications to any of the technologies listed in this report. The Steel Structures Painting Council is an excellent source of information regarding state-of-the-art technology and case study reviews. Periodic assessment of new technologies should also be done before any major new investments in depainting technologies are made.

RECOMMENDATIONS/CONCLUSIONS

A pollution prevention opportunity assessment was performed on the depainting operation at NASA Langley Research Center in September, 1991. A review of the operations currently being conducted by EG&G was performed, and documentation of their current system and process operations was obtained. More specific data on waste generation, cleaning rates, and costs is needed to refine the pollution prevention activities proposed in this report. Two types of technology based pollution prevention techniques were identified:

- Source Reduction Opportunities
  - Re-formulate new coatings to eliminate toxic hazard and minimize coating volume
  - Use cryogenic cleaning where surface profiles already exist (e.g. those previously grit blasted or rotary peened)

- Containment Opportunities
  - Use localized containment when feasible

In addition, sustained operator education efforts will continue to minimize fugitive emissions from the worksite.

NASA Langley Research Center, through its contractor (EG&G), already employs a number of recommended source reduction and containment technologies. Although NASA is currently employing pollution prevention activities resulting in the reduction of hazardous waste, additional data is needed to determine the overall "best available technology". The case study cited in this report details the type of pollution prevention study which should be conducted at NASA. This would result in direct comparative data which translates into potentially increased volume reduction of hazardous waste at NASA.

Other commercially available technology options were identified in this report. Additional future pollution prevention activities should include a review of these technologies to determine future potential implementation feasibility at NASA.

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT LABORATORY WASTES AT THE NASA LANGLEY RESEARCH CENTER HAMPTON, VIRGINIA

by

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA), the Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA), are developing a pollution prevention model community project in the Tidewater, Virginia area. The Tidewater Interagency Pollution Prevention Program (TIPPP) includes Langley Air Force Base, Norfolk Naval Base, Ft. Eustis (Army), and NASA Langley Research Center (LaRC). Under TIPPP, the participants are identifying, studying, and implementing alternative practices that will reduce wastes, emissions and adverse environmental impacts at these facilities.

This report summarizes a pollution prevention opportunity assessment conducted with NASA representatives at the Langley Research Center in Hampton, Virginia as part of TIPPP. EPA supported TIPPP facilities as part of its on-going Waste Reduction Evaluations at Federal Sites (WREAFS) Program. This assessment was funded by EPA and was conducted in cooperation with LaRC officials. The WREAFS Program is focused on identifying and developing management protocols as well as technical changes that might reduce waste at LaRC. This report has been developed to describe pollution prevention techniques that may be applicable to other similar governmental and industrial facilities.

The purpose of the WREAFS Program is to identify and promote use of pollution prevention techniques and technologies through technology transfer. Under the WREAFS Program, innovative pollution prevention techniques/technologies are identified through an initial opportunity assessment for a specific process or operation. Various prevention opportunities and alternatives may then be evaluated through research, development, and demonstration (RD&D) projects. In the past, EPA has initiated and conducted both individual and joint RD&D projects that investigate pollution prevention alternatives. The results of these projects are then presented to both the public and private sectors through various technology transfer mechanisms, including: project reports, project summaries, conference presentations, workshops, and EPA information clearinghouses, libraries, and document repositories.

As part of the WREAFS Program, pollution prevention opportunities are assessed using the procedure described in the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003). An opportunity assessment consists of the following phases:

- **Planning and Organization** - organization and goal setting
- **Assessment** - careful review of a facility's operations and wastestreams and the identification and screening of potential options to minimize waste
- **Feasibility Analysis** - evaluate the technical and economic feasibility of the options sele cted and subsequent ranking of options
- **Implementation** - procurement, installation, implementation, and evaluation (at the discretion of the host facility).

Many of the opportunities identified during WREAFS projects involve low cost changes to equipment and procedures that may be employed at other federal facilities or in private industry. These pollution prevention opportunities can often be implemented by the facility without extensive engineering evaluations. Other opportunities identified during these projects will require further study before full implementation can be realized. Typically, opportunities requiring further evaluation are those that have the potential to affect the process and/or require the use of new procedures or equipment. In such cases, it may be necessary to conduct demonstration projects to generate detailed data on the feasibility of the option.

As part of the WREAFS Program, pollution prevention opportunities were assessed at LaRC in the spring and fall of 1991. The assessment team consisted of EPA Risk Reduction Engineering Laboratory (RREL) and contractor staff. The assessment team met with representatives of LaRC's Safety and Environmental Management Section to determine the goals of the pollution prevention opportunity assessment. At this meeting, the participants decided that the assessment would focus on a general, facility-wide assessment of laboratory waste generation and management practices.

PROCESS REVIEW

LaRC is located in Hampton, Virginia occupying 787 acres of government-owned land. The facility shares aircraft runways, utilities and some facilities with neighboring Langley Air Force Base. An additional 3,200 acres of marsh land is under permit to LaRC and is used as a test range for model aircraft. More than 3,000 employees conduct research and/or work at LaRC in approximately 190 buildings including laboratories, wind tunnels, workshops, and offices.

In initiating the pollution prevention opportunity assessment, the first effort focused on understanding those activities that resulted in waste operation. The nature of these activities provided insight into the specific types of wastes and potential pollution prevention alternatives. A summary of the types and volumes of waste generated was used to identify those operations of greatest concern that may be amenable to pollution prevention. As part of the LaRC assessment, therefore, both the general site activities and types of wastes generated were characterized.

Site Activities

LaRC's primary mission is basic research in aeronautics and space technology including aerodynamics, material sciences, structures, flight controls, information systems, acoustics, aeroelasticity, atmospheric sciences, and nondestructive evaluation. Approximately 60 percent of LaRC's efforts is in aeronautics, relying on over 40 wind tunnels and other unique research facilities as well as computer modeling capabilities which aid in the investigation of the full flight range -- from general aviation and transport aircraft through hypersonic vehicles. Various research efforts include:

- Studying improved flight control systems to aid aircraft in operating more efficiently in all kinds of weather and in crowded terminal airways;
- Examining wind shear, the cause of nearly 40 percent of U.S. airline fatalities; and
- Evaluating the National Aero-Space Plane to expand the limits in hypersonic (Mach 5-25) engines, heat-resistant materials, and supercomputers for engine and airframe design.

The additional 40 percent of LaRC's work supports the national space program studying atmospheric and earth sciences, developing technology for advanced space transportation systems, conducting research in laser energy conversion techniques for space applications, and providing the focal point for design studies for large space systems technology and Space Station Freedom activities. Various research efforts include:

- Managing data analysis from the Long Duration Exposure Facility (LDEF), retrieved from low-Earth orbit, where it exposed a wide variety of candidate space materials, optics, coatings, and other items to prolonged presence in space;
- Doing extensive work on the structure, aerodynamics and thermal protection for the Space Shuttle and contributed significantly to the return-to-flight effort that launched Discovery;

- Managing an extensive program in atmospheric sciences, seeking a more detailed understanding of the origins, chemistry and transport mechanisms that govern the Earth's atmospheric data using aircraft, balloon, and land- and space-based remote sensing instruments designed, developed, and fabricated at LaRC.

- Contributing to remote sensor technology for the Earth Observing System (EOS), the first phase of the international Mission to Planet Earth. EOS is envisioned as a network of up to five equatorial and four polar orbiting research satellites.

LaRC's record of accomplishments has made it a leader in diversified aeronautics and space research. These varied research activities result in various types of laboratory wastes that may pose threats to human health and the environment.

Waste Generation

Since LaRC includes a variety of individual laboratories, the majority of wastes are generated in relatively small quantities from laboratory research. Specifically, LaRC research results in spent chemicals, experiment residuals, and expired shelf-life chemicals. Further, most LaRC research activities may include common lab wastes such as solvents, used oils and gas cylinders; due to it's "cutting edge" research it may also generate exotic chemicals and materials (e.g. resins, composites, ceramics, etc.). In the past, such research activities have resulted in wastes requiring offsite hazardous waste disposal. Table 1 shows the types and quantities of waste generated. The 1991 waste disposal budget for LaRC was approximately $460,000. The types and amounts of wastes provide some opportunities for pollution prevention initiatives. These opportunities are discussed in the sections that follow.

ASSESSMENT

The LaRC pollution prevention opportunity assessment focused on the hazardous materials usage and resulting waste management. In general, the hazardous materials handling, usage, and disposal protocols of the facility was reviewed to identify any opportunities to reduce the amounts of hazardous waste generated and disposed. The assessment team sought to identify methods that would not limit or hinder current (or required) activities or and its researchers. The general pollution prevention opportunities that were identified as part of this assessment are described in the section below.

Several of the researchers at LaRC use the High Pressure Liquid Chromatography (HPLC) analytical method. A pollution prevention assessment conducted at the Department of Agriculture's Beltsville research facility concerning HPLC has been developed in a previous WREAFS project. Since LaRC researchers were interested in this assessment and the possible applications it might have on their HPLC usage, a brief discussion of general prevention techniques presented in that report is provided.

In conducting the assessment, several laboratory facilities were visited within the LaRC. In general, the nature of hazardous materials handling and usage depended upon the complexity and types of research conducted. The large variety of laboratories, varying research foci, and different waste types prevented identification on opportunities related to specific techniques. Rather, the emphasis was on providing LaRC with a general discussion of prevention techniques that might prove valuable for all of its laboratory facilities. In addition, this assessment was intended to identify laboratory operations that, upon future study by LaRC, might provide reduction opportunities. With the goal of providing LaRC researchers with a general discussion of prevention opportunities, the team studied several laboratories that were identified as representative of the various sizes and complexities of most

TABLE 1. HAZARDOUS LAB WASTE STREAMS AT NASA

Chemical Groups	Total
Solvents	3630 gal
Lab Packs	195 boxes
Used Oils	3000 gal
Spent Gas Cylinders	#
n-pentafluoroethyl	2
isobutylene	12
vinyl chloride	6
ammonia, anhydrous	14
sulphur dioxide	14
carbonyl sulfide	10
phosgene	2
mercaptan	2
methane	6
methyl chloride	8
difluoroethylene	4
dimethyl ether	4
ethyl chloride	4
ethylene oxide	4
trimethyl tin	2
argon hydrogen sulfide	2
monomethylamine	8
lithium metal	8
unknown	20

Notes:

The number of cylinders were generated between August 1990 and March 1991. All other waste quantities were estimated based upon manifests for the same eight-month timeframe. Waste volumes identified above do not reflect amounts of materials, if any, directly released to the environment (i.e., volatilized, spilled, etc.) during use or storage.

research labs at LaRC. Specifically, this document addresses the following topics related to the reduction of general laboratory wastes at NASA:

- current management activities aimed at reducing waste
- general pollution prevention techniques
- implementation of general pollution prevention alternatives
- prevention opportunities for specific laboratory functions

Current Management Activities Aimed at Reducing Waste

The LaRC Safety and Environmental Management Staff oversees an extensive hazardous waste management program. Since individual laboratories generate relatively small quantities of wastes, LaRC consolidates lab wastes into lab packs at collection points in each laboratory facility. The operation of each collection point is maintained by the research staff. Specifically, each research facility identifies a hazardous waste officer who is responsible for the lab's accumulation area. The hazardous waste officer is responsible for proper use of the collection point with respect to storage of hazardous materials prior to disposal.

LaRC has distributed responsibility for materials handling to the individual laboratories. As such, hazardous materials usage, handling and awareness concerning the potential impacts of hazardous chemicals tended to vary according to the type of research facility. Those facilities that primarily function as wet laboratories and use a large variety of chemicals tended to have more sophisticated hazardous materials tracking and handling procedures. For example, the composite materials laboratory in Building 1293 has established a program and computer system to track and manage hazardous materials. The process was designed to help the laboratory meet health, safety, and compliance requirements, but could be used to:

- Reduce toxic materials usage;
- Conduct mass balances to reduce emissions;
- Provide a model for other research labs to develop similar materials tracking systems;
- Function as an initial model for a Center-wide materials management network;
- Provide this research lab an opportunity to transfer excess chemicals to other laboratories onsite or sell excess chemicals through a regional waste/materials exchange.

Building 1293 provided a good example of how hazardous materials can be managed and tracked within a laboratory. The organization at this facility could be used as a template for all other facilities.

Various activities have been initiated at LaRC research facilities that may result in either source reduction or recycling of wastes generated in laboratory operations. For example, the LaRC environmental staff have already initiated an effort to segregate and recycle oils generated at the various laboratory facilities. Further, the LaRC purchasing organization encourages its laboratories to use existing chemical supplies before purchasing materials. Materials exchange or transfer is promoted through use of Center-wide electronic mail and on-line chemical inventories. Finally, in some laboratories, LaRC personnel were aware of the potential impacts of certain chemicals and were proactively investigating substitutes, especially for chlorofluorocarbons.

General Pollution Prevention Techniques

While evidence was found of existing pollution prevention efforts at the Center, there was not a uniform understanding of reduction concepts among the researchers interviewed. As such, to fully appreciate and capitalize on specific pollution prevention opportunities, LaRC personnel must first become more aware of prevention concepts and their potential impact on the environment. A number of references related to laboratory pollution prevention were identified during the course of this project. The American Chemical Society (ACS) is a leader in studying and promoting methods to reduce laboratory wastes. ACS has published two documents that provide useful information: The Waste Management Manual for Laboratory Personnel (1990), and Less Is Better, Laboratory Chemical Management for Waste Reduction

(1985). Further, EPA has published a document that describes applicable reduction techniques: Guides to Pollution Prevention, Research and Educational Institutions, (EPA/625/7-90/010 1990).

EPA has estimated that the total amount of hazardous waste generated by research/educational institutions is from 2,000 to 4,000 metric tons per year, less than 1 percent of the national total of hazardous waste generated annually. Most of these facilities generate small quantities of a wide diversity of wastes, and the types of waste generated may vary over time. The references above provide a number of generic "common-sense" approaches to laboratory pollution prevention including both source reduction and recycling methods. Examples of these methods are provided in Table 2. In addition, while source reduction and recycling methods are generally the preferred waste management technique, treatment can be an integral component of any laboratory waste management program. The American Chemical Society's (ACS) Waste Management Manual for Laboratory Personnel (1990) discusses in-lab treatment of hazardous waste that does not require the laboratory to have a (TSD) permit.

Implementation of General Pollution Prevention Alternatives

Although there are unique impediments to pollution prevention at laboratory facilities in general, LaRC can promote pollution prevention concepts through various efforts. The pollution prevention process is in the beginning stages at LaRC. Initially, LaRC personnel must gain a complete understanding of waste generating processes at the site. The waste tracking system contains information on waste generation (by building), yet the system does not report the quantities of wastes generated by individual processes. Until individual waste streams are identified and quantified, LaRC personnel will be unable to determine the full extent of existing pollution prevention opportunities. Additional information will be needed to develop any comprehensive pollution prevention program for the center.

Even without these data, LaRC could consider a number of pollution prevention initiatives. Specifically, they could increase control over the purchase and use of toxic materials through a centralized purchasing and warehousing system. Chemical orders are currently sent through a central purchasing department, but research and purchasing personnel are not instructed (or trained) to identify material substitutions (i.e., identify and procure less hazardous materials). Procurement personnel cannot order less hazardous materials when specific materials are requested by researchers. Responsibility for identifying less hazardous substitutes for laboratory uses lies with researchers. Procurement personnel, however, can be trained to identify and purchase less hazardous materials for non-research functions. The initial components of a systematic hazardous materials procurement and management procedure and computer tracking system already exist within some sectors of the Center.

Purchasing personnel do not have a procedure to limit or eliminate duplicative orders to avoid stockpiling of hazardous materials that might subsequently require disposal after shelf-life expiration. Under the current procedure, each laboratory places orders through the purchasing staff without cross-checking the chemicals currently stocked in other laboratories. LaRC's expansion of the central purchasing system in conjunction with establishing a central chemical warehouse is one potential solution to this problem.

Common laboratory chemicals such as solvents would be available immediately from a central location and dispensed in quantities required by laboratory researchers. This would minimize wastes generated from unused surplus. The central purchasing staff could be augmented with a pollution prevention procurement official who, understanding chemical acquisition and use throughout the facility, could police product substitution measures.

TABLE 2. EXAMPLES OF SOURCE REDUCTION AND RECYCLING OPTIONS

Pollution Prevention Techniques	Pollution Prevention Options
Waste Stream Segregation	Segregating hazardous and non-hazardous wastes.
Inventory Controls	Ordering chemicals in smaller containers in order to reduce onsite inventory and unused surplus.
	Conducting inventory control from cradle to grave onsite.
	Providing central warehousing for storage and distribution of chemicals to minimize excess inventory in individual labs leading to excess surplus.
Process or Equipment Modifications	Using smaller scale operations including microscale techniques. Such microscale approaches are not universally applicable to all experiments. Certain reactions, for example, may overheat and are more difficult to control when using microscale quantities.
	Reducing the amount of solvent used to rinse equipment.
Raw Material Substitution	Modifying specific experiments either by substituting non-hazardous or less toxic chemicals, using different analytical equipment, or improving the efficiency of yields. (Instrumental analysis can use 1/10 to 1/100 the volume typically used in wet chemistry techniques.)
	Substituting detergents, potassium hydroxide, or sonic baths for chromic acid solutions used to clean glassware.
Recycling	Reusing spent solvents in applications where purity standards are less critical, such as performing initial cleaning of glassware with spent solvent from the final rinse of previous cleaning operations (cascade reuse).
	Using spent acids and solvents on routine maintenance of buildings.
Training	Providing all employees with education on pollution prevention. For example, laboratory technicians who manage hazardous residuals should be trained in proper waste segregation and disposal practices. Researchers should be instructed on the adverse impacts research activities may have on the environment and possible strategies to design research projects that result in minimal waste and release of chemicals to the environment.

The key to reducing wastes at a laboratory facility rests in educating the personnel to be conscious of the amounts of waste they generate. In general, the chemical user may have some control over the volumes of waste produced but may not consider their relatively small individual volume a problem. They may not realize that all of the laboratories are contributing a relatively small amount to a cumulatively large problem. LaRC inform its researchers of waste issues and steps to reduce individual generation rates. To institutionalize pollution prevention, LaRC staff should consider the options discussed in Table 3. These options have been qualitatively ranked in Table 4.

These efforts would target the implementation of simple practices which would increase the awareness of the individual researchers. By incorporating waste reduction into routine laboratory activities, LaRC personnel can succeed in promoting waste reduction in all aspects of the facility. In the long-term, researchers may begin to incorporate waste reduction practices into their experimental design and implementation.

TABLE 3. LaRC POLLUTION PREVENTION OPTIONS

Pollution Prevention Techniques	LaRC Options
Training and Assessments	Expand on the existing pollution prevention ethic with further education and training. Successful efforts are already underway including paper recycling and source reduction in individual operations.
	Appoint a pollution prevention "officer" within each research institute to assist researchers with reduction and recycling initiatives. Pollution prevention representatives from all the institutes could meet periodically to discuss and compare efforts among institutes. Such information transfer is crucial for the adoption of pollution prevention throughout the LaRC and reduces repetitive pollution prevention development efforts.
	Develop and implement a plan to conduct periodic laboratory pollution prevention laboratory assessments using suitable, in-house expertise. Such assessments may uncover additional pollution prevention opportunities over time, emphasize NASA's commitment to pollution prevention and can be used to monitor the success of pollution prevention efforts.
Process or Equipment Modification	Keep abreast of commercially available technology changes as they relate to laboratory pollution prevention. When new technology is too expensive for individual labs to implement, consider pooling resources and locating instruments at a centralized facility which may be used by several laboratories.
	Reduce atmospheric emissions of chemicals from laboratories as part of a comprehensive pollution prevention program. Glassware and automated extraction systems are commercially available which will reduce these emissions. In addition, for some samples, emissions can be reduced through solid phase extraction techniques as opposed to classical liquid evaporation techniques that result in the release of the solvent carrier into the fume hood and subsequently to the atmosphere.
Waste Segregation	Segregate hazardous from non-hazardous wastes. Hazardous waste volumes are often unnecessarily increased due to the addition of non-hazardous wastestreams. Segregation alone can significantly reduce hazardous waste generation rates and disposal costs.
Pollution Prevention Policy	Require each lab to have a written waste management/reduction policy. Minimum requirements would include annual chemical inventories, the dating of chemicals as received, etc.
	If LaRC institutes a charge-back policy, they might consider encouraging laboratory chiefs to pool resources previously spent on hazardous waste disposal for the purchase of pollution prevention equipment or technologies (i.e., computers for inventory control, centralized solvent recovery stills, or new waste minimizing analytical equipment.

Prevention Opportunities for Specific Laboratory Functions

The objective of this assessment was to survey various types of laboratories to identify general prevention opportunities and subsequently provide NASA with some documentation concerning options. Also, the assessment was designed to provide LaRC researchers and environmental staff with specific pollution prevention concepts in order that they could perform more detailed analyses of commonly used, waste generating operations. These detailed pollution prevention assessments are being identified and initiated as part of LaRC Pollution Prevention Program Plan, currently under development.

TABLE 4. QUALITATIVE RANKING OF ACTIVITIES AFFECTING LaRC LABORATORY WASTESTREAMS

CRITERIA	Option #1 Education and Training	Option #2 Appoint Pollution Prevention Officer	Option #3 Conduct Lab Pollution Prevention Assessments	Option #4 Utilize New Technology by Pooling Resources	Option #5 Reduce Air Emissions through new extraction techniques
Effect on product or operation quality	4	5	5	5	5
Space requirement	3	3	3	3	3
Compatibility with existing operating procedures	5	3	4	4	4
Treatment/disposal cost reduction	5	3	4	4	4
Input material cost reduction	5	4	4	5	4
Extent of current use in industry	2	2	2	2	2
Capital cost	3	3	2	3	2
O&M cost	3	2-3	3	5	2
Additional labor requirements	3	2-3	3	4	2
Implementation period	4	4	5	4	3
Ease of implementation	4	4	4	4	3
Utility requirement and availability	3	3	3	4	4
Special expertise requirement	3	2	3	5	5
Alternative's adverse environmental impacts	4	5	5	4-5	5
TOTAL	51	46	51	57	48

The qualitative ranking system is based on the assumption that each option will have either a positive, a negative or no effect on current operating procedures. Using a system of 1 through 5, with 3 as a neutral or middle point, each option was ranked as either positive (more efficient, more cost-effective, more material-conserving, etc.), negative (more labor intensive, more expensive, more incompatible, etc.) or neutral. The scores were added, and an overall ranking was determined for each option. The options with the highest scores are those that best balance feasibility and accomplishment.

1 = very negative
2 = negative
3 = neutral
4 = positive
5 = very positive

TABLE 4. (Continued)

CRITERIA	Option #6 Waste Segregation	Option #7 Require Written Policy for Each Lab	Option #8 Institute Charge-back Policy	Option #9 Exotic Materials Reclamation
Effect on product or operation quality	5	4	3-4	5
Space requirement	3-4	3	3	1-2
Compatibility with existing operating procedures	4	5	5	4
Treatment/disposal cost reduction	4	4	5	5
Input material cost reduction	5	4	5	5
Extent of current use in industry	3	3	4-5	2-3
Capital cost	3	3	3	1-2
O&M cost	1-2	3	2-3	1
Additional labor requirements	4	2	1	2
Implementation period	3	4	3	3-4
Ease of implementation	5	5	4	5
Utility requirement and availability	3	3	3	2
Special expertise requirement	5	5	5	3-4
Alternative's adverse environmental impacts	5	4	5	5
		5		
TOTAL	54	46	53	46

The qualitative ranking system is based on the assumption that each option will have either a positive, a negative or no effect on current operating procedures. Using a system of 1 through 5, with 3 as a neutral or middle point, each option was ranked as either positive (more efficient, more cost-effective, more material-conserving, etc.), negative (more labor intensive, more expensive, more incompatible, etc.) or neutral. The scores were added, and an overall ranking was determined for each option. The options with the highest scores are those that best balance feasibility and accomplishment.

1 = very negative
2 = negative
3 = neutral
4 = positive
5 = very positive

As mentioned previously, researchers in the Center's wet laboratories were interested in understanding pollution prevention techniques that might apply to High Pressure Liquid Chromatography (HPLC) analyses. Further, providing LaRC with an example of a more detailed discussion of pollution prevention concepts as they might apply to a specific laboratory operation was desired. Based upon an assessment performed at the USDA Beltsville Agricultural Research Center (BARC), a discussion of pollution prevention techniques for HPLC usage by LaRC personnel was developed. The following discussion is presented to demonstrate the possible results of a more detailed assessment.

High Performance Liquid Chromatography (HPLC)

HPLC is widely used in routine analyses. In contrast to gas chromatography (GC), HPLC is capable of analyzing up to 20 percent of all known organic compounds, and would potentially analyze 60 to 70 percent of compounds analyzed by LaRC researchers. GC requires compounds to be relatively volatile and thermally stable, while HPLC can be used to perform analyses of low volatility compounds at room temperature. HPLC techniques are becoming much more important in the analyses of environmental samples. In 1988, EPA formed an HPLC Methods Development Group. This group works to develop HPLC methods for analytes that currently, cannot be detected and also to develop better methods of employing HPLC over existing techniques.

Some laboratories at LaRC rely upon HPLC in their research. Like other forms of chromatography, HPLC is used to separate, isolate, and identify components of mixtures. Sample components separate on a column containing solid adsorbent based on differing affinities for the packing material. The solvent system carries the sample through, separates the materials in the column, and washes separated fractions off the column. A pump provides the required solvent flow, while sensitive detectors identify and quantify eluting compounds. Sample extraction, HPLC analyses and other operations at LaRC result in solvent and sample wastes. In 1990 alone, LaRC personnel disposed an estimate of 3,600 gallons of solvent waste. HPLC samples, solvents, and sample preparation solvents were major contributions to this total waste volume.

There are numerous laboratories at the LaRC facility undertaking a variety of research oriented problems. Each lab uses specific sample preparation procedures and analyses. Based on comments received from interviews with LaRC personnel during the assessment, two general practices were identified that may provide opportunities for waste reduction: sample preparation and the HPLC analysis.

Sample Preparation

The sample preparation step isolates either components of interest or interferents from the sample matrix prior to analysis and quantitation by HPLC. LaRC personnel routinely perform liquid-liquid or solid-liquid extraction; extracting aqueous samples with an organic liquid, and solid samples directly with solvent. Often, LaRC personnel rely upon secondary extractions of the sample extract or the sample itself.

The two basic types of sample preparation are analytical (small scale) and preparative (large scale). The type employed depends upon the researcher's specific needs and goals. As its name implies, preparative procedures apply to the generation of large quantities (i.e., gram-scale) of material. This amount may be used to support numerous and varied sample analyses or to provide a purified component in sufficient quantity. Preparative processes command large sample sizes and solvent volumes; consequently, large sample wastes are generated.

In contrast, analytical preparations involve small scale processes, with the primary aim concentrating on sample information and identification rather than production. Additionally, these steps and studies are usually the precursors to the preparative stage. The focus on sample information/identification emphasizes the concern of analyte detection and therefore of analyte concentration in analytical preparation steps. To increase analyte levels, concentration steps are employed. The most common involves evaporation to dryness and redissolution. Different concentration factors depend upon the initial and final sample volumes. As an example, a sample volume of 2 to 3 L is concentrated to 10 to 100 mL. The resultant factor achieved is between one to two orders of magnitude. The higher analyte levels allow easier detection by HPLC.

As previously discussed, LaRC researchers engage in the analyses of varied samples and components. As an example, for an analysis that relies on a chloroform extraction, the sample is initially prepared by extraction with solvent. Afterwards, the analyst distills under vacuum the organic solvent, and the redissolves the extract distillate. The analyst discards the distilled solvent as hazardous and proceeds with the HPLC analyses. This example typifies the sample preparation step. The following sections consider possible pollution prevention ideas to minimize wastes generated from sample preparation.

Source Reduction--

As a result of the BARC assessment, two source reduction techniques were identified for sample preparation procedures that might result in reduced waste. They consist of solid phase extraction (SPE) and supercritical fluid extraction (SFE). SPE utilizes small disposable extraction columns containing sorbent. Columns are available commercially, and with a variety of sorbent types. The sample solution is introduced to the cartridge (or a filter) and either analytes of interest or interferents are selectively concentrated on the sorbent. The bound components can then be eluted off the column using a solvent with a higher affinity for the analyte than the sorbent. Separation, purification, and concentration of analytes of interest therefore occur based on the bonded silica chemistry of the sorbent. Cartridge costs range between $1.50 to $3.00 each.

SPE offers substantial savings compared to typical liquid-liquid extractions through reduced disposal costs. Estimates of reduced solvent usage by 98 percent are contained in one manufacturer's literature, and other literature indicates that 1 to 2 mL of solvent and a SPE filter accomplishes the same function as would 200 to 300 mL of solvent used for a direct extraction. While SPE should be useful in reducing wastes for LaRC, its application for pollution prevention is limited to aqueous solutions. Scientists at LaRC routinely use solvents to extract certain constituents from samples. In these instances, organic solvent use is required to solubilize or extract the constituents of interest from a sample. SPE in these cases would only be useful regarding pollution prevention if further component classification or purification is needed. Clearly, SPE usage lies in the domain of analytical sample preparation.

SFE is an innovative technique that offers great promise for replacing chlorinated solvent extractions in the near future. SFE requires a highly compressed gas above its critical temperature and pressure points. The gas is transformed into a supercritical fluid exhibiting high diffusion coefficients and low viscosities (relative to a liquid). These properties allow for very efficient transfer of solutes from the sample matrix into the supercritical fluid. Carbon dioxide is typically used and modifiers may be added to selectively extract fractions or compound classes from a sample. Varying the temperature and pressure (density) of the supercritical fluid can also allow for very selective extractions. For example, low density CO_2 extraction is similar to hexane, while higher density CO_2 extracts similar to benzene. SFE also offers shorter extraction times compared to organic solvents. After the extraction, supercritical CO_2 returns to a gaseous state at room temperature and pressure.

The benefits of SFE have been documented in various journals and trade magazines. When extracting hexadecane and chlorobenzene from diatomaceous earth, the standard Soxhlet extraction required a 20 to 40 gram sample and 300 mL of freon™. The analogous SFE method used 2 to 5 grams of sample and only 6 mL of freon. Extraction speed was increased with SFE, and the "cost of the analysis dropped from $12.50 for the standard Soxhlet extraction to $1.65 for SFE..." Another article states that a Soxhlet extraction using 450 mL of organic solvent varying in cost between $1.60 and $3.00, can be replaced with SFE methods at a fluid cost of $0.10. An additional $0.90 per extraction is required to dispose of the Soxhlet organic solvent, while no disposal costs are involved with SFE. This article further states that assuming an SFE instrument expenditure of $30,000, and based on an average workload of 150 extractions per week, the payback period would be less than 1½ years.

Various groups within EPA are currently studying SFE. Some EPA environmental laboratory methods will soon incorporate SFE into analytical methods. While the outlook for SFE looks very positive, additional research as well as formal method validation and promulgation is required before this technique becomes universally accepted and used. In addition to the concepts discussed previously, micro-extraction techniques should be used whenever feasible to reduce solvent usage and hazardous waste generation.

Recycling--

Although source reduction methods are highly preferred over recycling for pollution prevention purposes, recycling methods do play an important role. Distillation and reuse of waste organic solvents from sample preparation procedures may be feasible. Recycling is an issue of concern for LaRC researchers in that recycled solvents may not provide purity required for analyses. Currently, however, some LaRC researchers are distilling and reusing these spent extraction solvents. As such, LaRC researchers should identify those operations where recycled spent solvents can be used.

The distillation or rotary vacuum evaporation of spent extraction fluids should yield a virtually clean solvent for reuse. The solvent purity is achieved through the differing boiling points of the solvent and impurities. Since the impurities are biological and tend toward high molecular weights, they should have a small or negligible vapor pressure. Conversely, the low molecular weight solvents have much higher vapor pressures. A simple distillation under vacuum should separate the solvent cleanly from the biological impurities. A vacuum lowers the heat requirements for the distillation; and, thereby minimizes thermal degradation and subsequent distillation of biological impurities.

The efficacy of the distillation depends on the spent fluid composition. A mixture containing solvents of similar boiling points yields a clean but compositionally impure liquid. As such, spent extraction solvents should be bulked and categorized prior to distillation. This preliminary effort should produce a clean and compositionally pure distillate. The purity of the distilled liquid can be checked by injecting a sample into a gas chromatograph (GC) or by using a refractive index detector.

<u>HPLC Analyses</u>

HPLC analyses generate hazardous wastes through the solvents employed as the carrier media. This fluid provides the essential vehicle for sample transport through the HPLC instrumentation. The solvent delivery system pumps the aqueous/organic mixture through the injector, the column, and the detector. The resulting effluent is a blend of the sample and the initial influent liquid. Acetonitrile, methanol, and tetrahydrofuran typifies the organic portion of the media. As such, HPLC effluents are characteristically flammable and therefore hazardous.

Pollution prevention in HPLC begins with an understanding of how the separation process proceeds. The goal of the analyst is to achieve the best separation in the shortest time. To obtain this separation, the analyst can optimize the following variables:

- Mobile Phase Composition
- Stationary Phase Composition
- Temperature

- Flowrate
- Column Configuration
- Particle Size

Each of these factors play a significant role in achieving the desired level of separation. The first three variables control the elution time of the component (i.e., the time taken between component injection and detection). The last three variables control the width of the peak. As the peak narrows, detection sensitivity increases since the signal level rises above the detector's instrumental noise level. Conversely, as the peak broadens, the analyte signal mires in detector noise. Further, fast and slow eluting compounds will intuitively possess a corresponding narrow and broad peakwidth. The ensuing cumulative objective is therefore the segregation of analytes through time (elution time) and space (peakwidth).

The variables affecting the analyte elution time and peakwidth intermingle. The injected analyte has a relative affinity for both the mobile phase (solvent) and the stationary phase (column packing). A stronger affinity for the mobile phase yields a short elution time and narrow peakwidth, whereas a stronger affinity for the stationary phase yields a long elution time and broader peakwidth. To separate two or more components, their elution times must be different and their peakshapes must have minimal overlap. Additionally, the analyte exiting the column must be within a specific concentration range dependent upon the analyte and the type of detector being used. This ensures analyte detection.

By manipulating the parameters, the analyst obtains a separation within the shortest analysis time. This creates a higher sample throughput since more analyses can be done in an allotted timespan. More importantly, solvent waste is lowered because the generated waste volume (column flowrate x run time x # analyses) is minimized.

Source Reduction--

HPLC source reduction occurs from the minimization of solvent use. This impacts several areas, but in general, focuses on the column processes and the instrumentation involved. A typical column contains 5 micron packing material and is configured at 4.6 mm i.d. x 25 cm length. Further, the typical column flowrate is approximately 1 mL/min. By switching to a different column internal diameter while holding the column length and particle size constant, solvent flowrate is reduced and separation integrity maintained. The comparisons are shown below:

Flowrate Comparisons

Column Dimensions (i.d., (mm) x length (cm))	Flowrate [mL/min]
4.6 x 25	1.0
2.0 x 25	0.2
1.0 x 25	0.05

Narrowing the column bore effectively reduces solvent consumption. However, other effects are created by modifying the column configuration. A narrower column (and therefore smaller volume) contains less packing material. Consequently, smaller sample sizes (and analyte levels) must be injected to prevent column overloading. On the contrary, this may be advantageous since a minimal sample amount reduces waste at the sample preparation step.

To increase sensitivity when using a smaller column, the analyst may also choose to reduce the packing particle size from 5 to 3 micron. This change enhances sensitivity by narrowing the analyte peakwidths. Further reductions in solvent consumption can then be attained if the column length is diminished. A shorter column length produces shorter elution and analysis times, while still maintaining adequate resolution.

Assuming an average laboratory performs 50 HPLC analyses per month with an average run time of 20 minutes, switching to a 2.0 mm i.d. column would result in a reduction of 2.5 gallons of hazardous waste generated per year. With HPLC solvent costs of $50 to 100 per gallon, and disposal costs of $5 to 10 per gallon, the method described above may result in significant economic gains when applied (if possible) on a facility-wide basis. If the column is reduced to a 1 mm i.d., other changes must be implemented to retain a required separation. The detector cell volume must be minimized from a standard 8 μL. This change is needed because the elution volume of the analyte has been lowered. A lowered detector cell volume is required to give an accurate portrayal of the analyte peak. Additionally, the injection volume must be less than 1 μL. An injection volume greater than 1 μL may change the composition of the mobile phase. This fluctuation affects the analyte elution times. Both the injection and detector cell volume changes are therefore required to maintain optimum sensitivity and peak characterization.

In summary, LaRC researchers might reduce wastes by converting to shorter and narrower bore columns containing a 3 micron particle packing for appropriate analyses. The resolution of the separation is maintained or increased, while waste volume is decreased. Conversion to a different column configuration requires a minimal or zero capital investment, dependent on column bore reduction. The cost of 4.6 and 2.0 mm i.d. columns incorporating either 3 or 5 micron packings are almost identical. If a 1 mm i.d. column is used, however, the injection loop and detector cell volume must be changed. These conversions require a typical investment of approximately $500 to $800, depending upon the instrumentation.

Communication between researchers may also foster source reduction methods. It was observed that numerous laboratories employ HPLC for analyzing the same constituents. Communication between group analysts may yield valuable information regarding the use of other methods and their analysis speed, reproducibility, accuracy, method detection limit, and prospective pollution prevention. A rapport between the facility HPLC users would distribute knowledge and expertise to all analysts. Besides communication, other source reduction methods for HPLC include:

- Preparing only the necessary amount of HPLC mobile phase solvent. Researchers can prepare an excess of this solvent which either is never used or requires disposal due to compositional changes over time.

- Stopping the introduction of solvent to the HPLC column as soon as required experimental conditions have been met.

Recycling--

An HPLC separation can be run under isocratic or gradient conditions. An isocratic separation means that the mobile phase composition is kept constant during the analysis. A gradient separation occurs when a mobile phase constituent, usually the organic modifier (acetonitrile, methanol, THF), is altered during the analysis. At LaRC, both types of separations are used. Isocratic HPLC wastes, however, are easier to recycle and reuse. The mobile phase employed in an isocratic mode is always of constant composition. Thus, the mobile phase exiting the column is approximately that entering the column. The added difference is that the exiting effluent contains the injected sample mixture.

"Spent" mobile phase can be reused depending upon the detection method employed. Typically, a sample component is diluted 100 fold after passing through the column. If this waste solvent is used again for separation, the waste injection analytes will again be reduced 100 fold when they exit the column. The dilution effects on the original sample multiply to yield a minimal increase in the baseline noise. This approach can generally be used for detection with a UV-Vis detector. It is, however, not as useful for very sensitive detectors such as the fluorescence detector or with highly absorbing compounds in the UV-Vis detector. A 10,000 fold analyte dilution may still be detected.

Alternatively, spent solvent could sequester previously eluted sample analytes prior to reuse by passing the solvent through a "trap" column. The trap column may contain the same support, but with a higher coating of stationary phase to ensure a high trapping efficiency. The particle size should also be large compared to the analytical column. This helps maintain a low backpressure prior to the solvent delivery system. Overall, this configuration enables the analyst to maintain a closed loop system whereby the solvent is continuously recycled. A periodic check on the trap column is advised in order to prevent contaminant breakthrough.

Distillation of the HPLC solvent is also a potentially effective procedure to purify solvents for recycle and reuse. This is analogous to recycling methods described previously for sample preparation waste solvents. In this case, however, the aqueous HPLC solvent would form an azeotropic (constant composition) distillate for reuse. This liquid should be as pure as the starting solvents (HPLC grade) since the biological impurities are nonvolatile. However, with respect to the initial HPLC fluid, the distillate composition may be different. The addition of fresh solvent to the distillate regenerates the initial HPLC mobile phase.

As previously discussed, the purity and compositional make-up of the solvent can be checked by using the GC or refractive index detector. This would be beneficial when solvents have been stored in containers over a long period of time. Furthermore, the waste HPLC solvents should be segregated respective of the assay. This separation enables easier and cleaner recycling and reuse. Recycled solvent unsuitable for use in HPLC applications could potentially be used in other ways by researchers. The required costs for distillation equipment and the trap column are minimal. Coupled with the high costs of HPLC-grade solvents ($50 to $100 per gallon) and of disposal ($10 to $15 per gallon), spent solvent recycling and reuse seems ideal. However, the required labor costs and solvent purity concerns may prove to be significant, and unacceptable to researchers.

Suggestions described above are general pollution prevention concepts that may or may not be applicable to the individual researchers at LaRC. In addition, some researchers may not consider their efforts to contribute to waste generation and thus are not likely to expend effort and funds on pollution prevention. The concepts described above should, however, have broad application to LaRC. The goal of any pollution prevention program is to ensure that all facility residents systematically identify whether or not they adversely impact the environment. further, if they do contribute to an environmental problem, they must know how to resolve it (preferably through source reduction) or who can help them resolve it.

Future Methods and Trends--

There are several methods currently under investigation which would greatly reduce organic solvent waste generation from HPLC analyses. The method theories, instrumentation, and application of these techniques are still in a developmental stage. SFE has previously been discussed as a method which could replace organic solvent extraction. An analogous method with respect to HPLC and SFE is supercritical fluid chromatography (SFC). SFC is in the developmental stage, less advanced than SFE practices, even though commercial units are on the market. SFC operation lies between the realms of GC and HPLC. As in SFE, the supercritical fluid possesses viscosities between those of liquids and gases. This provides for a more efficient separation of nonvolatile compounds when compared with HPLC. Additionally, SFC can utilize the detectors employed in GC. The universal flame ionization detector can therefore aid in quantifying difficult HPLC components such as carbohydrates, triglycerides, and fatty acids. It is similar to GC, however nonvolatile compounds can be separated and detected. By coupling SFE to SFC, a complete sample extraction and analyses may be obtained wherein virtual elimination of organic solvents is attained.

Capillary zone electrophoresis is another method which would greatly reduce organic solvent usage from HPLC. This technique involves the use of a high voltage differential between the inlet and outlet of a capillary column. Samples are loaded into a capillary filled with buffer solution. An electric potential field is established causing analytes to migrate at different rates and separate into discrete zones. The capillary tube length is approximately 100 cm with a diameter of 50 μL. This method has high resolving power and may replace HPLC as the method of choice for analyses performed at LaRC. The technique, however, is not widely accepted at this time as a standard method to replace HPLC.

FEASIBILITY

Waste generating operations at LaRC and similar research institutions provide obstacles to pollution prevention initiatives. Some of these obstacles are due to the nature of laboratory research, while others can be solved only by forces outside of LaRC's direct control.

There are over 70 individual laboratories performing scientific research at this facility. The nature of laboratory work results in a large number of small quantity wastestreams being generated. LaRC is different from industrial operations where large quantities of a certain waste type are generated, and payback periods for pollution prevention initiatives are relatively short given the application of appropriate technology (e.g. replacing solvent degreasers with alkaline washers). Conducting an engineering/scientific analysis of ways to reduce each LaRC wastestream will not be cost effective, and due to the small quantities generated, there may be little economic incentive for the free market to devise pollution prevention solutions to these problems. The limited solution to this problem is that scientists should be trained in the pollution prevention ethic. With such training, scientists can use their specialized knowledge in their research to incorporate individualized pollution prevention concepts into each research effort.

Scientific research presents other unique problems. There is a need for reproducibility of lab results over a long time period, and naturally scientists are reluctant to entertain changes in accepted procedures. Also, many of these analyses are performed according to standard methods used nationally and internationally. Deviations from those methods may cast suspicion on or invalidate their research in the eyes of their peers. Authorities responsible for methods development (e.g., EPA or Association of Official Analytical Chemists (AOAC), etc.) will need to continue to develop and incorporate techniques in approved methods that result in reduced waste. Further, it may be useful for these developing authorities to develop a comprehensive laboratory pollution prevention manual that becomes part of their standardized methods. This manual could include major topics such as solid phase extraction as well as other issues; such as substituting ethyl acetate for ether, hexane, or dichloromethane for cleaning the grease from ground glass. Such a manual, however, would require extensive research to define scientifically acceptable methods that result in minimal wastes. The techniques used in this report as alternatives were developed because they could provide more accurate or reliable results while coincidentally resulting in less waste. Laboratories could benefit from standardized, scientifically acceptable methods that are designed with reduced waste as a goal of the development effort. Such a method development effort, however, would require modification of how scientists are taught to design and develop techniques and research projects.

LaRC may also consider material and waste exchange as a viable option for pollution prevention. However, the discussion of waste exchange keys the issue of transportation issues with respect to moving chemicals. Using waste exchanges requires movement of waste be performed by a licensed hazardous waste transporter, with packages meeting all Department of Transportation (DOT) requirements. This increases costs for transfer of to the receiving facilities. Many of the regulations affecting LaRC support the overall public interest. Better communication between government agencies would be helpful in alleviating some of the unnecessary problems described above.

The researchers themselves present special challenges to pollution prevention efforts. While scientists are certainly able to implement pollution prevention, some believe that waste generation a necessary part of their work and that it is relatively unimportant. Other researchers do not believe it is cost effective for them (or their technicians) to spend time on recovering small quantities of solvent or taking similar steps. The complexity of the hazardous waste regulations acts as a barrier, preventing scientists and engineers from dedicating time to pollution prevention engineering.

For LaRC the problem lies in the fact that a variety of small operations may contribute to a large problem but researchers do not see themselves as a major contributor. In order to help in this potential problem it may be useful for LaRC to provide a forum to make researchers more environmentally aware while providing a unified forum to challenge or demonstrate inconsistent regulatory barriers.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

Wet chemistry research labs exist at all other TIPPP bases. The philosophical and awareness options identified in this report should be transferred throughout the TIPPP. The opportunity for TIPPP-wide material and waste exchanges would enhance source reduction effectiveness.

MEASUREMENT OF POLLUTION PREVENTION

Measurement of the successes of the options identified are dependant on establishing a definitive baseline of current waste generation and specificity. These data were not available at the time of the writing of this report.

IMPLEMENTATION PLAN

LaRC can begin implementing pollution prevention specific projects. Similarly, implementing a charge-back system to generate revenues for pollution prevention research would support the program. Finally, general awareness training, coupled with the development of a Center-wide plan will provide the foundation and support for subsequent pollution prevention initiatives.

RESEARCH DESIGN AND DEVELOPMENT NEEDS

Site-specific RD&D should be conducted for HPLC analysis. Establishing the exotic materials and waste exchange will also require research of the viability of the system, identification of exchange partners, and the tracking documentation to satisfy control of liability from one lab to another.

RECOMMENDATIONS

The initial effort provided to the LaRC is intended to be the with a starting point from which LaRC may begin to systematically investigate pollution prevention opportunities. During this initial assessment, several areas and concepts were identified that NASA could investigate further to define pollution prevention opportunities:

- Baseline Development -it is important to study and characterize the sources of laboratory wastes to understand the exact sources of waste materials, lab packs, and excess chemicals. This study should include identifying similar processes or operations among laboratories that may result in similar wastes. For example, LaRC personnel and scientists realize that they use HPLC analyses but the volumes generated by various laboratories is not well defined. To remedy this, LaRC should take existing waste generation records and identify the specific wastes and associate them with specific laboratories and operations.

- Materials Tracking - Some of LaRC's laboratories have already initiated computerized toxic materials inventory, use, and disposal tracking systems. Such efforts should be standardized, networked and expanded to include all laboratories at the Center. Such an system would provide the Center with a better understanding of the sources of wastes, amounts by waste type (as opposed to numbers of laboratory packs) and usage statistics. A chemical materials tracking system might allow the Center to order and use chemicals more efficiently. With this system, LaRC might reduce operating costs (through more efficient ordering) and decreasing waste of chemicals.

- Materials and Waste Exchange - In understanding its usage and waste generation patterns, LaRC may find opportunities to transfer materials between laboratories at the Center. The Center already has a limited system of exchange between laboratories using a computerized inventory of available chemicals. As this system is developed internally, LaRC may find that exchange with parties external to the NASA may also provide opportunities to find additional uses for materials that would otherwise require disposal as hazardous waste. Such activity may be limited by Transportation and/or LaRC regulations but still may be viable for some materials. Further, the establishment of a Chesapeake Bay Waste Exchange may provide a useful forum to test the usefulness of waste exchange practices for the Center.

- Exotic Materials Reclamation - The nature of LaRC's research may also provide a unique opportunity for reclamation of exotic (and usually valuable) chemicals at a centralized reclamation area. Specifically, the amounts of specialty metals and solvents used at the Center may provide LaRC with the opportunity to establish a chemicals reclamation operation onsite. The chemicals reclamation operation would be developed to reclaim specialty solvents, metals and other chemicals commonly used in various Center research operations. The reclamation operation could be funded with savings from decreased raw materials usage and hazardous waste disposal. In cases where the reclaimed material is not needed, the reclamation operation could receive additional funds through sales of reclaimed chemicals. In developing such a reclamation operation, the Center would need to:

    - identify exotic chemicals used;
    - quantify costs associated with purchase of these chemicals;
    - characterize the nature, volumes, and costs for disposal of wastes;
    - identify procedures and equipment needed to reclaim the materials;
    - determine which chemicals could be reused by LaRC researchers and which would be sold to parties outside of LaRC, and
    - balance the potential cost savings against costs for reclamation;

    Such a reclamation operation would be developed slowly with initial efforts focusing on easily reclaimed, extremely expensive chemicals that are currently disposed as hazardous materials after use.

Even after investigating and initiating appropriate efforts, LaRC must still perform what may be the most difficult effort of its pollution prevention program: bringing pollution prevention concepts to the consciousness of all LaRC personnel especially researchers. For pollution prevention to succeed at it is essential to identify and develop specific demonstration projects that can provide tangible results. Communication, education, and technology will help to bring about reductions in hazardous waste propagation. The personnel at LaRC have already demonstrated willingness to participate in some programs. For example, materials tracking is being developed and used at Building 1293. Such efforts might be used to demonstrate the ease of changing old procedures and the potential environmental, economic, and compliance gains that can be achieved through prevention concepts. Lastly, it is recommended that the Center develop a plan for educating its personnel on pollution prevention concepts and techniques as part of its pollution prevention program plan.

September 28, 1992

POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

NAVAL AVIATION DEPOT, NORFOLK, VIRGINIA
ELECTROPLATING OF NICKEL AND CHROME

by

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INTRODUCTION

Purpose

The purpose of this project was to conduct a Pollution Prevention Opportunity Assessment (WMOA) for selected processes at NADEP's Electroplating Shop. The assessment was conducted for the EPA's Risk Reduction Engineering Laboratory under the purview of the Tidewater Interagency Pollution Prevention Program (TIPPP) and the Waste Reduction Evaluations at Federal Sites (WREAFS) program of the Pollution Prevention Research Branch. A procedure described in the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003) was used to conduct the study. The manual provides detailed worksheets and a process/option evaluation method for use in industrial settings.

Approach

A PPOA consists of four systematic steps: Planning and Organization, Assessment, Feasibility Analysis, and Implementation. Figure 1 presents the PPOA process. Of the 19 worksheets in the WMOA manual, selected sheets were completed for the processes and waste minimization options considered. The detailed worksheets used are presented in Appendix A. The implementation of the recommended options presented in this report is at the discretion of the host facility.

PROCESS REVIEW

The Naval Aviation Depot (NADEP) at Norfolk, VA is one of six U.S. Navy facilities where aircraft are routinely overhauled. Each of these facilities employs up to 4,000 skilled industrial workers. The NADEP at Norfolk performs rework of F14 and A6 airframes, engines, and landing gear. The aircraft rework process consists of complete disassembly, inspection of reusable parts, remanufacture of parts, reassembly, and testing. The remanufacturing operations include numerous machining and metal finishing operations which generate significant quantities of hazardous and oily wastes. The focus of this study was metal plating which is performed at the NADEP plating shop. This facility contains more than 30 different metal finishing operations including: degreasing, aqueous cleaning, stripping processes for existing coatings, electroplating, electrolytic plating, anodizing, conversion coating, passivation, etching, and abrasive blasting.

A Pollution Prevention Opportunity Assessment (PPOA) was conducted for hard chromium and nickel sulfamate electroplating operations performed at NADEP, Norfolk. The two processes are used by the Navy primarily for building up worn surfaces of metal parts including engine and landing gear components. Following plating, the plated deposits are machined back to the specified dimensions of the part. Each of the two processes consist of several steps including degreasing, stripping, cleaning, plating, machining, and rinsing. Use and maintenance of the plating processes generates wastewaters contaminated with dilute concentrations of dissolved metals, spent process solutions, tank bottom sludges, spills/leaks of concentrated solutions, and spent carbon and cartridge filters from bath maintenance systems. Some provisions for pollution prevention have been successfully implemented at this facility and are documented in this report. Additional pollution prevention opportunities have been identified and evaluated during this study and recommendations for implementation have been developed.

The NADEP plating shop is located in building LP-24 which also houses a machine shop. The building was constructed in 1986. The plating shop has a first floor working area of 41,600 ft^2 and support operations and equipment on the perimeter, including: parts receiving/shipping, masking/demasking, abrasive blasting, ovens, chemical storage, precleaning, laboratory, offices, maintenance, mechanical, and rest room/break facilities. The plating room has a 16 ft. ceiling to accommodate the movement of long parts which are transported using manually activated electrical hoist systems. The tanks are arranged in 16 lines with each line being dedicated to one or two processes. Mezzanines, which hold rectifiers and support

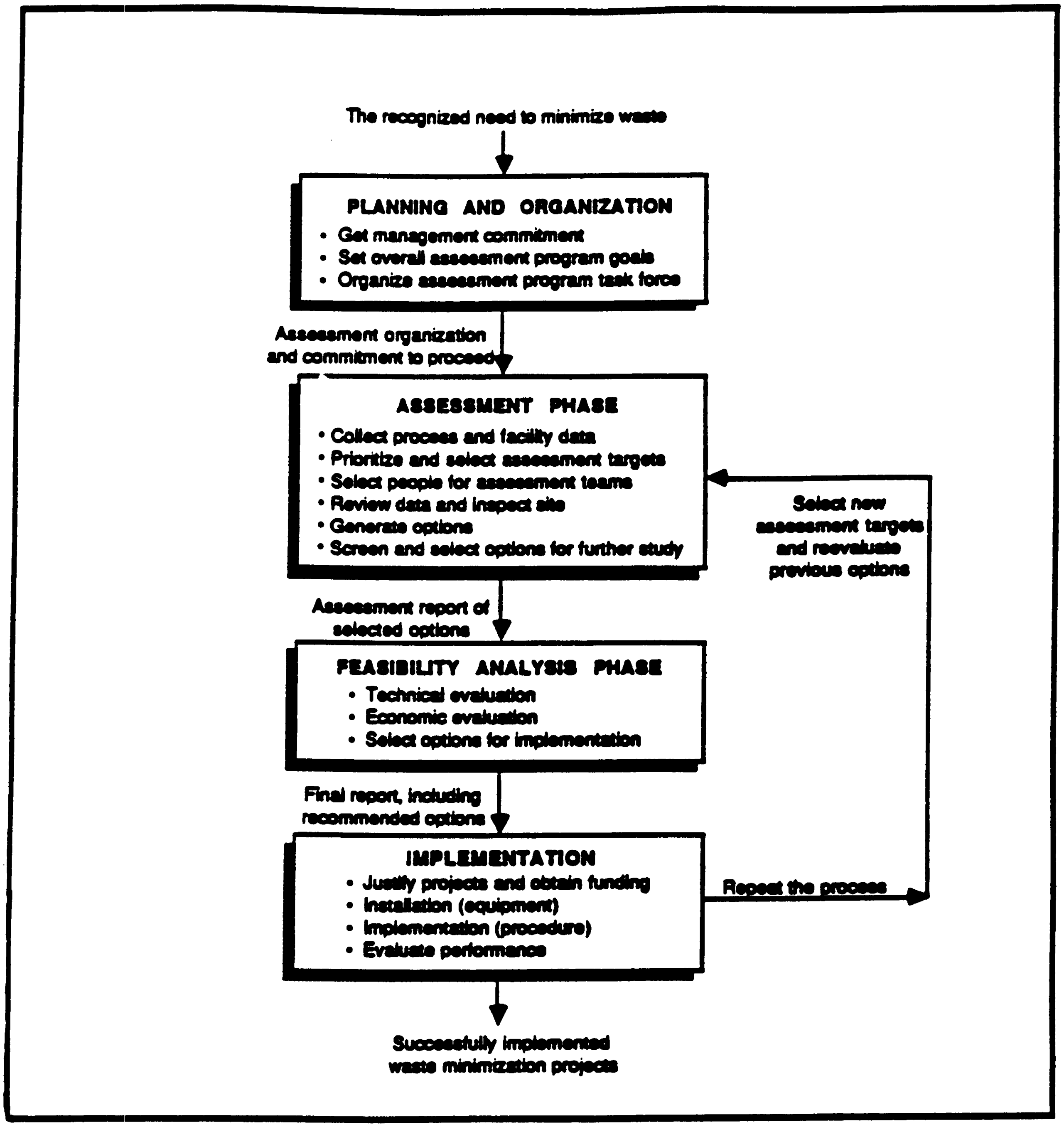

FIGURE 1. THE WASTE MINIMIZATION ASSESSMENT PROCEDURE

utility conduit are located between the plating lines. The plating area has a grated floor, below which is a basement. The basement contains ventilation ducting, scrubbers, wastewater piping and storage tanks, and miscellaneous support equipment.

The NADEP plating shop has made significant strides in pollution prevention, due primarily to a commitment by management, good inhouse engineering, and the cooperative efforts of plating personnel. The following are examples of the NADEP's efforts.

- Rinse water use was cut 75% (from 80,000 gpd to 20,000 gpd) by installing flow restrictors on all water inlets feeding rinse tanks and through training platers to close water valves on idle plating lines. Periodic inspections (at least two per day) are made of each plating line to assess water use. Water meter readings are recorded on a daily basis to track water use and identify unusual conditions.

- Process solutions are rarely discarded at the NADEP. This is primarily due to the exclusive use of deionized water for evaporative makeup in the process tanks. Also, the facility performs some bath maintenance including filtering, sludge removal, carbonate control, dummying, and carbon filtering.

- Electrolytic metal recovery has been installed for the recovery of cadmium. The recovered cadmium is reused as anode material.

- A non-cyanide nickel strip solution was substituted for their conventional cyanide bath.

- The shop contains a mist eliminator system to recover chromic acid from hard chromium plating tank emissions.

Hard Chromium Plating

Hard chromium plating refers to chromium electroplating that is deposited in heavy thicknesses, usually directly onto a base metal such as steel. It is used to provide resistance to heat, wear, and corrosion and a low coefficient of friction. It is also commonly applied at rework facilities to increase the dimensions of worn bearing surfaces. Hard chromium plating differs from decorative chromium plating which is usually applied in thin deposits as a final or top coat over copper and/or nickel deposits.

The NADEP hard chromium shop plates approximately 4,000 parts per year. Approximately 25% of this workload is landing gear components. The hard chromium processes used at the NADEP shop are shown graphically in Figures 2 and 3. Table 1 contains data relative to the equipment and chemical solutions used for the stripping and hard chromium plating processes. Most of the parts that are chromium plated are made of steel. The following describes the procedures used for plating steel parts. Variations of the process are used for other base metals.

The used parts typically arrive at the shop with an existing chromium deposit and varying amounts of grease, oil and dirt. Initially, oils and greases are removed in a 1,1,1-trichloroethane (TCA) vapor degreaser. If the parts have an existing chromium deposit, this deposit is stripped. Prior to stripping, the parts are sometimes masked (depends on the part) to protect nonplated surfaces by dipping the parts into a hot plastic compound and carefully removing the plastic film from the surfaces to be stripped. The masked parts are then placed into a caustic solution where a reverse current is applied (the part is positively charged and anodes are negatively charged) and the existing chromium plate is stripped. After stripping, the parts are rinsed and then placed into hot water to remove the bulk of the plastic masking. Small amounts of residual maskant are then removed by returning the parts to the vapor degreaser. At this point,

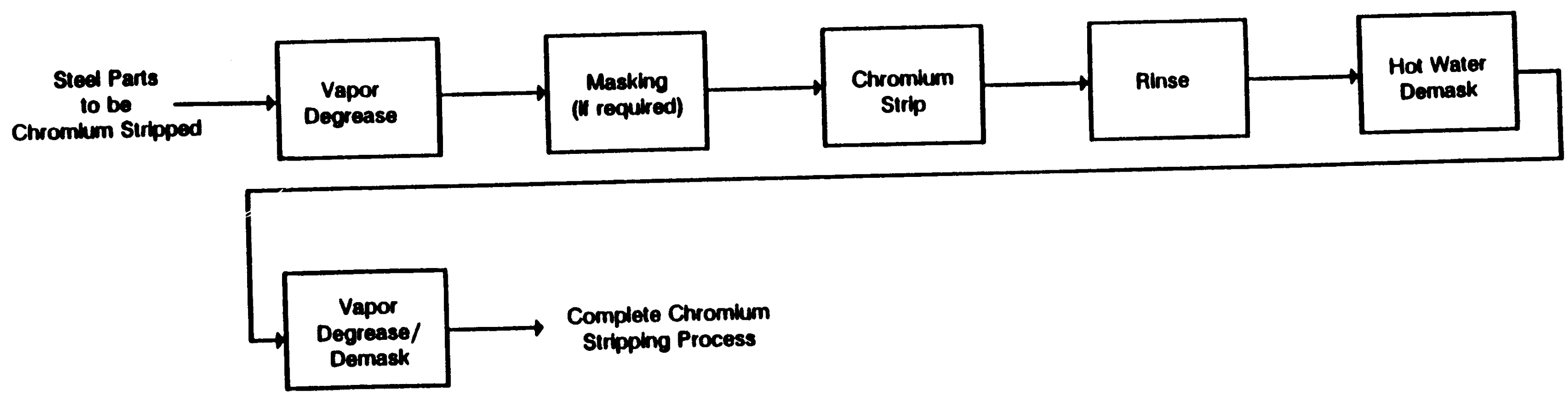

FIGURE 2. CHROMIUM STRIPPING PROCESS

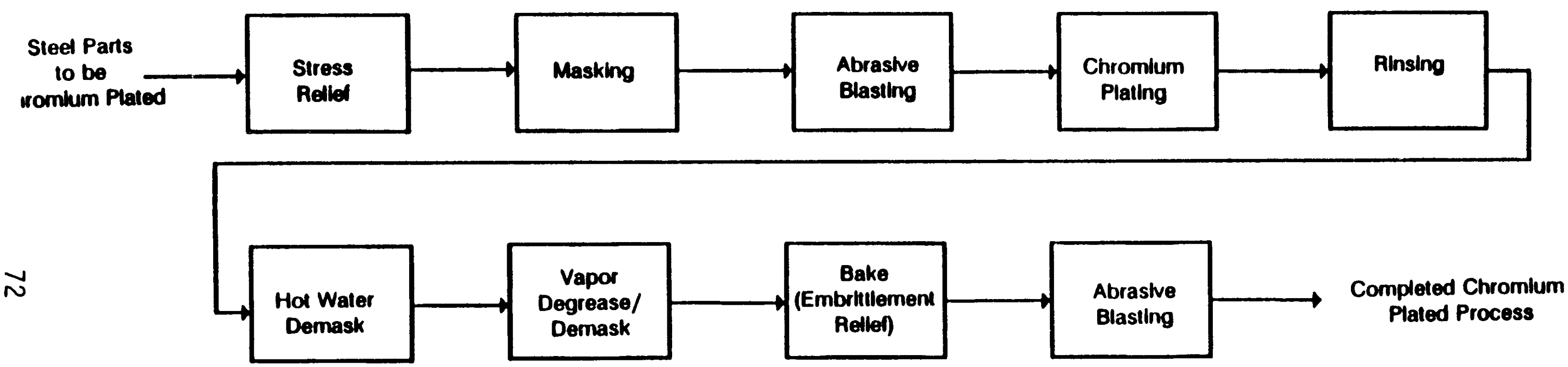

FIGURE 3. HARD CHROMIUM PLATING PROCESS

TABLE 1. PLATING AND RINSE DATA

Operation	Tank Number	Tank Function	Tank Dimensions (ft.) L	x	W	x	D	Capacity (gals.)	Solution Temp. (F)	Bath Chemistry
Vapor Degrease	T-1	TCA Degrease								1,1,1-trichloroethane
Vapor Degrease	195a	TCA Degrease								1,1,1-trichloroethane
Chrome Strip	T-191	Maskant	6.0		3.0		3.0	337		Hot plastic
Chrome Strip	T-69	Cr Strip	8.0		4.0		8.0	1,795	Amb.	8 to 16 oz/gal caustic
Chrome Strip	T-70	Cr Strip	8.0		4.0		8.0	1,795		8 to 16 oz/gal caustic
Chrome Strip	T-71	Rinse	8.0		4.0		8.0	1,795		
Chrome Strip	T-36	Demask	6.0		4.5		10.0	1,919		Water
Chrome Plate	T-192	Maskant						0	350	Hot plastic
Chrome Plate	T-27	Chrome Plate	8.5		4.0		5.0	1,144	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-29	Chrome Plate	8.5		4.0		5.0	1,144	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-30	Chrome Plate	8.5		4.0		5.0	1,144	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-31	Chrome Plate	8.5		4.0		5.0	1,144	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-32	Chrome Plate	8.5		4.0		5.0	1,144	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-33	Chrome Plate	12.0		4.5		10.0	3,837	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-34	Chrome Plate	8.0		4.5		10.0	2,558	130	Chromic acid (33 oz/gal), sulfuric acid (.33 oz/gal)
Chrome Plate	T-35	Dragout Rinse	6.0		4.5		10.0	1,919	N/A	
Chrome Plate	T-36	Hot Water Demask	6.0		4.5		10.0	1,919		Water
Nickel Strip	T-50	HCL Activation	4.0		4.0		4.0	419		Hydrochloric acid
Nickel Strip	T-54	Non-brazed Strip	6.0		4.0		4.0	628		Metalx B-9 (protein) solution
Nickel Strip	T-55	Non-brazed Strip	4.0		4.0		4.0	419		Enthrone NP Strip
Nickel Strip	T-52	Brazed Strip	6.0		4.0		4.0	628		Enthrone (amine) solution. Mechanical agitation.
Nickel Strip	T-51	CWR*	4.0		4.0		4.0	419		
Nickel Strip	T-53	CWR*	4.0		4.0		4.0	419		
Nickel Strip	T-56	CWR*	4.0		4.0		4.0	419		
Nickel Strip	T-59	Desmut	4.0		4.0		4.0	419	200	Chromic acid (60 oz/gal)
Nickel Strip	T-60	CWR*	4.0		4.0		4.0	419	N/A	
Nickel Plate	T-196	Maskant	6.0		3.0		3.0	337	190	Wax
Nickel Plate	T-104	Electroclean	4.0		4.0		5.0	539	180	Isoprep 54P
Nickel Plate	T-106	Anodic Etch	4.0		4.0		5.0	539	Amb.	Sulfuric acid
Nickel Plate	T-108	Activation	4.0		4.0		5.0	539	Amb.	Hydrochloric acid (20 to 30%)
Nickel Plate	T-105	CWR*	4.0		4.0		5.0	539		
Nickel Plate	T-107	CWR*	4.0		4.0		5.0	539		
Nickel Plate	T-110	CWR*	4.0		4.0		5.0	539		
Nickel Plate	T-109	Nickel Strike	4.0		4.0		5.0	539	Amb.	Nickel chloride (32 oz/gal), HCL (16 oz/gal)
Nickel Plate	T-115	Nickel Plate	6.0		5.0		4.0	785	130	Allied Kelite bath
Nickel Plate	T-116	Nickel Plate	6.0		5.0		4.0	785	130	Same as T-115
Nickel Plate	T-117	Dragout Recovery	6.0		5.0		4.0	785		
Nickel Plate	T-118	CCR**	4.0		4.0		5.0	539		
Nickel Plate	T-119	CCR**	4.0		4.0		5.0	539		

* cold water rinse
** counter current rinse

the parts are ready for the next rework procedure which is typically rechroming or an intermediate machining step.

Initially, the parts are baked in an oven for stress relief (baking eliminates internal stress in ferrous metals caused by machining, grinding, etc.) to alleviate potential adhesion and cracking problems. A maskant step is then performed using a hot plastic coating, vinyl and aluminum tape, and aluminum and lead foils. Following masking, the surface of the parts to be plated are exposed. The parts are then subjected to abrasive blasting with glass beads to ensure that the surface is clean and to roughen the surface to improve bonding of the chromium deposit. The parts are now ready for rechroming and they are arranged on fixtures and electroplated in a chromic acid solution. The chromium plating process often takes one to two days to complete since thick chromium deposits (i.e., up to 0.05 in.) are usually applied and the deposition rates are slow (0.001 in./hr). Following chromium plating, the parts are rinsed and then demasked in hot water and the vapor degreaser. The parts are then baked for hydrogen embrittlement relief (parts adsorb hydrogen during plating which must be removed by baking to prevent cracking and other deformations of the deposit). Abrasive blasting is then used for final cleanup and the parts are sent to the machine shop for further processing (i.e., grinding).

Information and data relative to the hazardous wastes and wastewaters generated by the hard chromium plating process are shown in Table 2. Generally, hazardous wastes and wastewaters generated in plating shops can be grouped into six categories: (1) spent process solvent and solutions resulting from contamination or exhaustion, (2) rinse water, (3) scrubber water blowdown, (4) tank bottom sludges and solids from filter cleanout, (5) miscellaneous chemical losses including spills and drips, and (6) miscellaneous solids, including used masking materials and abrasive blasting dusts.

The process solvent and solutions used for hard chromium stripping and plating include: TCA, caustic stripper, and the chromium plating solution. TCA degreasing is performed in two degreasers, one of which was recently installed. The newer unit has an integral still which is used to recover TCA when the solvent becomes contaminated. The older unit does not have an integral still and when the solvent is contaminated with grease, oil and maskant, or becomes acidic it is discarded. Disposal of the solvent and sludge from the older unit occurs approximately once per year. The caustic stripper is discarded when it becomes overly ladened with dissolved chromium. This has occurred only once since 1986. Chromium plating solution is not routinely discarded, although one of the chromium plating tanks currently contains contaminated solution.

Rinse water is generated by rinsing operations following chromium plating and stripping. The rinse waters are discharged to the industrial wastewater treatment plant (IWTP). Treatment of these wastewaters results in the generation of hazardous sludge (F006). Rinsing following chromium stripping is performed in a single overflow rinse. Rinsing following chromium plating includes use of a hand-held air assisted water spray over the plating tank followed by rinsing in a dragout tank and an overflow rinse. The solution contained in the dragout tank is periodically pumped into the plating tanks to recover the chromium. This recovery method has not been fully implemented because the pump is undersized and operators are reluctant to use it. The method will work, but the pumping time required is not acceptable to the operators.

The chromium plating and stripping tanks are ventilated to remove toxic fumes from the work place. The exhausted air is treated by wet scrubbers to remove contaminants before releasing the air to the atmosphere. The chromium exhaust system also includes a demister unit which removes most of the chromic acid from the exhausted air stream before it reaches the scrubber. Although not reported, typical demister efficiency is 97 to 99% removal. Based on NADEP data, the demister recovers approximately 4,000 lbs of chromic acid (CrO_3) per year. Scrubber water is periodically discharged from the scrubber units to the IWTP for treatment. The chromic acid recovered by the mist eliminator is pumped to an unused chromium plating tank. At one time the demister contained chevron-type plates that were made of stainless steel. The plates corroded during use and the recovered chromic acid contained too much dissolved iron

TABLE 2. WASTE GENERATION SUMMARY

Process Step	Current Waste Products	Waste Quantity	Current Waste Deposition
Chromium Stripping			
Vapor Degreasing	- Contaminated TCA (F002) - Still bottoms from recovery still (F002)	Unknown (3) Unknown (3)	- Offsite disposal - Offsite disposal
Masking	- No routine hazardous wastes or wastewaters generated	N/A	- N/A
Stripping	- Spent stripping solution - Rinse water	360 gpy (2)	- Offsite disposal - Treated onsite with sludge to offsite disposal (1)
	- Scrubber water	Unknown	- Treated onsite with sludge to offsite disposal (1)
Demasking	- Miscellaneous solids (D007) - Vapor degreasing during demasking contributes TCA contamination and increases quantity of dirty solvent and still bottoms (see vapor degreasing)	Unknown Unknown	- Offsite disposal - See vapor degreasing
Chromium Plating			
Vapor Degreasing	- Contaminated TCA (F002) - Still bottoms from recovery still (F002)	Unknown (3) Unknown (3)	- Offsite disposal - Offsite disposal
Baking (stress relief)	- No hazardous wastes or wastewaters generated	N/A	- N/A
Masking	- No routine hazardous wastes or wastewaters generated	N/A	- N/A
Abrasive Blasting	- Blasting dusts (D006)	Unknown	- Offsite disposal

TABLE 2. Continued

Process Step	Current Waste Products	Waste Quantity	Current Waste Deposition
Chromium Plating (con't)			
Electroplating	- Tank sludges (D007)		- Offsite disposal
	- Rinsewater	(2) (4)	- Treated onsite with sludge to offsite disposal (1)
	- Scrubber water	Unknown[4]	- Treated onsite with sludge to offsite disposal (1)
	- Spills and drips	Unknown	- Treated onsite with sludge to offsite disposal (1)
Demasking	- Miscellaneous solids (D007)	Unknown	- Offsite disposal
	- Vapor degreasing during demasking contributes to TCA contamination and increases quantity of dirty TCA and still bottoms (see vapor degreasing)	Unknown	- See vapor degreasing
Baking (embrittlement relief)	- No hazardous wastes or wastewaters generated	N/A	N/A
Abrasive blasting	- Blasting dusts (D006)	Unknown	- Offsite disposal
Nickel Stripping			
Vapor Degreasing	- Contaminated TCA (F002)	Unknown (3)	- Offsite disposal
	- Still bottoms from recovery still (F002)	Unknown (3)	- Offsite disposal
Acid Activation	- Spent acid solution	Unknown	- Treated onsite with sludge to offsite disposal (1)
	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)
Nonblazed Nickel Strip	- Spent strip solution	Unknown	- Treated onsite with sludge to offsite disposal (1)
	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)

TABLE 2. Continued

Process Step	Current Waste Products	Waste Quantity	Current Waste Deposition
Nickel Stripping (con't)			
Brazed Nickel Strip	- Spent strip solution	250 gpy	- Treated onsite with sludge to offsite disposal (1)
	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)
Desmut	- Spent desmut solution	0 gpy	- Never dumped (infrequently used)
	- Rinse water		- Treated onsite with sludge to offsite disposal (1)
Abrasive dust (D006)	- Blasting dust (D006)		- Treated onsite with sludge to offsite disposal (1) - Treated onsite with sludge to offsite disposal (1)
Nickel Plating			
Vapor Degreasing	- Contaminated TCA (F002) - Still bottoms from recovery unit (F002)	Unknown (3) Unknown (3)	- Offsite disposal - Offsite disposal
Baking (stress relief)	- No hazardous wastes or wastewaters generated	N/A	- N/A
Masking	- No routine hazardous wastes or wastewaters generated	N/A	- N/A
Abrasive Blasting	- Blasting dusts (D006)	Unknown	- Offsite disposal
Electrocleaning	- Spent electroclean solution - Rinse water	0 gpy (2)	- Never dumped - Treated onsite with sludge to offsite disposal (1)
Acid Etch	- Spent acid etch solution	220 gpy	- Treated onsite with sludge to offsite disposal (1)
	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)

TABLE 2. Continued

Process Step	Current Waste Products	Waste Quantity	Current Waste Deposition
Nickel Plating (con't)			
Acid Activator	- Spent activator solution	650 gpy	- Treated onsite with sludge to offsite disposal (1)
	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)
Nickel Strike	- Spent solution (infrequent generation)	220 gpy	- Treated onsite with sludge to offsite disposal (1)
	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)
Nickel Plate	- Rinse water	(2)	- Treated onsite with sludge to offsite disposal (1)
	- Scrubber water	Unknown	- Treated onsite with sludge to offsite disposal (1)
	- Filter cartridges and spent carbon	Unknown	- Offsite disposal
	- Spills and drips	Unknown	- Treated onsite with sludge to offsite disposal (1)

(1) Waste is treated onsite at the IWTP and discharged to a POTW. The IWTP generates a sludge (F006) which is disposed offsite.

(2) Rinse tanks only flow when plating line is active. Usually it is nonflowing.

(3) Approximately 16 tons of TCA is used annually. Most of this quantity is lost through evaporation.

(4) Approximately 2,500 to 4,000 lbs. of chromic acid (CrO_3) are added to the plating tanks annually to make up for losses. Approximately 10-20% is plated onto the parts. The remainder is mostly lost through dragout and unrecovered emissions.

for reuse as plating solution. The chevron plates have been recently replaced by mesh pads made of synthetic material. The recovered chromium is being stored in an unused chromium plating tank until the usefulness of the material is determined. Also, NADEP is testing electrodialysis (ED) technology in the same inactive tank in an effort to removed the dissolved iron. Use of ED technology is discussed in the assessment/feasibility sections.

In order to reduce the misting of process solution from chromium stripping, a mist suppressant is used. To reduce air emissions from chromium plating, the NADEP is planning on replacing existing air agitation with mechanical agitation.

Sludge is periodically removed from the bottom of the chromium plating tanks. The sludge is primarily lead chromate generated from corrosion and flaking of lead alloy anodes. This material causes pitting of the chromium deposits when it contacts the parts during plating. The frequency of sludge cleanout is not known exactly; however, it is less than once per year per tank. A recent cleanout of the largest chromium plating tank generated six 55-gal. drums of sludge (D007).

The greatest threat of miscellaneous losses is from tank overflows that could occur during refilling for evaporation makeup. Evaporation makeup is needed for heated solutions such as the chromium plating solution. The makeup water (deionized water) is added from a hose. It is shop policy that during refilling the operator remains at tank site to prevent overflows; however, some instances of overflows have occurred. The shop is ordering high level alarms for critical tanks to help prevent these occurrences.

Nickel Sulfamate Electroplating

Nickel sulfamate plating is used at NADEP, Norfolk for many of the same reasons as hard chromium, (i.e., to provide resistance to heat, wear, and corrosion). The mechanical properties of the nickel deposit are similar to hard chromium, however, nickel deposits are slightly less hard. Nickel is applied in thick deposits, when required for resizing worn surfaces. The speed of deposition is significantly faster than with hard chromium plating and therefore the process takes less time to complete. Approximately 1,000 parts are nickel sulfamate plated annually at the NADEP.

The nickel sulfamate process is described in Figures 4 and 5. Table 1 contains data concerning the equipment and chemical solutions used for the nickel sulfamate plating process. The nickel stripping process is similar to that for chromium and it consists of vapor degreasing, acid cleaning and activation, stripping, desmut, and abrasive blasting. Two types of stripping solutions are used, the choice depends on whether the part is brazed or not. The nickel sulfamate plating process consists of degreasing, stress relief, masking (wax maskant rather than plastic), abrasive blasting, electrocleaning, acid etch, acid activation, nickel strike, and nickel electroplating. Each of the aqueous process steps is followed by rinsing.

Table 2 contains information and data concerning the waste generated by these processes. These wastes can be grouped into the same five categories discussed for hard chromium plating. The following is a discussion of the key wastes in each category.

The process solvent and solutions used for nickel sulfamate stripping and plating include: TCA, acid activator, two stripping solutions, desmut, electrocleaner, acid etch, nickel strike, and nickel plate. All of these solutions and the TCA solvent are routinely discarded, except for the nickel strike and nickel plating solutions.

Rinse water is generated from rinsing after each of the aqueous process steps. The rinse waters are discharged to the IWTP. Treatment of these wastewaters results in the generation of hazardous sludge (F006). Efforts are underway at the NADEP to recover nickel from rinsing after nickel sulfamate plating using

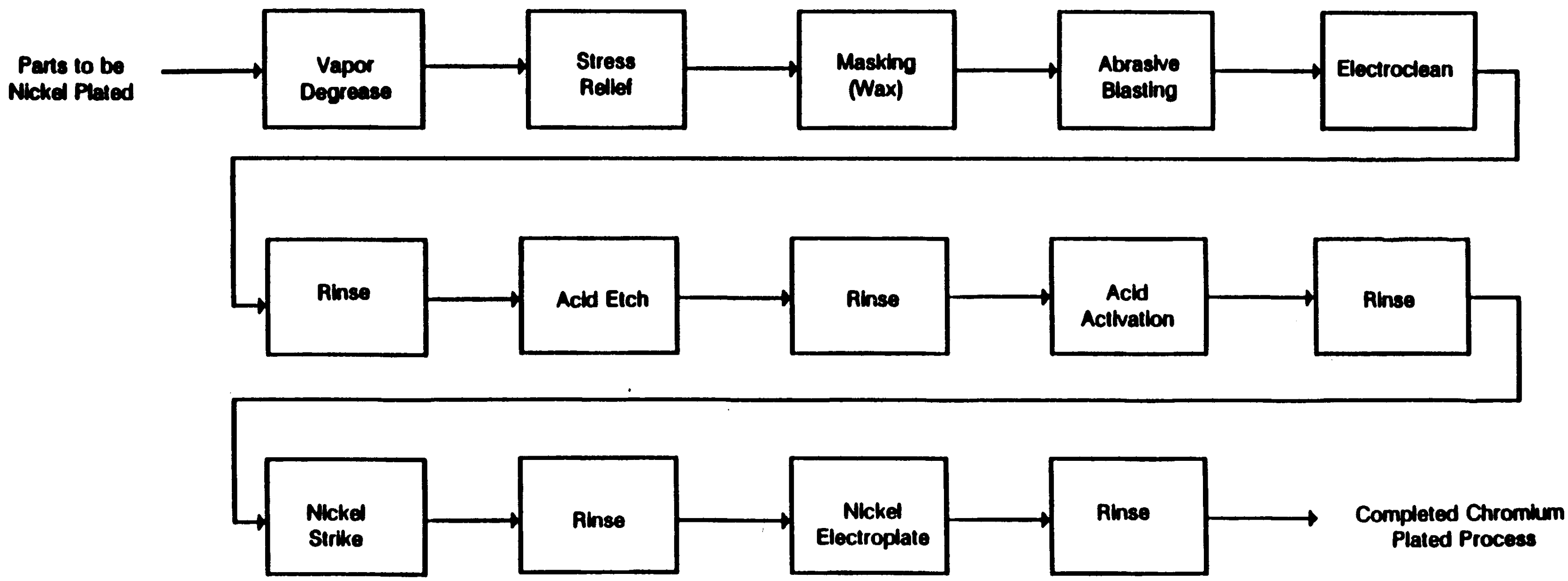

FIGURE 4. NICKEL SULFAMATE PLATING PROCESS

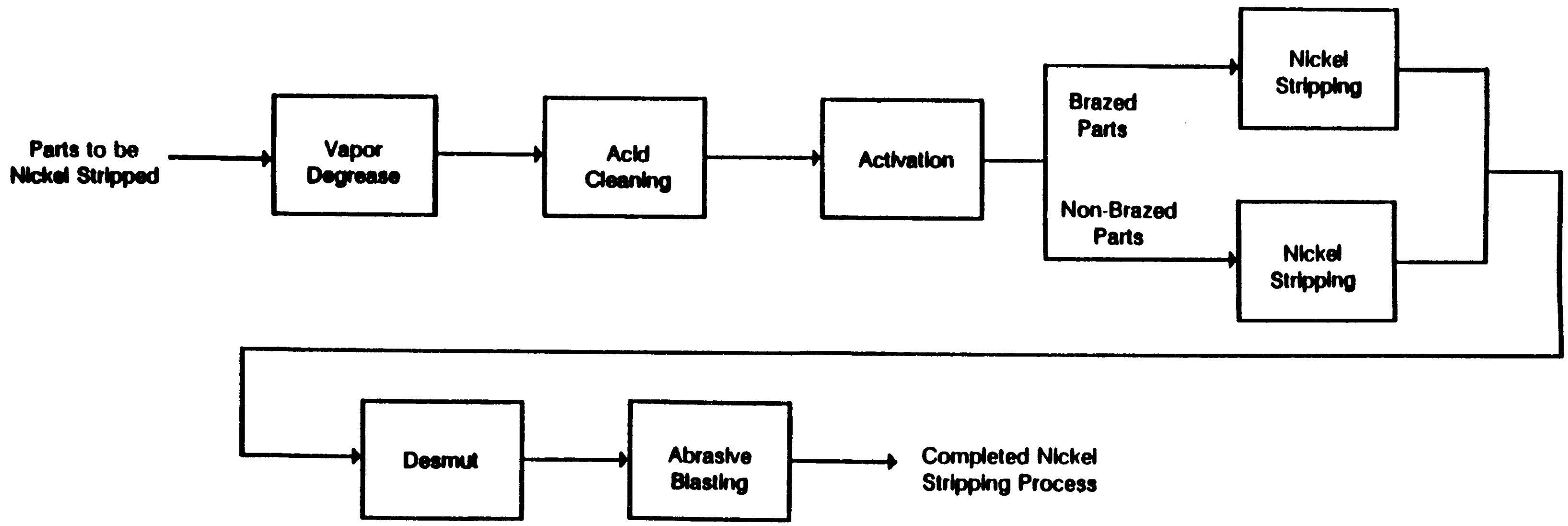

FIGURE 5 . NICKEL STRIPPING PROCESS

an electrolytic metal recovery (EMR) unit. A similar device has been successfully used for cadmium recovery at this shop.

Each of the aqueous process tanks used for nickel stripping and plating is ventilated and the fumes pass through wet scrubber units. The blowdown form these units is treated at the IWTP.

The nickel plating solution is maintained through continuous filtration to remove suspended solids and periodic carbon treatment to remove excess organics. These operations generate miscellaneous solids that are drummed for offsite disposal.

As with hard chromium plating, tank overflows are a serious pollution threat and these occurrences are most likely to occur with heated process tanks which require frequent replacement of evaporated water. The nickel plating tank is of particular concern in these operations since this solution is heated to a relatively high temperature and it contains the highest concentration of metal of the nickel plating process.

ASSESSMENT/FEASIBILITY

Identification of Pollution Prevention Options

Numerous methods and technologies have been utilized by electroplating shops for pollution prevention. A list of common source reduction and recycling options is presented in EPA's *Guides to Pollution Prevention, The Fabricated Metal Products Industry (USEPA 1990)*. Using the applicable suggestions from this reference and ideas generated by NADEP personnel and the assessment contractor, the list of potential options in Table 3 was developed. The following is a discussion of key pollution prevention options from the list.

Good Operating Practices

Good operating practices are defined as procedures or institutional policies that result in a reduction of waste. The practices include: waste stream segregation; personnel practices such as management initiatives and employee training; procedural measures such as documentation/record keeping, inventory management and control; and loss prevention practices such as spill prevention, preventative maintenance and emergency preparedness. The following are specific good operating practices that are applicable to the NADEP plating shop.

- Construct and utilize a data base for tracking water use and chemical use. Presently, records are maintained for water use and chemical use in files and logbooks. A computer data base would provide a convenient means of storing and retrieving the data and preparing statistical evaluations that would show usage trends, identify unusual incidents, and help the NADEP to quantify the success of their pollution prevention program.

- Improve tracking of water use. Presently, water use is measured daily at the NADEP shop through readings of a water meter located in the shop's basement. The location of the meter is inconvenient and it cannot be seen from the production areas. The only other water meter present in the shop is located on the feed line to their deionized (DI) water system that feeds most rinse tanks and all process tanks. This meter is not in working condition.

TABLE 3. POTENTIAL POLLUTION PREVENTION OPTIONS

Wastestreams	Applicable Pollution Prevention Options	Potential Impacts
All Wastestreams	- Implement good operating practices	- Creates employee awareness, reduces waste generation, improves work quality and improves work place environment
Contaminated TCA and Still Bottoms	- Substitute aqueous cleaner with bath maintenance technology for degreasing operation	- Eliminates F002 wastes
	- Eliminates use of vapor degreaser that does not have an integral still	- Minimizes discarded quantity
	- Minimizes use of degreaser for maskant removal	- Minimizes contamination of solvent
Spent Chromium Strip Solution	- Substitute mechanical stripping (grinding) where practical - Recover strip solution with electrodialysis (ED)	- Reduces disposed frequency of strip solution - Eliminates disposed of strip solution and recovers chromium in reusable form
Chromium Strip Rinse Water	- Dragout recovery rinsing	- Reduces dragout loss but must be implemented with ED to prevent frequent bath disposal
Chromium Plating Rinse water	- Use multiple stage recovery rinsing and an atmospheric evaporator	- Eliminates dragout losses but requires use of ED for bath maintenance
Chromium Plating Tank Sludges	- Implement conforming anode plating	- Reduces introduction of anode corrosion products into bath
Chromium Plating Scrubber Water	- Improve mist eliminator operation by eliminating tank and adding additional pads	- Eliminating one tank will reduce ventilation requirement and permit use of additional pad for higher recovery rate
Chromium Plating Spills and Drips	- Install high level tank alarms	- Reduces potential for tank overflow
	- Install drip pan below plating tanks	- Recovers chromic acid dripped through grated floor
All Aqueous Nickel Strip Process Solutions	- Install in-tank filtration units to remove suspended solids	- Reduces bath dumps
Nickel Strip Solutions and Rinses	- Recover nickel using ion exchange and electrolytic metal recovery	- Prolongs life of strip solution and recovers nickel in reusable form
All Aqueous Nickel Plating Process Solutions Except Ni Plating	- Install in-tank filtration unit to remove suspended solids	- Reduces bath dumps
Nickel Plating Spills nd Drips	- Install high level tank alarms	- Reduces potential for tank overflow
	- Install drip pan below plating tanks	- Recovers chromic acid dripped through grated floor

Water meters are an excellent means of tracking water use at any plating shop. Meters or remote readouts should be conveniently located on the main water line and throughout the shop. Internal shop meters should be located on individual process lines. All meters should be maintained in working condition. All meters should be read, at a minimum, on a daily basis to help identify unusual conditions before a major problem occurs. If possible, the meters should be read during each shift since operational procedures oftenvary from shift to shift. The water meter readings should be recorded in a data base and analyzed as described in Reference 2.

- Improve instrument maintenance. It was observed that the plating shop is well maintained in terms of general housekeeping. For example, the basement floor, which is designed to catch drips and spills, is relatively free of dampness or chemicals. However, many computer controls and instruments present in the shop were not functioning. Some controls have never functioned since the opening of the facility in 1986. Repair or replacement of controls and instruments that are not in working condition will improve the overall operation of the shop. Continued maintenance will be necessary to keep them functioning in the future. The proper instrument/control maintenance personnel need to be assigned to the shop or a maintenance contract should be considered.

- High level alarms on process tanks. At present, there are no high level alarms on process tanks. Alarms are needed on heated process tanks where water is routinely added to make up for evaporation. Even though the NADEP has a strict rule requiring operators to stay at a tank when it is filling, the potential exists for a tank overflow. The NADEP has recognized the need for high level alarms and is in the process of procuring them.

- Segregate abrasive blasting workload. Abrasive blasting dust from aluminum oxide and glass bead blasting is manifested offsite as a hazardous waste due to cadmium contamination. The cadmium is contributed to the dust from incompletely stripped parts that were previously cadmium plated. The NADEP may be able to reduce the quantity of hazardous waste generated by segregating the cadmium plated parts from other parts and blasting the cadmium plated parts in its own blasting unit.

- Energy conservation. At present, most process and rinse tanks that are used at an elevated temperature are maintained at the elevated temperature even when not in use. Depending on the tank heat-up time and the scheduling of work, it may be possible to reduce the heating of idle tanks.

Vapor Degreasing Options

The Clean Air Act Amendment of 1990 phased out production of 1,1,1-Trichloroethane (TCA) by 2002 due to its harmful impacts on stratospheric ozone. Facilities presently dependent on this material should initiate efforts to find a replacement which does not have negative effects on human health and the environment. Other chlorinated solvents such as trichloroethylene (TCE), perchloroethylene (PERC) and methylene chloride (METH) are not considered good alternatives due to carcinogenicity and, for TCE and PERC, due to their contributions to photochemical smog formation. Rather, investigations should focus on aqueous and semi-aqueous cleaning materials. Those that are especially attractive are materials that are amenable to the maintenance techniques for extending usage (e.g., microfiltration) and for dragout recovery (e.g., ultrafiltration). The choice of an appropriate substitute cleaning method is highly dependent on the specific cleaning characteristics of the operation (e.g., types of oil, grease and dirt present, workload, base metals cleaned); therefore testing is recommended. Due to the regulatory deadline for TCA phaseout many companies are developing alternative cleaning methods including both chemicals and equipment. Simultaneously, many private industry and government metal finishing facilities are conducting research and testing of available substitute products. A wealth of current information and data are available in product literature, technical journals, conference proceedings and reports. This information will serve as a starting point for finding substitute degreasing processes.

The implementation of a substitute degreasing process may take up to several years to complete. To reduce present F002 waste quantities the NADEP should consider: (1) eliminating use of the existing old degreaser which does not have provisions for solvent recovery, (2) minimizing use of vapor degreasing for maskant removal. The latter of these options can be implemented by using hand scrubbing and rinsing to remove as much maskant as possible prior to use of the degreaser and/or improve the design of the vapor degreaser. The degreasers are conventional units with a boiling chamber, vapor or working zone, cooling zone, and freeboard. TCA usage is 16 tons per year (the shop's air permit allows a much higher emission rate). Discussions with NADEP personnel indicate that the majority of the TCA is lost through evaporation. Some TCA is removed as spent material and drummed for disposal. The evaporative losses from the degreasers could be decreased by retrofitting the units with a refrigeration zone (freeboard chiller), just above the cooling zone. The refrigeration zone will condense vapors that escape the cooling zone.

Hard Chromium Plating Process Options

Various methods and technologies are presently available that permit nearly 100 percent closed-loop operation of hard chromium plating processes. In general, these approaches are most effectively applied when designing and installing new operations due to space requirements and processing configurations. However, retrofitting existing hard chromium processes can also achieve better efficiency and less waste.

There are six pollution prevention components of a closed loop hard chromium process: (1) conforming anode plating, (2) recovery rinsing, (3) chromic acid emissions recovery, (4) plating bath maintenance, (5) caustic strip solution reformulation, and (6) spill and drip prevention. The NADEP has partially implemented elements 2, 3, and 4. A potential approach for completing the existing system follows.

Conforming anode plating refers to the use of anodes shaped similarly to the surface of the part being plated. These anodes are fabricated from cast lead alloy mats. There are several commercial sources that specialize in conforming anode production. Use of conforming anodes replaces conventional "stick" anode plating. The conforming anode method reduces rejects and rework, reduces plating time by a factor of two to four, and permits a higher loading of plating tanks (i.e., more parts can be plated simultaneously in the same tank). Higher loading of tanks permits consolidation of operations and the potential for eliminating 50 percent of tankage.

At present, there are six hard chrome plating tanks at the NADEP. Potentially, three of these tanks could be eliminated if conforming anode plating is implemented. The space made available could be used to add additional recovery rinse stations. Countercurrent rinsing reduces the volume of rinsewater required. When a sufficient number of recovery rinses are added, 100 percent of the dragout can be returned to the plating baths. The reduced air exhaust requirement would permit altering or replacing the mist eliminator unit (e.g., adding pads that could not be added if the design air flow had to be maintained) and increasing its recovery percentage (EPA sponsored tests show the mesh pad design can remove an average of 99.7% of Cr^{+6} from the airstream).

When dragout and chemicals in the exhaust are recovered, bath contaminants are also recovered. Eliminating these purges of contaminants will result in a buildup of trivalent chromium, iron, copper and aluminum; this will eventually cause the baths will become unusable. To prevent this condition from occurring, the baths should be maintained. Electrodialyses has recently been applied for chromium bath maintenance. A single test unit is presently installed at the NADEP. This unit may have sufficient capacity to maintain all chromium plating baths. If not, an additional unit might be installed.

The spent caustic strip solution can be recovered by the separation of caustic and chromic acid. The recovery process is performed using a multiple cell electrodialysis unit. The recovered caustic is reused as strip solution and the chromic acid is reused for plating tank make up.

Spills and drips can be minimized through prevention and recovery. As discussed previously, the potential for spills can be reduced by installing high level alarms. Also, pH and conductivity sensors, with associated alarm systems, can be installed in floor drains, pits, or at other points in the collector system to identify spills and tank leaks before an entire tank's contents are lost. Drips from parts and racks can be captured by installing drip pans below the grated floor. The pans should extend across the work isle to capture solution from parts that are placed onto or above the floor for inspection purposes. The collected solution can be returned to the plating baths after adequate filtration to remove any dirt and debris. These devices supplement the use of existing drip guards which effectively prevent drips from falling between tanks. The pans are mostly needed on processes such as hard chromium plating where parts are often removed from the tank and placed on the floor for periodic measurements.

Nickel Plating Process Options

The identified pollution prevention options for nickel stripping and electroplating relate to the quantity of process bath discarded. Preplating process baths such as cleaners and acid dips have a limited life span. Filtering (in-tank cartridge type) can be used to remove suspended solids and aid in maximizing bath life. Reusable filter cartridges are available that eliminate the bulky waste caused by throw-away cartridge filters.

Nickel recovery is possible from nickel strip solutions and rinsewaters from stripping, nickel strike and nickel plate. The NADEP plans to install an electrolytic metal recovery (EMR) unit on the rinse following sulfamate nickel plating. It may be possible to use the same EMR unit to directly recover nickel from the spent stripping solutions. Recovered nickel can be used as anode material in the sulfamate nickel plating tank. If direct recovery of nickel from the strip solutions is not possible, the nickel can be removed using ion exchange and the EMR unit can recover the nickel from the ion exchange column reagent. Similarly, ion exchange and EMR can be used to recover nickel from the rinses following stripping and nickel strike.

As with chromium plating, high level alarms and other devices for sensing spills and leaks could be used to prevent catastrophic chemical losses.

A drip pan located below the grated floor in front of the nickel plating tank could reduce nickel losses during parts inspection. The recovered chemical could be returned to the plating bath, after adequate filtration to remove dirt and debris.

Some of the rinse tanks on the nickel stripping/plating line are equipped with conductivity controls to limit the flow of rinse water. The facility has experienced maintenance problems with the units and most of them are no longer used. In place of automatic control, this facility relies on the operator to manually close water valves when the rinse tank is not in use. The Navy should consider the use of pushbutton timer controls to replace the conductivity units and manual control method. With pushbutton timer controls, the operator pushes a button located at the rinse tank which activates a timer and opens a solenoid valve. The valve remains open for a preset time period and then automatically closes. A flow restrictor should be placed on the incoming water line. Knowing the flow rate through the restrictor, the shop can set the timer to provide any needed volume of water. The timer setting should be selected to provide adequate rinsing. Countercurrent rinsing was considered at the site, however there is no additional space for further rinse tanks. Reducing dragout through the increase of draintime, thus slowing withdrawal rates from process tanks, was not considered due to the fact that it is not applicable to manual lines. Also, drainage time can't be increased with some parts.

The pushbuttons and timers are commonly available equipment than can be procured and installed by Navy personnel or an electrical contractor. The existing solenoid valves used with the conductivity controllers can be reused with the pushbutton timer system. This method of rinse water control is especially suited to intermittent production like that observed at this shop.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

A minimal amount of electroplating is conducted at NASA-LaRC and at Langley AFB. The general pollution prevention guidance in this report should find application at other TIPPP facilities, but not on the scale of NADEP.

MEASUREMENT OF POLLUTION PREVENTION

Good operating practice implementation is relatively easily monitored in terms of water use and direct waste generation. Other options, such as changeover to aqueous cleaning will require documentation of current baseline generation data, preferably on a waste per square foot of plated area basis.

IMPLEMENTATION PLAN

Due to the diverse nature of the selected options, implementation will require a staged approach. The good operating practices option can be immediately implemented through the creation of an internal NADEP program.

Eliminating the F002 wastes can be achieved through implementation of aqueous cleaning. The selection of effective cleaning equipment and chemistry will require an investigation of available technology and some testing. Due to the range of variables involved, the substantial cost of an aqueous cleaning system and the installation/startup requirements it is estimated that a three year time period is needed for implementation. During this interim period, use of vapor degreasing should be restricted to the newer unit which has an integral recovery still. The older unit should be removed from service. Operators should be instructed to avoid use of vapor degreasing for heavy soil/grease or maskant removal.

Implementation of the selected hard chromium plating options will require: (1) collection of additional production and waste generation data; (2) design of an integrated hard chromium plating system that includes conforming anode plating, effective dragout and emissions recovery, bath maintenance, and spill/drip pollution prevention; (3) phased installation that prevents production shutdowns, and (4) startup and training.

Implementation of the selected nickel sulfamate plating options also involves a staged plan. Initially, efforts should focus on bath maintenance (in-tank filters) and spill/drip pollution prevention (high level alarms, drip pans). These options are relatively inexpensive and easy to procure and install. Implementation of the nickel recovery options (strip solutions and rinses) will require some initial investigation and testing to define, and subsequently design, a suitable system. Operation of the system will require skilled labor and training.

RESEARCH & DEVELOPMENT AND DEMONSTRATION NEEDS

Aqueous Cleaning

Vapor degreasing with chlorinated solvents is an effective and fast cleaning method for a wide range of organic soils. A single TCA vapor degreaser can meet most of the precleaning needs of shops such as the NADEP's plating facility. Aqueous cleaning is a more specific technology in that the equipment and bath chemistry must be more carefully tailored to the application. For many facilities, multiple aqueous cleaning operations will be needed to meet their various cleaning needs. Therefore, before any investigation is performed, the NADEP should fully define their cleaning needs. This effort should include determining: base materials, parts, dimensions, soil types, cleanliness criteria, and corrosion protection requirements.

A wide range of cleaning equipment and chemistry is commercially available that can meet nearly all cleaning needs. Therefore, the process of finding a substitute method is one of selecting the best existing technology rather than developing a new one. To select the proper system an investigation should be performed to find successful applications for similar cleaning requirements. The aerospace industry has taken the lead in this area and should be consulted. Various technical information sources exist that can guide the investigative efforts including journal articles, conference proceedings, and government reports.

Once a set of viable methods is identified, testing should be performed to find the most suitable system(s). Testing can be accomplished through equipment and chemical manufacturers and vendors. Some chemical testing work can be performed onsite while other testing, such as equipment testing, may be performed at the manufacturers location. Offsite testing should be viewed by Navy personnel.

Hard Chromium Plating

A data collection effort is needed to develop the design criteria for an integrated closed-loop hard chromium plating system. The required data includes: workload (e.g., number and dimensions of parts, plating times, base metals plated), existing ventilation system dynamics (flow rates, pressure drops), dragout quantities, evaporation rates, and bath contaminant build up rates.

Nickel Sulfamate Plating

Testing is needed to determine the applicability and design criteria for ion exchange and electrolytic metal recovery technologies. Testing could be performed either onsite or at a vendor's facility.

Baseline data are needed to properly size the selected equipment. The data collection effort should determine average dragout rates for each process solution and the nickel build up rate in the strip solutions. These data should be collected over a sufficient time period to show average conditions.

RECOMMENDATIONS/CONCLUSIONS

Good operating practices and collection of baseline data must be conducted as soon as possible. Both nickel and chrome plating process waste can be reduced by these methods. Significant reduction in waste operation can be accomplished by implementation of closed loop hard chrome plating, nickel recovery systems, and use of aqueous cleaning systems.

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT CHEMICAL MATERIAL MANAGEMENT SYSTEM

Naval Base Norfolk

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INTRODUCTION

Chemical materials are an indispensable part of the day-to-day operations of many industrial processes. Chemicals may be used for a variety of purposes including raw materials, catalysts, or reactants during process unit operations. They may also be used in conjunction with on-site pollution control or waste treatment operations.

Although essential for many industrial processes, chemical materials have the potential to pose serious threats to human health and the environment if not managed carefully. Examples of chemical mismanagement include excessive procurement, poor bookkeeping, unauthorized handling or exchange of materials by untrained workers, chemical storage in leaky or otherwise unsuitable containers, hoarding, and inappropriate material applications, (i.e., using the wrong chemical for the wrong job). Also, inflexible procurement systems may require the use of one material when another, less toxic material will do the job just as well. Any of these scenarios can result in the unnecessary generation of hazardous waste, site contamination, and/or harm to exposed workers.

Hazards are compounded at large installations, such as the Naval Base Norfolk, because of the large number of shops requiring the acquisition, storage, and use of chemical materials. However, large complexes can offer economies of scale through centralized inventories, bulk purchases, and employee training sessions, and thereby achieve pollution prevention opportunities. A well-planned materials management and training program is essential to ensure the safety of personnel, as well as the pollution prevention potential and cost-effectiveness of hazardous chemical material usage at Norfolk.

The NSC currently has made limited progress toward control of chemical inventory and in solvent recovery and a Paint Mart exchange. They do not have a regimented, computerized system for tracking chemical purchases, matching purchases to processes, identifying viable substitutes or changes to procedures, and in controlling the large amounts of chemicals disposed each year due to expired shelf life. Such a control system allows systematic environmental reporting, establishment of accountability for waste generation and chemical use in the workplace, and clearer tracking of usage patterns to reduce shelf life problems.

This report outlines several strategies for environmentally sound chemical materials management, with an emphasis on computer tracking systems, worker training, and centralized control of acquisition, handling, use, and disposal of chemicals. These strategies were compiled from a number of sources, including the experiences of several large chemical companies, such as Dow, Du Pont and 3M, as well as other military facilities. The information for this report was acquired from the Environmental Protection Agency's Pollution Prevention Information Clearinghouse (PPIC). The objective behind the chemical materials management strategy presented in this report is to minimize hazardous waste generation at the Norfolk Naval Supply Center (NSC) through effective elimination of hazardous materials misuse.

PROCESS REVIEWS

The Naval Supply Center is one of many commands located at the Naval Base in Norfolk, Virginia. Its mission is to provide materials and supplies to all naval shore activities east of the Mississippi river and all units in the Atlantic and Mediterranean fleets. Among the services provided are procurement, customer services and industrial support. In addition, the NSC performs equipment maintenance duties and maintains its own print shop.

Hazardous waste generation from the NSC totaled 404,670 pounds in 1991, including approximately 165,200 pounds of paint, 19,400 pounds of trichloroethylene (TCE), and 129,500 pounds of cleaning compounds which were discarded as a result of having exceeded their shelf life. The NSC is considered a prime candidate for implementation of a chemical materials management system (CMMS).

ASSESSMENT

Current Chemical Materials Management Initiatives

Naval Base Norfolk has already implemented a number of chemical materials management practices including:

- Direct delivery of chemicals to requestors;
- Approving all new chemicals of safety prior to purchase;
- Investigating nonhazardous substitutes for process chemicals by materials engineers at the Naval Aviation Depot, Norfolk (NADEP);
- Recycling of process solvents;
- A Paint Mart run by the NSC in which paint is exchanged;
- Solvent elimination studies presently being conducted by the Naval Energy and Environmental Support Activity.

The identification of spent solvent generators and potential applications of recovered solvents are among the options identified for future pollution prevention projects.

In addition to the above initiatives, NSC Norfolk and the General Services Administration (GSA) have coordinated activities to overcome problems encountered by the NSC in obtaining supplies from GSA and to promote more efficient chemical materials management initiatives. Discussion has focused on shelf-life, paint testing, packaging and just-in-time delivery.

Shelf-life

The GSA has proposed several methods of supplying shelf-life materials to the NSC Norfolk with the intent of providing maximum remaining shelf-life. These include:

- Direct vendor delivery of priority chemicals, (i.e. those large order chemicals which create undesirable shelf-life distribution situations);

- Establishing direct requisition-specific codes to identify those requisitions which may require other means of support, such as partial issue from stock balances;

- Differentiating between materials which will be directly delivered and those stored;

- Pre-stock agreements between the Navy and GSA for direct delivery materials.

Paint Testing

Through a Memorandum of Understanding between the Navy and GSA, certain Navy shipyards have been recognized as being capable of conducting paint testing. With this agreement, GSA will accept paint test reports from certain shipyards without the need for further laboratory verification of complaints. This satisfies Navy and GSA objectives of eliminating the generation and storage of hazardous waste through expedient return to the vendor of rejected paints, and improving productivity and paint quality.

Packaging

NSC Norfolk has several old storage facilities with storage racks set up for pallets of two-high-stacking of 5-gallon can materials. Often, GSA ship pallets are packaged three high with 5-gallon cans, meaning that a lot of labor is expended to take apart the three-high shrink-wrapped pallets and re-stack the materials two-high. GSA is working to address this packaging problem in order to eliminate the excess packaging waste and improve productivity.

Just-in-Time Delivery

NSC Norfolk is willing to work with GSA to establish a delivery system that minimizes shop inventory by distribution close to the time of use (just-in-time delivery) of materials if GSA can meet the required delivery dates.

Pollution Prevention Options

As described above, the NSC has initiated several methods of effective chemical materials management. However, additional measures can be implemented to achieve further waste reductions. This section attempts to identify other pollution prevention alternatives currently available to chemical materials managers. It should be noted that some of the ideas presented here may already be in use at the NSC. The pollution prevention options presented here are divided into three categories: information management; management initiatives; and employee education.

Information Management

Careful tracking of quantities and uses of chemicals at a facility can result in more efficient material use and ensure that hazardous materials are not misused. Comprehensive chemical tracking utilizes a computer program to track the procurement, storage, distribution, use, disposal of, and recycling of every chemical purchased.

Kelly AFB CMMS--

Several years ago, staff at the Kelly Air Force Base-San Antonio Air Logistics Center in Texas developed a computerized system for tracking chemical material purchases, distribution, processes and users, and waste generation. The system was developed with government personnel, and is therefore available to other interested users without charge. The system configuration and program elements are described in reference 2.

The Kelly CMMS was designed to satisfy the following objectives:

- It must meet required employee "right-to-know" standards;
- The hazardous nature of chemicals used in facility processes must be assessed prior to use, and that use must be strictly controlled throughout the process;
- A "paper trail" must be used to keep managers informed of the quantities and locations of materials currently in use;
- Unsafe or unauthorized practices, such as hoarding, improper storage, and/or trading of chemicals must be eliminated.

The CMMS provides a life cycle tracking and control mechanism for chemical materials entering and leaving the SA-ALC and related staging areas and shops. The movement of chemical materials through the industrial processes at the facility is rigorously controlled and documented, from raw material inputs to final product and process waste outputs. The tracking and control mechanisms of the CMMS system serve to connect all functions connected with chemical materials management including MA, Industrial Hygiene (IH), supply functions, and chemical staging areas as well as individual shops.

The heart of the Kelly AFB CMMS system consists of both a computer data management system (an HP-3000 computer network) and a material tracking form (AFLC Form 3916) which the Center developed for controlling the use of each chemical. This form serves both as the initial step of the procurement process and as an on-site repository of material-specific information.

In developing the system, the SA-ALC identified the shops or work areas likely to request chemical materials. Each was assigned a specific code number for tracking purposes and furnished with a chemical information management notebook. This notebook contains site specific spill plans, the most recent industrial hygiene survey for the shop, and the AFLC Form 3916 for each chemical used in the shop.

The Kelly AFB CMMS tracking process begins with the completion of AFLC Form 3916 for each chemical. By design, only authorized persons may receive a hazardous material under CMMS. In filling out the form, the requestor must identify the material needed and justify the request by describing the process for which the chemical is intended and its proposed use. Upon completion, the form is sent to the shop's engineering support group for approval.

The form is then sent to the MA environmental office for review. Before issuing its approval, MA checks the requestor's hazardous material training level, the chemical's intended use, the quantity requested, and the material's hazard against the computer database. If accepted, the form is entered into the database and forwarded to Industrial Hygiene which adds a Material Review Code, a material hazard classification, a Material Safety Data Sheet (MSDS), and the time period for which the authorization is valid.

Upon approval, both the MA and the shop receive a copy of the final form and accompanying information. The chemical is then issued to the authorized person from one of several chemical staging areas. This process ensures that no unauthorized person can receive a hazardous material, and that quantities and locations of chemical materials at the Center are documented.

Du Pont's Corporate Waste Data Base--

Du Pont's Corporate Waste Data Base is another example of a waste tracking system. This system takes advantage of Digital Equipment Corporation's Datatrieve interactive language, and is designed to run on VAX/VMS mainframe computer systems. An important feature of Du Pont's waste tracking system is its ability to monitor the progress of pollution prevention measures. The computer program normalizes waste generation figures to production increases, so that gains in process efficiency are not masked by increases in overall waste generation. Also, reporting of waste figures is done on an annual basis. This allows for meaningful comparisons between successive yearly waste generation figures, without requiring excessive reporting by individual shops.

Management Initiatives

This option encompasses a number of initiatives which can help to increase hazardous material management efficiency. These initiatives include inventory control, chemical storage, proper labeling, and reusing chemical containers.

Inventory Control--

Expired shelf-life materials have been identified by the NSC as a major waste generating source. Strict inventory control is the most effective and cost-efficient way to prevent materials from needlessly becoming wastes. Inventory control practices range in sophistication from simple operating procedures to more complex computerized inventory control systems. Despite these differences, all inventory practices share the common goal of minimizing hazardous waste generation due to expired shelf life or material obsolescence.

Simple material control practices include "first-in, first-out" inventory control -- that is, using older materials before new supplies -- and direct delivery of process chemicals to specific shops. These practices prevent excess chemicals from accumulating and minimize the amount of waste generated due to material obsolescence.

The 3M Company provides an example of a more complex inventory control system. Their system, known as "just-in-time inventory control", is designed on the principle that no more of any given material is stored at the facility than is absolutely necessary. Just-in-time procurement and delivery are the cornerstones of 3M's inventory control approach. As such, only the minimum amount of a chemical needed for a specific job is purchased at a time, and the material is transported to the shop only when it is needed for production. This type of inventory control system effectively eliminates excess inventory and the potential for waste from becoming obsolescent material through strict purchasing, storage and transportation control. Despite its pollution prevention advantages, just-in-time inventory control is difficult to maintain because it requires predictable production scheduling and coordination between the purchasing and the production departments.

Purchase quantity management, the technique of purchasing only the specific amount of a raw material for a certain task, is another 3M initiative for effective inventory control. Stockless production, in which the amount of required end product dictates how much of its feedstock will be produced, is another variation of the same concept.

Finally, many out-of-date chemicals can be returned to supply centers and recertified for use, or returned to the chemical supplier. Some suppliers will even give credit for returned materials against future purchases. It is important to remember that disposal of materials should take place only after other pollution prevention options, such as materials recertification and return, have been considered.

Chemical Storage--

Proper chemical storing and handling can reduce the needless loss of materials. There should be an ensurance that chemicals are compatible with the containers and conditions in which they are stored. For example, organic solvents should be stored under proper conditions so that they do not undergo temperature extremes. Routinely check storage areas for damaged or leaking containers, and promptly correct identified situations. Storing chemicals off the ground (on pallets or shelves) simplifies the task of identifying leaking or damaged containers. Finally, keeping lids closed and bungholes tightly plugged prevents the evaporation of solvents, reduces spills, limits contamination from dirt and moisture, and minimizes health risks and air pollution.

Material Identification--

Perfectly good chemicals may enter the waste system due to improper or missing identification or labeling. Keeping container labels up to date, including names, expiration dates, and other pertinent information can prevent this waste source. One suggestion might be to install a bar code system for hazardous material containers. In such a system, each container is issued a unique code that records the chemical content, the recipient, the date it was issued, the chemical's intended use, and the chemical's expiration date. This would make additional information available while allowing for easier tracking of the chemical through its life cycle.

Container Management--

Empty material containers often contain hazardous residue, forcing the containers to be disposed of as hazardous waste. Many suppliers will accept returned containers for reuse as part of their pollution prevention effort. In addition, purchasing large-sized containers may reduce the number of partially filled or empty containers in the management life cycle. However, according to the American Chemical Society, purchasing chemicals in exact quantities and in smaller containers may prove more cost-effective than purchasing large "economy-size" containers, due to the costs associated with disposing of any excess chemical. The decision on which size container to buy therefore depends on the relative demand for the chemical and the probability that excess chemicals will exceed their shelf life.

Material Substitution--

Many nontoxic substitutes are now available for hazardous chemicals. For instance, aqueous, biodegradable cleaners can be used instead of halogenated solvents in many cleaning operations. Using these materials can eliminate hazardous waste generation fr~m many process operations, and eliminate having to stock, store and track hazardous materials.

Waste Exchanges--

A waste exchange allows one facility to sell or give its waste to another facility which can use the waste as a raw material. Generally, a waste exchange lists both those who have materials available and those who need them. Exchanges can be conducted "in-house" or between facilities, and can reduce disposal and raw material purchases while promoting environmental protection. Of course, use of a waste exchange should be considered only as a last resort, after all other source reduction opportunities are exhausted.

Employee Education

A well-trained staff is the cornerstone of any successful chemical materials management program. Every employee should receive training in the following areas:

- The importance of pollution prevention;
- Proper use and handling of the chemicals used in the shop;
- Spill prevention and safe cleanup;
- Proper disposal and/or recycling practices for all chemicals used in the shop.

Properly trained employees can help to ensure that the correct chemical is used for the correct job, and that chemicals that can be reused, recycled or otherwise segregated from the waste stream receive appropriate handling.

FEASIBILITY

Following the initial pollution prevention assessment, a feasibility analysis was conducted for each component of the pollution prevention options using a modified Worksheet Number 13 (*Waste Minimization Opportunity Assessment Manual*, p. A18, EPA/625/7-88/003). Each option was rated qualitatively for a number of different criteria since quantitative data were not available. Table 1 displays the data. A brief discussion of each option is presented below.

Chemical Material Management System (CMMS)

Computer data base tracking systems are available in a number of different forms. The NSC would likely require a system similar to the one used by SA-ALC which is available free of charge from the Air Force Material Command (AFMC). There will most likely be substantial institutional resistance to the extra work load required by the new reporting practices. In addition, the time required to get the CMMS started may create resistance to the system. One year of data input was required to obtain the funding and installation of seven chemical distribution centers for the CMMS.

TABLE 1. QUALITATIVE ASSESSMENT OF POLLUTION PREVENTION OPTIONS FOR THE NAVAL SUPPLY CENTER

Criteria	Information Management	Just-In-Time Inventory Control	Chemical Storage and Material Identification	Container Management	Material Substitution	Waste Exchanges	Employee Education
Effect on Base Operations	No long term effect	No long term effect	No effect	No effect	No effect	No effect	No effect
Waste Reduction	Positive effect	Positive effect	Positive effect	Positive effect	Partially compatible; will require changes in procurement policies and shop operating procedures; may require military specification changes	Partially compatible; will require changes in procurement policies and shop operating procedures	Fully compatible
Compatibility with Existing Operating Procedures	Partially compatible; will require changes in procurement policies and shop operating procedures	Partially compatible; will require changes in procurement policies and shop operating procedures	Fully compatible	Fully compatible	Unsure; may result in slight cost increase; further evaluation needed	Should be positive; may result in slight cost increase; further evaluation needed	Cost savings
Cost Requirements Compared to Current Costs	Significant initial costs; will be offset by disposal costs savings in the long run	Unsure; may result in slight cost increase; further evaluation needed	Cost saving	Cost saving	Unsure; material specific, need further research	Minimum	Instructors are required
Additional Labor Requirements	Additional workload to run system and fill out forms	None	None	None	Identification and testing of alternatives necessary before implementation can proceed; may take time to perfect new material with operations	Immediate	Immediate implementation
Implementation Period	Can run to several months before system reaches steady state	May require a significant start-up period before steady state is reached	Immediate implementation	Planning required before implementation can occur	Can be difficult to implement, depending on organizational resistance; may require modifying environmental permits	Easy to implement	Easy to implement
Ease of Implementation	Can be difficult to implement, depending on organizational resistance	Can be difficult to implement, depending on operational requirements	Easy to implement	Unsure; depends on organizational requirements and supplier resistance	None; positive benefits	None; positive benefits	None; positive benefits
Adverse Environmental Impacts	None; positive benefits	None; positive benefits	None; positive benefits	None; positive benefits			

Inventory Control

The feasibility of implementing just-in-time inventory control depends on several factors, including shop operating requirements, institutional resistance to the extra planning required, and quick turnaround of chemical procurement requests. Ships pose a special set of complications to just-in-time scheduling since the delivery of materials is hindered by the vessels' deployments away from the naval base and the supply center.

In addition, ships create difficulties for inventory control due to the length of time a vessel is at sea which can be a large factor in determining which chemicals are stocked. Enough chemical materials for an entire voyage may have to be purchased and transported aboard at one time. Estimating the correct amount of a specific chemical required for a job can be difficult. If the job is not done well, certain chemicals may not be used and will have to be returned. If the vessel does not return to port prior to the chemical's expiration date, it will become obsolescent and will have to be recertified, returned to the supplier, or disposed of as waste.

First-in, first-out inventory is crucial since the number of different operations for which a chemical may be used is more limited aboard ship than at the base.

Chemical Storage and Material Identification

Container labeling practices and bar coding should be much easier to implement since they simply require an increased awareness and attention to detail on the part of inventory workers. Employee education will help make implementation go smoothly.

Container Management

Planning and cost/benefit analysis should be done for each chemical before the various container management schemes, such as correct-size purchasing and container recycling, are implemented. Most suppliers should be willing to work with the NSC in implementing a container return/optimal product-sizing system.

Material Substitution

A number of substitutes for hazardous chemical materials are currently available in the marketplace. However, research will need to be done to identify and test these materials under base conditions. In addition, military specifications may need to be changed to allow substitution of materials.

Waste Exchange

Waste exchanges, both "in-house" and between facilities, are an efficient method of reducing disposal and raw material purchases. This concept may be applied to the NSC in two ways. One would be to participate in a waste exchange outside the base, such as the exchange serving the Tidewater area which is currently under development. The other would be to expand the concept of the Paint Mart to include other materials, such as cleaning compounds.

Employee Education

Training and technical information from other chemical supply centers in the military should be investigated for applicability with the NSC. In particular, SA-ALC's experiences may prove to be a valuable resource.

CROSSFEED POTENTIAL

The information management systems discussed in this report have the potential to be adapted for use at all other TIPPP facilities. The chemical management initiatives and employee education options are also widely applicable, and are in fact utilized in chemical material management operations in both the public and private sector. As with the NSC, other facilities would have to conduct a number of planning studies before the feasibility of any of the options discussed in this report could be fully evaluated.

MEASUREMENT OF POLLUTION PREVENTION

Measuring the impact of pollution prevention activities requires baseline data on chemical material types, costs and volumes, as well as handling and disposal costs and volumes. Other categories of required information include inventory maintenance costs (physical plant, administrative, overhead, etc.), transportation costs (equipment, labor, maintenance) and sales of surplus inventory, in particular those from the Paint Mart. Although this information apparently exists, it was not made available by the time this report was written.

Once this baseline data has been established, a given set of pollution prevention measures may be implemented. Following implementation, a database similar to the one outlined above should be gathered to compare and identify program benefits. In order to ensure a reliable comparison, the new system should be allowed to approach a steady state before data is collected. Finally, adapting some of the normalization and reporting-period features of Du Pont's Corporate Waste Data Base to the NSC system will permit more accurate assessments.

IMPLEMENTATION

As with any major procedural change at a large industrial setting, there will likely be significant start-up delays associated with the CMMS. Initial implementation of the CMMS at Kelly AFB did not run as smoothly as the SA-ALC had planned. First, construction lead times for the chemical staging areas delayed full implementation. Second, the time required for the forms to pass through the entire system turned out to be longer than expected, due primarily to the difficulty of acquiring sufficient technical data to support use of a given chemical for a given task. Third, the organization was initially hesitant to accept the new system, due to the extra work required of all involved parties. However, in time this reluctance vanished as personnel gained experience and recognized the benefits of the life cycle tracking system.

RESEARCH DEVELOPMENT AND DEMONSTRATION NEEDS

In order to optimize the benefits from the installation of a CMMS, the NSC should undertake several studies to identify which option or combination of options fits best with the available budget and material management needs. These are briefly outlined below:

Information Systems - Two versions of a CMMS, SA-ALC's and Du Pont's, have been described in this report. The NSC may be able to implement either system in its entirety, or develop its own tracking system code that implements the best features of both systems. In addition, there are other computer-based material management systems that should be investigated.

Management Initiatives - Cost/benefit analysis of many of the management initiatives presented in the Assessment section should be undertaken before any are implemented. For instance, the conflict over the cost efficiency of buying in bulk or on an as-need basis should be studied. Only by analyzing specific situations and needs can such questions be resolved.

Employee Education - As is the case with management initiatives, cost/benefit analyses should be undertaken before any training initiatives are implemented. Questions such as whether it is more cost-effective to train one responsible person for each shop, or if all workers should receive at least some training should be answered before implementation of a training program.

RECOMMENDATIONS/CONCLUSIONS

Of the pollution prevention options listed above, the CMMS, just-in-time inventory control, and increased use of waste exchanges all require additional study prior to implementation. Tight budgets may preclude the full implementation of one or more of these options, especially the CMMS. One approach might be to select high visibility waste streams (paints, TCE, cleaning compounds, etc.) for selective implementation, then to expand these programs as budgetary constraints permit. Other options, such as chemical storage and material identification, may have a lesser pollution prevention impact but will probably be easier to implement. Material substitution may be the most cost effective option presented for immediate hazardous waste stream reduction, but its application as a technique may be limited.

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

NAVAL AVIATION DEPOT, NORFOLK, VIRGINIA
MACHINE COOLANT FLUIDS

by

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EPA Contract No. 68-C8-0062, WA 3-70
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INTRODUCTION

Purpose

The purpose of this project was to conduct a Pollution Prevention Opportunity Assessment (PPOA) for selected processes at NADEP's Machine Shop. The assessment was conducted for the EPA's Risk Reduction Engineering Laboratory under the purview of the Tidewater Interagency Pollution Prevention Program (TIPPP) of the Pollution Prevention Research Branch. The procedure described in the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003) was used to conduct the study. The manual provides detailed worksheets and a process/option evaluation method for use in industrial settings.

Approach

A PPOA consists of four systematic steps: Planning and Organization, Assessment, Feasibility Analysis, and Implementation. Figure 1 presents the PPOA process. Of the 19 worksheets in the PPOA manual, selected sheets were completed for the processes and waste minimization options considered. The detailed worksheets used are presented in Appendix A. The implementation of the recommended options presented in this report is at the discretion of the host facility.

PROCESS REVIEW

The Naval Aviation Depot (NADEP) at Norfolk, Virginia is one of six U.S. Navy facilities where aircraft are routinely overhauled. Each of these facilities employs up to 4,000 skilled industrial workers. The NADEP at Norfolk performs rework of F14 and A6 airframes, engines, and landing gear. The aircraft rework process consists of complete disassembly, inspection of reusable parts, remanufacturing of parts, reassembly, and testing. The remanufacturing operations include numerous machining and metal finishing operations which generate significant quantities of hazardous and oily wastes. The focus of this study was machining and grinding which is performed in building LP-24. This facility contains approximately 100 machines used for manufacturing new aircraft parts and remanufacturing used parts.

This report presents the results of the machining and grinding PPOA. These two operations generate oily waste as a result of discarding used machining and grinding coolants and hydraulic oils. Coolants are discarded when they become contaminated with solids and tramp oil and/or become rancid. Due to its chromium concentration, the spent coolant is discarded as a hazardous waste. Hydraulic oils are discarded as non-hazardous waste when they are contaminated with solids and/or moisture. Both wastes are hauled offsite for disposal.

General Overview of NADEP Machine Shop

The NADEP machine shop is located in two adjoining buildings (V-28 and LP-24) that have the appearance of a single building. In addition to housing a portion of the machining operations, building LP-24 also houses the plating shop. Building V-28 is approximately 80 years old and the machine shop portion of Building LP-24 is one year old. The machines and equipment in the machine shop range in age from 5 to 50 years.

Machining and grinding operations at the NADEP were recently grouped into a cellular organization. With this method, machines that work on the same parts are grouped together rather than grouping the same types of equipment together (e.g., locating all drill processes of milling equipment in the same area). The NADEP management believes that their new method of organization creates a greater sense of responsibility and ownership among machinists and results in higher facility work and greater care for equipment. Also, the reorganization eliminated the need for approximately 25 machines which were removed from the NADEP.

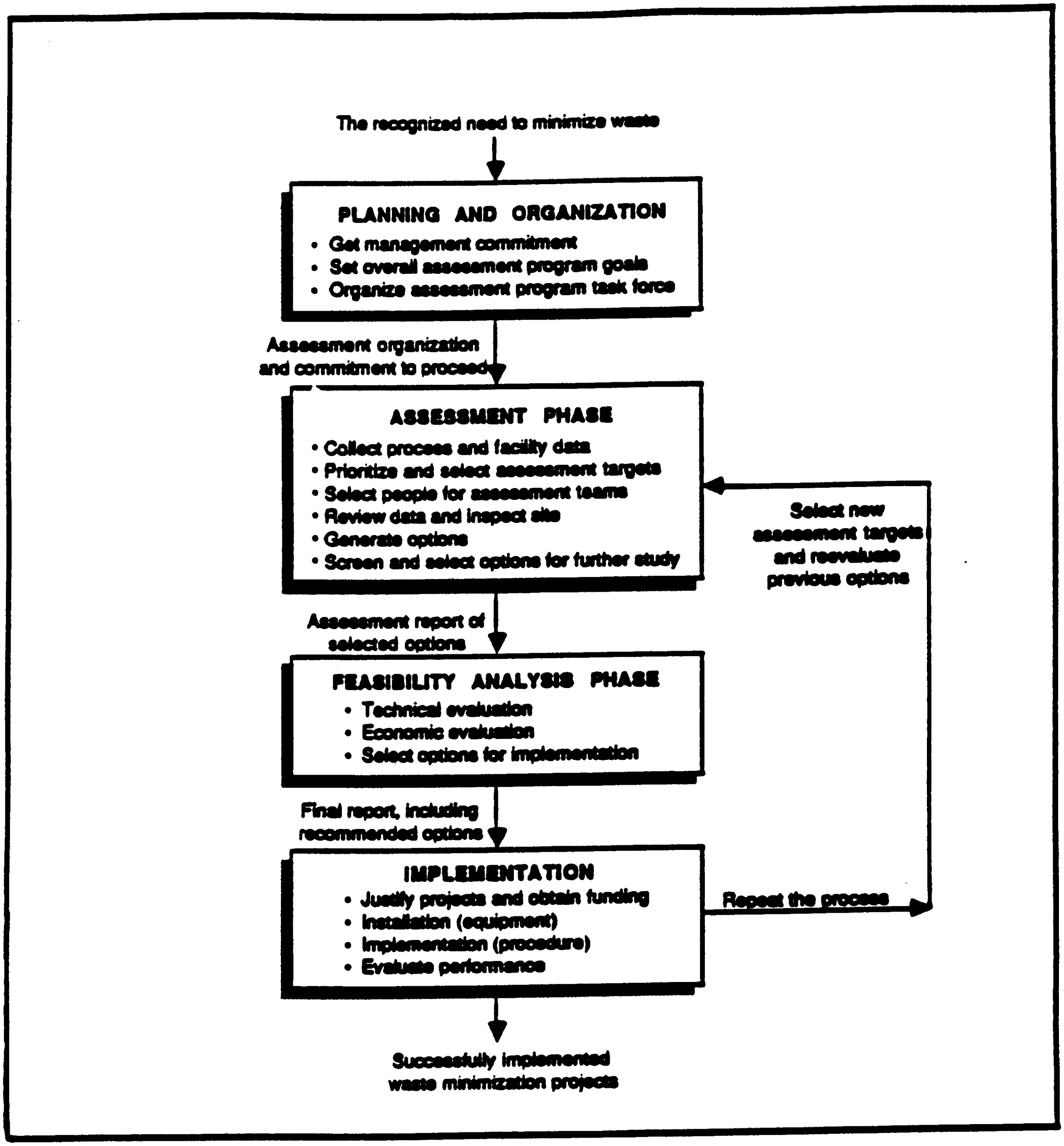

FIGURE 1. THE WASTE MINIMIZATION ASSESSMENT PROCEDURE

The cellular organization presently includes six cells. A seventh cell is under construction. The key operations in each cell include:

- Cell 1 - Turning
- Cell 2 - Milling
- Cell 3 - Large turning, grinding
- Cell 4 - Cylinder grinders, drill presses
- Cell 5 - Large milling, drill presses
- Cell 6 - Small turning, grinding
- Cell 7 - Flexible manufacturing system (FMS), numerical controlled mills

The machining shop manufactures and reworks approximately 6,200 different aircraft parts with a wide range of base metals from aluminum to high tensile steel. A central computer is being installed that will track the inventory of parts and permit use of the "just-in-time" inventory concept. This plan is expected to reduce operating costs. Also, a separate computer has been purchased to provide statistical process control (SPC). The types of data that will be tracked include total parts manufactured, reject rate, and tool life. The SPC program is expected to increase efficiency at the facility and reduce operating costs.

The NADEP machine shop has an excellent housekeeping program. All equipment is laid out in an orderly and organized fashion. No unused equipment is present that could clutter work areas. An area under reconstruction (Cell 7) was clearly roped- off to prevent co-mingling with production areas. Floors are kept relatively free of chips, dirt, and debris, and no fluid leaks were found. These conditions deserve a tribute to management, engineering and machinists. Such conditions, by themselves, reduce the generation of pollution by reducing contamination of machine fluids. Also, they create an amenable environment for the implementation of other pollution prevention options.

Machine Coolant and Hydraulic/Lubricating Oil Usage

Machine coolants are used primarily for cooling and lubrication during machining and grinding. Cooling is needed to remove heat from the tool and workpiece that is generated by the friction of the metal-on-metal contact. If left uncontrolled, the high temperatures would eventually damage the workpiece and/or the tool. A good coolant allows a faster production rate for a given tool life than a poorer coolant would for the same given tool life. When the chip-tool interface is lubricated, the cutting operation becomes more efficient and less heat is generated than without a lubricant.

Water is an excellent fluid for cooling. It is capable of dissipating heat 2½ times faster than the type of oil typically used for machining. However, water is a very poor lubricant and it causes rust. For lubrication, oil is a much better fluid. [1] Therefore, coolant formulation strategies often lead to combining these two fluids to give overall satisfactory results.

In addition to lubrication and cooling functions, a coolant must also inhibit corrosion and bacterial growth, and be free of objectional odors. A coolant must also be nontoxic both for inhalation and for skin contact.

Actually there are various types of machine coolants in use; the choice depends mostly on the cooling/lubricity requirements and cost. The available coolants can be categorized into four groups: synthetic, semi-synthetic, straight oil, and soluble fluids. Synthetic fluids are generally more expensive than other types of coolants; however, they also last longer. Straight oils are used infrequently due to health and safety problems such as fire hazards and slippery floors. Water soluble fluids are the most commonly used. They contain an oil and an emulsifying compound and are diluted with water for use. The water provides cooling and the oil provides lubricity. [1][2]

Hydraulic/lubricating oils are used in metalworking operations for non-contact purposes such as transferring energy hydraulically and lubricating gear boxes and moving parts in metalworking machines. Except for way lubrication, these lubricating oils and greases are contained within enclosed reservoirs in the individual machines. [2] Way lubricant is used to lubricate the surface or slide (way) on which the carriage of a lathe, etc. moves along its bed. Straight oils are typically used for these applications; however, soluble oils can be used under certain conditions.

There are a total of 100 machines in the NADEP machine shop. The average machine coolant sump size is 50 gallons (5 to 200 gallon range). Therefore, the total machine coolant capacity is approximately 5,000 gallons.

Two types of machine coolants are employed at the NADEP. These include Microcut 5863, which is used for machining, and W&B Grinding Coolant E-55 (referred to as E-55) which is used for grinding. Both products are water soluble fluids. The annual quantities of coolant purchased are 8 drums of Microcut 5863 and 4 drums of E-55. The purchase costs are $6.85 per gallon and $15.36 per gallon respectively. Microcut 5863 is diluted with tap water to a 5% concentration for use and E-55 is diluted to a 2% concentration. Therefore, the total quantities and unit costs of diluted coolant are:

- 8,800 gal. of 5% Microcut 5863, $0.34 per gal.
- 11,000 gal. of 2% E-55, $0.31 per gal.

Data concerning hydraulic oil type, use and cost are not available.

Machine Coolant

Coolant replacement is necessary when the coolant becomes contaminated leading to degradation. There are various interacting factors that affect the rate of coolant degradation. The primary contaminants of coolant are tramp oils such as way lubricant that is flushed into the coolant system during machining and hydraulic oil that is contributed through leaking hydraulic seals. Other contaminants include metal particles, grease and dirt. Bacteria can grow in a coolant and tend to flourish in contaminated coolant. The use of poor cleaning techniques between coolant changeouts hasten the growth rate of bacteria.

Two general types of bacteria are found in coolant systems: 1) aerobic, which multiply in the presence of oxygen, and 2) anaerobic which propagate in the absence of oxygen. The anaerobic bacteria produce hydrogen sulfide as they degrade coolants which is responsible for the rancid or "rotten eggs" odor of some coolants. Although the odor is unpleasant , it is not an indication that the coolant is degraded in terms of capability. Aerobic bacteria consume coolant constituents and reduce the lubricity and corrosion inhibition properties of the fluid. [3] The bacterial life cycle while "eating" the fluid concentrate also results in the deposition of various acids and salts. These can cause rusting/corrosion of machine parts, tools and work pieces. [1]

The degraded and rancid coolant creates a very unpleasant working condition and a potential health hazard. At the NADEP, the determination of when coolant sumps/reservoirs will be changed is made by a supervisor at the request of an operator. Most sumps are changed every one to three months. The removal, cleaning, and replacement of coolant is performed by the Maintenance Department.

The waste coolant generation rate reported by the NADEP is 178,000 lbs. per year (21,340 gpy). This quantity is slightly higher than the diluted raw material usage rate (19,800 gal.). The difference can be accounted for by: 1) over dilution during usage; 2) reservoir wash-out water being combined with spent coolant; and/or 3) the data representing slightly different time periods.

When a coolant reservoir is changed, the spent coolant is pumped into 55-gallon drums and shipped offsite for hazardous waste disposal by the Defense Reutilization and Marketing Office (DRMO). The spent coolant contains chromium in excess of RCRA criteria for a toxic hazardous waste (D007). The cost of transportation and disposal is $2.10 per gal. or $41,580 per year.

Hydraulic/Lubricating Oils

Hydraulic and lubricating fluids used at the NADEP are straight oils. The condition of these oils is routinely checked by the Maintenance Department. During use, these oils become contaminated with dirt and other solids and water which can damage machine lubrication and hydraulic systems. Due to the high cost of machine maintenance or replacement, maintaining hydraulic and lubricating oils in good condition is a NADEP priority.

Previously, the NADEP changed-out these oils on an as-needed basis which has averaged two times per year. The contaminated soil was drummed and sent offsite for nonhazardous disposal. Recently, the NADEP purchased oil filtration equipment for maintaining and extending the useful life of these oils.

The selected filtration equipment is a portable unit with a 1 hp motor and a filtration rate of 12 gpm. The filtration equipment and motor are mounted on a hand truck or dolly for portability. It contains a 100 mesh reusable strainer and two duplex disposable filters, one set for particulate removal (two 7-inch, 10 micron filters) and one set for water adsorption (two 11-inch, 10 micron filters). Various replacement filter elements with different micro ratings are available (3 to 200 microns). The filtration unit has two 10 ft. flexible hoses (inlet and outlet) for connecting to a machine or drum. There is a drip pan located below the cartridge filters. Due to the newness of the hydraulic/lubricating oil maintenance efforts, there are no data that indicate their effectiveness.

ASSESSMENT/FEASIBILITY

A list of potential pollution prevention options is presented in Table 1 that were identified during the assessment phase. The following is a description of each option.

Frequent Coolant Testing and Control. Depending on the characteristic of the machining operation and usage, coolant should be monitored on a daily to weekly basis. Higher usage rates and conditions conducive to evaporation or contamination require daily monitoring. Monitoring should consist of the following measurements and observations: pH, specific gravity (refractometer), total dissolved solids (TDS), tramp oil (visual), and bacteria count (TDS and bacteria count are not needed more frequently than 1 per week). When monitoring identifies poor coolant conditions, the proper correction should be performed (e.g., adding water to reduce specific gravity).

Hydraulic and Lubrication System Maintenance. Leaking seals should be replaced immediately to prevent coolant contamination. Preventative maintenance should be performed on a routine basis.

Identify Chromium Source and Implementation Waste Segregation Plan. The spent coolant is currently discarded as a hazardous waste because of its chromium content. The source of chromium, possible grinding, should be identified by a sampling and analytical survey. Non-hazardous and hazardous waste coolants should be segregated to reduce the quantity of hazardous waste discarded.

Use Deionized (DI) Water for Coolant Make-up and Evaporation Replacement. Hardness present in the tap water used to formulate coolant and make-up for evaporation losses destabilizes coolant emulsions.[1] As little as 51 mg/l of hardness can have deleterious affects on coolant. [4] Testing at the NADEP shows that hardness ranges from 50 to 170 mg/l, with the higher readings taken in 1991. During

TABLE 1. POTENTIAL POLLUTION PREVENTION OPTIONS

Options	Potential Impact	Estimated Capital Cost
Machine Coolant		
Frequent coolant testing and control	Frequent monitoring will identify coolant quality problems before the coolant is degraded beyond the point where it can be corrected. Controlling coolant parameters within an operable range will extend coolant life.	$2,000 (laboratory equipment only)
Hydraulic and lubrication system maintenance	Preventative maintenance, including periodic replacement of hydraulic seals will reduce contamination of coolant with tramp oil.	
Identify chromium source and implement waste segregation plan	May reduce the quantity of spent coolant that is disposed of as a hazardous waste	
Use deionization water for coolant makeup and evaporation replacement	May reduce the disposal frequency of coolant	
Use concentrated coolant in hydraulic and lubrication systems where possible	Will reduce hardness contamination of coolant and extend coolant life	
Assign coolant testing and management to a single qualified individual	Will add consistency to coolant management program and reduce losses caused by ignorance	
Sterilize coolant reservoirs during change-out	Will retard the initial growth of microorganisms and extend the life of the coolant	
Utilize cellular organization to track coolant usage costs	Due to the importance of cost in the overhaul process, identifying particular problem cells with eventually lead to better coolant management	
Incorporate elements of fluid management into existing SPC system and total quality management program. Relate coolant quality to tool life, work quality and reject rate. Track and report machine coolant waste for each machine and organizational cell.	Will generate data useful in evaluating production quality and costs. Also will identify problem areas and eventually reduce coolant waste generation.	
Periodically filter coolant to remove contaminants	A cartridge filter system will remove suspended solids for the used coolant and extend its useful life.	
Recycle used coolant either using Navy purchased equipment of an onsite recycle service	Will reduce the quantity of coolant sent to offsite disposal.	
Hydraulic and Lubricating Oils		
Replace current fluids with high quality fluids containing additives which extend the life of the oils.	Will reduce the quantity of oil disposed of	
Replacement of hydraulics with electrical systems	Newer electrical system can replace hydraulic systems on some machines. Conversion would be performed during machine overhaul. Conversion will eliminate a major spent hydraulic fluid and minimize coolant contamination for that particular machine	

use, water evaporates from coolant. If the evaporated water is replaced by water containing hardness, the hardness concentration of the coolant will increase. If waste minimization methods are used to extend coolant life, then the hardness concentration will reach intolerable levels. Softened or DI water can be used to formulate coolant and for evaporative makeup without adding hardness. A small water softener or DI system can be purchased or leased.

Machining/Grinding Fluid Substitution. To implement this option, an evaluation of alternative machining and grinding fluids would be performed. These efforts should focus on: 1) finding a single fluid that works as both a machining and grinding fluid (i.e., most likely at different concentrations for the two applications); and 2) finding a fluid that has a long life span.

Use Concentrated Coolant in Hydraulic and Lubrication Systems, Where Possible. Coolant contamination from hydraulic fluids and machine lubrication can be reduced by using the concentrated form of a coolant for these purposes and the dilute forms for machining and grinding. Concentrated coolant is typically several times more expensive than hydraulic and lubricating fluids, but the losses from these uses would be assimilated directly into the coolant system, thus reducing tramp oil introduction. Coolant sales representatives often offer assistance in determining which machine applications can be converted.

Assign Coolant Testing and Management to a Single Individual. With this operation, a single person is assigned the task of monitoring and controlling coolant. For this particular task, this individual would report directly to the machine shop supervisor. After proper training, this individual will be able to identify coolant problems before the coolant becomes uncontrollably spent. Also, this plan will add consistency to coolant management and reduce coolant losses caused by ignorance.

Sterilize Coolant Reservoirs During Change-out. When spent coolants are removed from service, any residual coolant in the machine reservoir or sump will most likely be extremely high in bacterial count. If fresh coolant is added to the sump without killing most of the bacterial population, then the regrowth process of the bacteria will be hastened. Disinfection can be performed by rinsing sumps or reservoirs with a biocide or with steam cleaning.

Utilize Cellular Organization to Track Coolant Usage Costs. The cost of coolant usage (mainly material and disposal costs) is not presently tracked for individual cells within the NADEP machine shop. Tracking and reporting the cost data in this manner may identify cells that are not properly managing coolant and possibly discarding coolant before it is spent.

Use Existing SPC and Total Quality Management Systems to Improve Coolant Usage. This options involves incorporating coolant management into the existing NADEP statistical process control and total quality management systems. The existing SPC system focuses on work quality, reject rates, and tool life. Each of these factors is impacted by coolant quality and can be related using SPC. Using the total quality management program to assist in coolant management and will generate additional ideas for improving coolant use and control. To implement this option, coolant data should be collected and recorded on a regular basis for each coolant sump or reservoir.

Periodically Filter Coolant to Remove Contaminants. A portable filtration system is presently used to remove solids and moisture from hydraulic oils. A similar system could be purchased for coolant filtration to remove suspended solids. These devices will not remove substantial amounts of tramp oil, but will extend the time period between or required recycling treatment (discussed below).

Recycle Used Coolant. The usable life of coolant can be extended almost indefinitely with the use of sophisticated coolant reclamation equipment. Typical systems consists of a screen, cartridge filter, and centrifuge for removal of solids and tramp oils, flash pasteurization for killing microorganisms, followed by a biocide addition and adjustment of coolant concentration. The purchase of this equipment is generally not cost effective except for large machining operation. However, coolant reclamation services are available.

Replacement of Hydraulic with Electrical Systems. Some hydraulic systems can be replaced with equivalent electrical systems. Electrical systems do not have fluids and therefore the quantity of spent hydraulic fluid is eliminated. Also, tramp oil introduction to the coolant is reduced. Conversion to electrical systems would be most economically performed during a major machine overhaul. Electrical systems are a less direct method of transferring power and therefore, are less efficient. The additional energy usage would need to be evaluated on a case-by-case basis.

Replace Current Hydraulic/Lubricating Fluids with Higher Quality Fluids. Like coolant systems, there are various qualities of fluids available for hydraulic/lubricating systems. Except for synthetic hydraulic oils, most hydraulic oils are made from the same base oil (mineral oil). However, the additives vary from oil to oil. Sophisticated additive packages are available that increase the lifespan of the oil and improve machine operation. Synthetic oils may provide similar improvements and should also be considered. The number of fluids selected should be minimized to reduce the efforts associated with fluid control and maintenance.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

Machine coolants are used at least in some amounts at all four TIPPP facilities. Options that are supplemented should be measured as to their success, and described in detail at regular TIPPP monthly meetings.

MEASUREMENT OF POLLUTION PREVENTION

Many of the options presented in this report are relatively easily measurable. Extending the life of coolants and elimination of some hydraulic systems with electrical components would result in immediate reduction of waste quantities generated.

IMPLEMENTATION PLAN

In general, the suggested implementation plan (Table 2) involves a staged approach with organizational options implemented first, followed by inexpensive source reduction options, then moderate capital intensive source reduction options, and finally recycling. Proceeding in this manner will result in a highly organized and efficient fluid management program with an optimal return on investment and maximum waste reduction.

Organizationally, the plan suggests that a single person be assigned the responsibility for coolant testing and management. This person would report to the machine shop supervisor for this particular task. He or she would make decisions on methods of controlling fluid condition and determining if a coolant changeout is necessary. The existing SPC and Total Quality Management Systems should be used to support a fluid management program. For example an SPC system can be used to identify the impacts of extending coolant life on work quality and tool life. Use of the cellular organization is suggested for accounting purposes, to highlight both positive and negative coolant use and disposal frequency.

The inexpensive source reduction options, moderate capital intensive options, and recycling options (if implemented sequentially) will reduce, in a step-wise manner, the quantity of waste sent to off-site disposal. Also, by implementing the less expensive and complicated options first, the quantity of waste managed by subsequent, more expensive options, will be less.

The key inexpensive source reduction option is frequent coolant testing and control. This effort should be performed by the assigned coolant management person. The initial task would be an inventory of all machine sumps and reservoirs. The inventory should identify the machine, type and age of machine, sump or reservoir capacity, hydraulic/lubrication systems, and a measure of relative use. Subsequently, the coolant management person would develop and initiate a testing and control plan, and implement remaining inexpensive source reduction options.

TABLE 2. SUMMARY OF SUGGESTED IMPLEMENTATION PLAN

Organizational Options	Inexpensive Source Reduction Options	Moderate Capital Intensive Source Reduction Options	Recycling
Assign single individual to coolant testing and management with supervision of machine shop supervisor	Frequent coolant testing and control	Identify and substitute fluids*	Implement onsite recycling of coolant
Use of SPC and total quality management systems	Hydraulic and lubrication system maintenance	Install DI water system for coolant formulation and evaporation make-up	
Use of cellular organization to trade coolant usage costs	Identification and segregation of chromium contaminated coolant	Purchase mobile filtration unit for periodic coolant maintenance	
	Sterilize coolant reservoirs during change-out	Replace hydraulic with electrical systems	
	Continue use of hydraulic/lubricating oil filtration		

* Requires RD&D, see next section

The success of implementing the inexpensive source reduction options may reduce the need for moderate capital intensive source reduction options. A reevaluation is suggested at this point to estimate the impact of these additional source reduction options. Several of these options require that preliminary investigative work be performed. This is described in the next section.

The need for and the cost effectiveness of recycling will also require reevaluation once the source reduction options are implemented. The unit cost of recycling will increase as the quantity of recyclable material decreases.

RESEARCH, DEVELOPMENT & DEMONSTRATION NEEDS (RD&D)

Most of the pollution prevention options suggested for the NAPED have been previously implemented at other locations. There is not a need for basic RD&D. However, some investigative efforts and testing are needed before certain operations can be implemented. The following is a brief description of this work.

Material substitution is a potential source reduction method in terms of : 1) using higher quality fluids for coolant requirements and hydraulic/lubrication needs, including possible use of synthetic fluids; 2) use of same coolant product for machining and grinding, and; 3) use of concentrated coolant for hydraulic/lubricating systems.

Prior to an evaluation of these substitution options, the NADEP should establish baseline data from experience with existing fluids. This suggestion, in part , relates to use of the SPC system to aid in fluid management. Once established, the baseline data can be used as a starting point to investigate alternative fluids with fluid manufacturers/suppliers. Using the performance data, a short list of potential alternatives fluids can be identified and tested. Testing should be performed on representative machines covering the various applications where the fluids may be substituted.

RECOMMENDATIONS/CONCLUSIONS

Several options exist for reducing waste generation of various machine coolants at NADEP. The implementation plan and RD&D needs described should be initiated and their effects measured.

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

FT. EUSTIS GOLF COURSE
NUTRIENT MANAGEMENT

by

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INTRODUCTION

Golf courses have long been recognized for their recreational and aesthetic values. By preserving large areas of open space in increasingly urbanized areas, golf courses serve many important functions, including:

- provide wildlife habitat;
- provide buffer areas which help to mitigate flow and pollution impacts from runoff;
- enhance real estate value;
- provide noise abatement.

Despite these many benefits, golf courses can become damaging to the environment if sound land management practices are not followed.

Certain aspects of golf course nutrient and land management have the potential to increase point and nonpoint sources of pollution if not conducted properly and with care. Some of these impacts were addressed in a comprehensive literature review (Spectrum Research, Inc.,1990) conducted for the United States Golf Association (USGA), including:

- leaching losses of nutrients and pesticides to groundwater;
- runoff losses of sediment, nutrients, and pesticides;
- degradation of stream and lake quality resulting from sediment, chemical, and thermal pollution;
- excessive use of water resources for irrigation during drought conditions and in semi-arid and arid climatic zones;
- exposure of beneficial soil organisms, wildlife, and aquatic systems to pesticides;
- soil erosion and sediment transport during construction and from disturbed riparian zones;
- disturbance or loss of wetlands;
- disturbance and toxicity impacts on wildlife;
- runoff of contaminants from parking lots and maintenance facilities;
- development and resurgence of insect and disease populations resistant to current chemical management strategies.

This paper does not address all of the potential impacts listed above. Instead, it primarily examines those related to the impacts of golf course management on nutrient (and, to a lesser degree, pesticide) pollution of surface and ground water. This focus was selected because Fort Eustis is located in the Chesapeake Bay watershed, where issues associated with excess nutrients in water are of primary concern.

Nutrient enrichment (mostly nitrogen and phosphorus) is currently recognized as the major water quality problem facing the Chesapeake Bay. Elevated levels of certain toxic materials (e.g., pesticides) have also been noted and are beginning to receive attention, but the focus of most current programs is on nutrients. Water quality modeling estimates suggest that nonpoint sources (e.g., runoff from agricultural and urban/suburban areas) contribute 67 percent of the nitrogen and 39 percent of the phosphorus entering the Bay, with point sources (e.g., wastewater treatment plants) contributing the balance (Chesapeake Bay Program, 1988), of leachate.

The results of nutrient enrichment can be devastating to the aquatic environment and have contributed directly or indirectly to an array of interrelated problems in the Bay, such as:

- algal blooms and eutrophication;
- decrease in dissolved oxygen levels throughout the Bay, with many areas becoming depleted of oxygen at certain times of the year;
- decline in the Baywide abundance of submerged aquatic vegetation;
- decline in harvests of finfish and shellfish;
- decline of waterfowl.

Phosphorus and nitrogen are associated with eutrophication of surface water. Phosphorus is more easily bound to sediment than nitrogen. Since phosphorus is readily adsorbed by surface soils, it seldom contaminates ground water. However, transport of phosphorus to groundwater is possible if excessive loading of fertilizer or manure phosphorus is applied to sandy soils with limited phosphorus adsorption or buffering capacity. Nitrogen, especially the non-adsorbed anion nitrate, is more soluble than phosphorus and is the principal nutrient detected in appreciable quantities in subsurface water.

Concerns about the nutrient enrichment of Chesapeake Bay waters and associated water quality impacts has lead to a concerted effort to reduce and control these sources of pollution. Most of these efforts are guided by milestones established in the 1988 Baywide Nutrient Reduction Strategy. The Strategy called for tightened point source controls and increased emphasis on reducing nonpoint source nutrient loading from agricultural and urban/suburban sources. To achieve these goals, the jurisdictions are implementing a variety of actions and programs, and are depending on the cooperation and participation of all entities within the Chesapeake Bay basin. The problems in the Bay stem from the cumulative impacts of a wide array of activities of varying sizes and pollutant loadings. Cleanup activities for the Bay are addressing all levels of contributors, from the individual homeowner to larger corporate and government entities, with the recognition that all improvements, no matter how small, can help improve water quality in the Chesapeake Bay. The most recent initiatives within the Chesapeake Bay are focusing on pollution prevention, with the goal of stopping pollution before it starts.

This report outlines several strategies for environmentally sound golf course management, focusing primarily on nutrient and pesticide management. These strategies were compiled from documents provided by the United States Golf Association (USGA) and the Virginia Cooperative Extension Service (VCES). The report also describes a set of "Watershed Nutrient Control Standards", initially developed for commercial lawn care companies by the Northern Virginia Soil and Water Conservation District, Northern Virginia Planning District Commission, Virginia Cooperative Extension Service, and the Lake Barcroft Watershed Improvement District. The golf course management strategy presented in this report is a comprehensive approach for reducing the water quality impacts from golf courses. Fort Eustis is already implementing many of the suggestions contained in this report; the entire strategy is presented as guidance for ways Fort Eustis and similar facilities could enhance their current approaches. This report also introduces an option for using domestic wastewater and/or sludge material from the Fort Eustis Sewage Treatment Plant as an organic alternative to the currently used chemical fertilizers.

PROCESS REVIEWS

The Fort Eustis golf course is located on a triangular piece of land bounded to the northeast by the Warwick River and to the southwest by the James River. The 18 hole golf course covers approximately 70 to 80 acres and is primarily located adjacent to the Warwick River. In many places the golf course lies within 2,000 feet of the river or its wetlands and drainages. The golf course is constructed in a low-lying coastal plain area. Several natural wetlands are found within or beside the golf course. The water table is near the surface in all locations.

Greens are constructed on 70 percent sandy soil to promote rapid drainage. The fairways are planted on native soils. Runoff from the golf course drains into a small stream that feeds into the Warwick River. The greens and fairways drain into four water hazards or ponds. Three of the ponds are small, each is approximately 350 square feet in area. The fourth pond is approximately 2 acres in size. The larger pond is stocked with catfish.

The major golf course operations are nutrient management, pesticide use, and grounds keeping. Each of these operations and the major waste streams are discussed below.

Nutrient Management

Fairways and greens are fertilized. Fertilizer application frequency, timing, and amount is based on annual soil analysis results, best professional judgement, and the advice of the fertilizer supply company representatives. Care is taken to avoid fertilizing the course immediately before or when it is raining. Fertilizers are in a granular form and applied using a calibrated spreader. Annual fertilizer cost for fairways and greens was approximately $25,000 to 30,000 in 1991.

The fairways at the Fort Eustis golf course are planted with bermuda turf grass. These areas are fertilized using a slow release (32-3-10) homogeneous granular formulation. This fertilizer is applied two to three times in the summer to the fairway, tee box, and apron areas. Annual application rates are approximately 2 to 2.5 pounds of nitrogen, 0.18 to 0.23 pounds of phosphorus, and 0.6 to 0.78 pounds of potassium per acre. The golf course superintendent would like to increase the annual nitrogen rate to 3 to 3.5 pounds of nitrogen per acre. The fairways are seeded with perennial rye grass in winter so they stay green. No fertilizer is used on the rye grass.

The 3.5 acres of greens on the golf course are planted in bent grass and are fertilized using a slow release (19-26-5) homogeneous granular formulation. Fertilizer is applied two to three times in the summer and once in the spring. The annual application rate is approximately 4 to 5 pounds of nitrogen, 5.5 to 6.8 pounds of phosphorus, and 1 to 1.3 pounds of potassium per acre.

Wastes

The major wastes from fertilizer use are empty fertilizer bags and surface and subsurface losses of nitrogen and phosphorus. Empty fertilizer bags are disposed of as nonhazardous solid waste.

There are no quantitative data on nutrient loss from the golf course. Dissolved nitrogen and phosphorus can be lost in surface water runoff, subsurface baseflow, or groundwater. Factors that can contribute to high fertilizer loss include the timing of application, quantity applied, formulation used, and amount of water present. Fertilization prior to a rain storm or heavy irrigation can result in surface water runoff and subsurface leachate containing high nutrient concentrations. Over fertilization (i.e., adding more fertilizer than the grass can use) makes the excess nutrients available for runoff or subsurface leaching.

Rapid draining of the greens combined with a shallow water table are conditions which promote leaching and nutrient loss to groundwater.

A qualitative indication of nutrient loss would be excessive algal growth or eutrophic conditions in the golf course water hazards which collect drainage water from the course. According to the course superintendent, the ponds have not shown signs of excess algal growth in the past. Two to three years ago the grounds crew started adding Aqua-Shade, a dye, to the three smaller ponds for aesthetic purposes and to control algae. The use of Aqua-shade may mask signs of nutrient over-enrichment.

Pesticide Use

The golf course is in the third year of a five year pesticide control program. The program, established by the pesticide supply company, stresses limited pesticide usage aimed at preventing pest problems before they occur. Greens are treated with insecticides, fungicides, and herbicides. Fairways, tee boxes, and apron areas are treated with an herbicide. Greens and fairways are visually inspected daily for indications of disease or infestation. Pesticides are only applied when insect infestation is noticed or climatic conditions favorable for fungi growth occur. Pesticide application rates follow product label recommendations. Annual pesticide cost for 1991 was approximately $12,000.

Pesticides are purchased under a Blanket Purchase Agreement (BPA). This allows the course supervisor to place small orders throughout the year on an as needed basis rather than purchasing large quantities at the beginning of the year based on estimates of the total quantities and types of pesticide needed for the entire year. The BPA negates inventory problems such as pesticide storage and expiration of pesticides. Under the BPA pesticides are purchased in response to a specific pest. This may prevent excessive or improper use of pesticides that otherwise might occur because they were in stock.

Insecticides

Greens are treated with Dursban or Sevin in the spring to kill cut worm and chinch bugs. Insecticides are applied to an individual green only when insect damage is evident. The insecticides come in pre-packaged water soluble bags or powder form which is dissolved in water and applied in liquid form.

Insecticide dosage is determined by the infestation rate in a specific area. The amount of active ingredient per typical application is approximately ½ ounce per 1000 ft^2. The number of applications and the rate vary year to year; consequently, the annual quantity of active ingredient applied is not available.

Fungicides

Greens are treated against three different fungi: Brown Patch, Dollar Spot, and Pythium. Greens are susceptible to these fungi during a 2 to 3 month period in the spring when climatic conditions (temperature and humidity) are ideal for fungal growth. Greens are visually inspected daily for Brown Patch and Dollar Spot. When signs indicate damage from Brown Patch or Dollar Spot the green is sprayed with Daconil 2787. The early infestation stages of Pythium cannot be detected from visual inspection. Therefore, Pythium is controlled by spraying greens with a mixture of Foray™, a contact fungicide, and Subdue™, a systematic fungicide, whenever climatic conditions are conducive to its growth. The golf course personnel use two different application rates for the fungicides depending on the severity of the problem. Table 1 shows the application rate for fungicides used. Because the number of applications and the rate varies each year the annual quantity of active ingredient used is not available.

TABLE 1. FUNGICIDE APPLICATION RATES

Fungicide	Application Rate (Ounces of active ingredient per 1000 ft^2) Preventative Rate	Curative Rate
Daconil 2782	2	8
Subdue™	0.5	2
Foray™	2	8

Herbicides

Greens and fairways, tee boxes, and apron areas are treated once in the spring with a pre-emergent herbicide. Greens are treated with Scotts Goose Grass-Crab Grass Control. Benzolite, the active ingredient of Scotts Goose Grass and Crab Grass Control, is applied to greens at a rate of approximately 3.36 pounds per acre per year (11.76 pounds total for all of the greens per year). Fairways are treated with Southern Weed Grass Control. Annual use of Southern Weed Grass Control is 10,170 pounds. The quantity of Pendimethalin, the active ingredient, is unavailable. Average annual cost of herbicides for both the greens and the fairways is $6,000. Herbicides are in granular formulation and applied using a calibrated spreader. The course superintendent does not expect to have to use any herbicides on the fairways next year because nuisance grasses are under control. He does expect to begin reapplying herbicides the following year.

Pesticide Wastes

There are no quantitative data on pesticide wastes. Wastes from pesticide use include empty containers, contamination of surface and ground water, loss through volatilization, and impacts on non-target areas or species. Container waste is minimized for formulations packaged in water soluble packages. Empty pesticide containers are handled according to instructions on the container labels.

Grounds Keeping

The major groundskeeping operations are mowing, turf aeration, liming, brush control, and irrigation. Mowing and irrigation practices have the potential for causing the greatest environmental impact. Mowing operations are discussed below. Information was not available for irrigation practices.

Mowing

Mowing takes place year round but most frequently during the spring and early summer. Mowing is accomplished using gasoline powered riding mowers. Fairways and the short rough are mowed short to reduce weed growth. Greens are treated in the high growth season with a plant hormone (turf grass growth regulator) to slow the grass's growth so mowing frequency is lessened.

Grass clippings are left on the fairway as a soil nutrient. Grass clippings from the greens are collected and dispersed in the undeveloped areas adjacent to the golf course. Lawn mowers emit exhaust from the gasoline powered engines.

ASSESSMENT

Standard pollution prevention assessment worksheets contained in the ORD Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003) were not applicable to the evaluation of nutrient and pesticide management at the Fort Eustis golf course. Instead, Fort Eustis personnel were requested to provide process and facility information by completing a pre-assessment questionnaire (see Appendix A). This was followed-up by a site inspection of the golf course with Fort Eustis personnel in September, 1991. Further information was gathered through telephone interviews with Fort Eustis personnel.

Data Gaps

As the assessment team made its visual inspection of the golf course and follow up telephone interviews, it was never able to obtain written documentation of golf course management procedures, nor annual records of fertilizer or pesticide information (e.g., times or amount of application, weather conditions at time of application, etc.). Although much information on operating procedures was obtained through oral communication, much of the quantitative information needed to perform a rigorous and thorough assessment was unavailable. Therefore, the following data gaps were noted:

- precise records or information on application rates, date and time of application, weather conditions at time of application, detailed information on fertilizer brand and pesticide formulations, total annual quantities of nutrients and pesticides applied;

- adsorption, mobility, and persistence characteristics of pesticides;

- irrigation records (e.g., time and quantity of water applied);

- soil analysis results

- written documentation of fertilization and pesticide programs.

One pollution prevention option that will be proposed in this paper is the use of sludge and wastewater from the Fort Eustis sewage treatment plant as supplemental organic fertilizers for the golf course. A significant amount of background information is needed prior to assessing the feasibility of these techniques at Fort Eustis (e.g., sludge and wastewater characterization studies). Specific information needs are described in more detail in the Pollution Prevention Options section of this paper. This type of information was not available for the preparation of this report.

Pollution Prevention Activities

Fort Eustis staff already implement a number of environmentally-sound golf course management techniques that help to minimize wastes. Some of these techniques, as described in interviews with golf course personnel, are listed below:

- Conduct annual soil analyses to help determine fertilization rates;

- Use slow-release fertilizer;

- Leave grass clippings in place as a soil nutrient supplement, where possible;

- Do not apply fertilizers/pesticides if it is raining or threatening rain;

- Base most pesticide applications on visual inspection;

- Use purchasing policies that enable pesticides to be acquired on an "as needed" basis rather than purchased on an annual basis based on estimated need;

- Aerate the turf on a routine basis.

Pollution Prevention Options

As described above, the Fort Eustis staff already implement a number of nutrient and pesticide management approaches aimed at minimizing waste and reducing the environmental impacts of golf course management. This section presents information aimed at supplementing and enhancing Ft. Eustis's current golf course management program to become even more environmentally sensitive. Because the Ft. Eustis staff are already implementing some of these ideas, there may be some overlap. This section presents a comprehensive approach and does not separate out those activities currently practiced at Ft. Eustis. It presents the results of research by a variety of organizations on environmentally sound turfgrass maintenance and it proposes an alternative source of nutrients. The pollution prevention options are presented as two main options and discussed in the following sections.

Option 1 - Nutrient and Pesticide Management

The growth of healthy turfgrass suitable for golf courses requires an adequate supply of all essential plant nutrients. Nitrogen, phosphorus, and potassium are generally the most important nutrients with respect to turfgrass fertilization. Research suggests that turfgrass is most responsive to nitrogen fertilization, followed by potassium and phosphorus. Fertilization needs vary by site depending on plant, soil, and climatic conditions. Evaluation of soil nutrient levels ensures the best possible efficiency and economy of fertilization. Addition of soil nutrients far in excess of plant growth and uptake requirements can result in nonpoint source pollution, affecting both ground and surface water (Spectrum Research, Inc., 1991).

The USGA commissioned a study to examine "environmental issues related to golf course construction and management". The study presented a comprehensive literature review, from which a series of recommendations was made on how to reduce nitrogen and phosphorus contamination of surface and ground water. The study also evaluated pesticide management and developed guidelines on environmentally sound pesticide practices. Results from the USGA study were combined with recommendations from the VCES publication "Ecological Turf Tips... To Protect the Chesapeake Bay" to prepare a comprehensive set of recommendations on environmentally sound nutrient and pesticide management at golf courses (see Tables 2 and 3). The detailed recommendations from each of these publications are presented in Appendix B.

Another approach to reducing the impacts of nutrients on water quality resulted from a joint effort of the Northern Virginia Soil and Water Conservation District, Lake Barcroft Watershed Improvement District, Northern Virginia Planning District Commission, and the Virginia Cooperative Extension Service. These organizations teamed to develop a series of Watershed Nutrient Control Standards. These standards were initially developed for commercial lawn care companies, but are equally applicable to other turf grass management situations. The Watershed Nutrient Control Standards very closely follow the nutrient and pesticide recommendations developed by the USGA and VCES and can be used in conjunction with these standards to ensure an environmentally sound management approach. According to literature describing the Watershed Nutrient Control Standards, there should be no additional costs to turfgrass maintenance programs as a result of adopting these nutrient control principles. Table 4 outlines the Watershed Nutrient Control Standards and briefly describes available cost information; the environmental benefits from these practices are obvious, as most propose a form of pollution prevention (e.g., using less fertilizer).

TABLE 2
RECOMMENDATIONS FOR ENVIRONMENTALLY-SOUND
NUTRIENT MANAGEMENT

- **Nutrient Source:** Use slow release fertilizers. Water-soluble sources of nitrogen have a higher leaching potential than slow-release sources, especially when application is followed by a large amount of water (either from rainfall or irrigation). If water soluble sources must be used, apply in several split applications rather than all at once, to reduce pollution potential.

- **Application Rate:** Develop and implement a comprehensive nutrient management plan. Avoid applying excess fertilizer by using rates recommended as a result of soil testing and an understanding of the needs and growth requirements of the crop. Use the minimum amount of fertilizer necessary to meet the plant needs. The most effective method to reduce the loss of fertilizer-derived nitrate to groundwater is to reduce the quantity of nitrogen fertilizer applied. Even on greens, plan fertilization commensurate with uptake capacity of the specific turfgrass species. Increasing the rate of nitrogen application to highly sandy greens will lead to a deterioration in drainage water quality. Slow-release fertilizers should be used on sand amended areas of the golf course (e.g., greens and tees). If soluble sources are applied to these modified soils, nitrogen applied should not exceed 0.75 lbs N/1000 square feet. On traditional Virginia soils, nitrogen applications should not exceed 1.0 lbs N/1000 square feet.

- **Timing of Application:** Apply nitrogen fertilizer as close as possible to the time required for maximum plant uptake. Time nitrogen application to minimize leaching losses from rainfall or irrigation (i.e., apply after these events). The best time to fertilize cool-season grasses is in the fall. In late fall to winter, cool-season grasses are beginning to develop their root system and store carbohydrates. Warm season grasses have the greatest rate of uptake in the spring after green-up and throughout the summer.

- **Leave Vegetated Buffers Around Water Bodies:** Maintain and repair vegetative buffer strips around water bodies. Do not apply fertilizers directly into or immediately adjacent to water bodies; leave an unfertilized buffer strip.

- **Practice Water Conservation:** Avoid excess irrigation. Use sensors to determine the need and timing of irrigation. Intensive fertilization and irrigation practices can cause transport of nitrate to groundwater. The potential for subsurface loss of nitrogen is increased when the turfgrass is irrigated at a rate in excess of plant use, evapotranspiration, and soil storage.

- **Mow Wisely:** Use the highest mowing height acceptable for the use being made of the turf. Avoid mowing turfgrass areas that are too wet or under extreme heat or moisture stress (e.g., when temperatures are high or in time of drought).

(Table 2 continued on next page.)

TABLE 2 (CONTINUED)

- **Leave Grass Clippings in Place:** After mowing, leave grass clippings in place, where possible. In areas such as greens, where it is not possible to leave clippings, disperse clippings in roughs or wooded areas or compost clippings. The finished compost can be used as a soil amendment.

- **Aerate the Turfgrass:** Heavily trafficked cool-season grasses should be aerated spring and fall during periods of active foliage growth, although mid-summer aeration can be beneficial if irrigation is available and temperatures are favorable. Warm-season grasses can be beneficially aerated from the time they green up until they go dormant in the fall.

- **Investigate Alternatives to Nitrogen:** Research has shown that iron applications to turfgrass can increase chlorophyll content, carbohydrates, and rooting while decreasing respiration rates. Mid-summer green-up can be accomplished with iron instead of nitrogen. Late fall applications of iron with nitrogen on cool season grasses have produced earlier spring green-up and enhanced rooting.

- **Ensure Application Equipment (e.g., sprayer, spreader) Works Properly:** Calibrate equipment frequently. Calibrate on similar terrain and at speeds similar to actual spraying conditions. Check distribution pattern of sprayer/spreader. Ensure uniform distribution.

- **Keep Detailed Records:** Record information on golf course management procedures. Include such information as brand used, formulation, date and time of application, amount of application, climatic conditions during application, irrigation schedule, and annual quantities of fertilizers/pesticides used.

- **Work With the Virginia Cooperative Extension Service** to develop nutrient management plans and other environmentally-sound techniques for golf course management.

Source: VCES (1991); Spectrum Research, Inc. (1990)

<u>Option 2 - Use of Wastewater and Sludge as a Fertilizer Supplement</u>

Sewage treatment plant wastewater and by-product sludge can serve as useful supplements to chemical fertilizers. They contain significant amounts of important nutrients such as nitrogen and phosphorus, although the exact chemical compositions of wastewater and sewage sludge varies greatly from site to site. Typical chemical compositions for domestic wastewater and sewage sludge are given in Tables 5 and 6.

TABLE 3
RECOMMENDATIONS FOR ENVIRONMENTALLY-SOUND
PESTICIDE MANAGEMENT

- **Pesticide Source:** Aim to use pesticides with low mobility, high adsorption, and low persistence.

- **Application Rate and Timing:** Use the minimum amount of pesticide necessary to meet the plant needs. The most effective method to reduce the loss of pesticides to groundwater and surface water is to reduce the quantity of pesticides applied. Discard excess pesticide properly; do not dump or spray off excess. Unless the problem is extremely common and recurring, withhold pesticide application until scouting or monitoring indicates that unacceptable damage will occur.

- **Spot Treat:** Scout for and treat specific pest problems instead of treating large areas on a routine basis.

- **Understand Damage Thresholds:** Only apply pesticides when the pest populations develop sufficiently to cause damage; the presence of just a few insects or spots does not require full blown use of a pesticide.

- **Utilize Integrated Pest Management Techniques.**

- **Leave Vegetated Buffers Around Water Bodies:** Maintain and repair vegetative buffer strips around water bodies. Do not apply fertilizers directly into or immediately adjacent to water bodies; leave an unfertilized buffer strip.

- **Practice Water Conservation:** Avoid excess irrigation. Use sensors to determine the need and timing of irrigation. Intensive fertilization and irrigation practices can cause transport of nitrate to groundwater. The potential for subsurface loss of nitrogen is increased when the turfgrass is irrigated at a rate in excess of plant use, evapotranspiration, and soil storage.

- **Ensure Application Equipment (e.g., sprayer, spreader) Works Properly:** Calibrate equipment frequently. Calibrate on similar terrain and at speeds similar to actual spraying conditions. Check distribution pattern of sprayer/spreader. Ensure uniform distribution.

- **Keep Detailed Records:** Record information on golf course management procedures. Include such information as brand used, formulation, date and time of application, amount of application, climatic conditions during application, irrigation schedule, and annual quantities of fertilizers/pesticides used.

- **Work With the Virginia Cooperative Extension Service** to develop nutrient management plans and other environmentally-sound techniques for golf course management.

Source: VCES (1991); Spectrum Research, Inc. (1990)

TABLE 4. BRIEF ASSESSMENT OF WATERSHED NUTRIENT CONTROL STANDARDS

Nutrient Control Standard	Estimated Savings
Use less fertilizer	Research previously described in this paper indicates that the average "Do-it-yourselfer" applies 2 to 4 times the desirable amount of fertilizer. By reducing fertilization amounts, costs could equally be reduced.
Use no phosphorus or very little	The newsletter by NVSWCD et al. (1991) says that no additional costs should be incurred by adoption of these nutrient control standards. The NVSWCD is offering a 50-lb bag of "No-Phos Watershed Protection Formula" at $35/bag. A representative of Natural Lawn Co. stated that it cost them $1.00 to 1.50 more per household to use phosphate free fertilizer. In working with the Lake Barcroft Water Management District, Natural Lawn anticipates a fall reduction in the phosphorus loading of 7000 lbs and an 80 to 85 percent reduction in the spring (Bonifant, 1991, personal communication).
Use slow-release fertilizer	Organic fertilizers tend to be slow acting and less soluble than chemical fertilizers (Schultz, 1989). The Washington Post cited an interview with Jeff Edwards, President of Home Harvest garden store, where he said that to convert to organic fertilizer would result in an initial investment of nothing, as many municipalities have free composting services, to about $1.00 per 100 sq ft for top of the line, 100 percent commercial organic fertilizer (Cook, 1991).
Determine existing conditions with available soil test data	Soil tests (and the accompanying report which provides fertilizer recommendations) range in cost from nothing to an average cost of $5.00 if done by the Cooperative Extension Service. The cost of soil testing in Virginia is $6.00. Private soil test labs may charge $30 to $45 for their services (Carr et al., 1991).
Apply fertilizer periodically rather than all at once	Excess fertilizer is likely to leach into groundwater, rather than be used by the plant. Since a plant has a limited capacity to use fertilizer in any one application, any excess will be lost (i.e., it cannot be save for later use). Since the plant is unable to use all of large dosage, it may need to be re-fertilized at a later date to ensure that its annual fertilization needs are met. This excess fertilization results in wasted fertilizer and unnecessary costs.
"Spot control" for broad-leaf weeds instead of blanket applications	Natural Lawn Company reports that by switching from blanket applications to the spot application of herbicides, they were able to reduce 85 to 90 percent of their herbicide needs (Bonifant, personal communication, 1991). Obviously, such a dramatic reduction in herbicide usage would result in comparable cost savings.

TABLE 4. (continued)

Nutrient Control Standard	Estimated Savings
Avoid using broad-spectrum insecticides	No data, but intuitively suggests a cost savings by not purchasing such chemicals.
Mow lawns at the recommended height	No data, but proper mowing technique results in a healthier lawn and can reduce pesticide and fertilizer needs (Schultz, 1989; Carr, 1991).
Leave clippings when possible	Starr and DeRoo (1981) conducted research showing that the return of grass clippings to the lawn is beneficial to grass growth. They conducted research on grass growing in a low-N, sandy loam soil. In one test plot, clippings were not returned, in the other, clippings were returned. In the plot where clippings were not returned, "about half of the plant-N was derived from the fertilizer and half from the soil. Where clippings were returned, yield of grass increased by about one-third, with the additional plant-N derived from the cumulative return of the clippings over the 3-year period." The increase in grass yield by one-third by leaving grass clippings in place implies that fertilization could be reduced by a comparable amount (thus reducing costs). Natural Lawn Company confirmed this view and is promoting this practice. The Professional Lawn Care Association of America also recommends this practice.

TABLE 5. IMPORTANT CONSTITUENTS IN TYPICAL DOMESTIC WASTEWATER (mg/L)

	Type of wastewater		
Constituent	Strong	Medium	Weak
Biochemical Oxygen Demand	400	220	110
Suspended solids	350	220	100
Nitrogen (total as N)	85	40	20
Organic	35	15	8
Ammonia	50	25	12
Nitrate	0	0	0
Phosphorus (total as P)	15	8	4
Organic	5	3	1
Inorganic	10	5	3
Total organic carbon	290	160	80

TABLE 6. CHEMICAL COMPOSITION OF SEWAGE SLUDGES[1]

Component	Number of Samples	Range	Median	Mean
			(Percent[2])	
Total N	191	<0.1 - 17.6	3.30	3.90
$NH_3 - N$	103	5×10^{-4} - 6.76	0.09	0.65
$NO_3 - N$	43	2×10^{-4} - 0.49	0.01	0.05
P	189	<0.1 - 14.3	2.30	2.50
K	192	0.02 - 2.64	0.30	0.40
			(mg/kg[2])	
Cu	205	84 - 10,400	850	1,210
Zn	208	101 - 27,800	1,740	2,790
Ni	165	2 - 3,520	82	320
Pb	189	13 - 19,700	500	1,460
Cd	189	3 - 3,410	16	110
PCB's	14	<0.01 - 23.1	3.90	5.15

1 Data are from numerous types of sludges (anaerobic, activated sludge lagoon, etc.) in 15 states: Michigan, New Hampshire, New Jersey, Illinois, Minnesota, and Ohio (2); California, Colorado, Georgia, Florida, New York, Pennsylvania, Texas, and Washington (3); and Wisconsin.

2 Oven-dry solids basis.

Use of wastewater and sewage treatment plant sludge has been tried at some golf courses with proven success. As a second pollution prevention option, Fort Eustis could explore ways to use the wastewater and sludge generated from the Fort Eustis sewage treatment plant as a supplemental fertilizer for the golf course. This would not only serve to reduce the reliance on chemical fertilizers at the golf course, but it would also help reduce levels of solid waste and point source nutrient discharges from the sewage treatment plant. The primary disadvantages of these nutrient sources (odor, health concerns due to pathogens, public perception) can be overcome through treatment technologies and public outreach. Removal of pathogenic organisms in wastewater can be achieved by disinfection or by natural processes in biological treatment or storage ponds. Any objections from sludge use (e.g., odor, elimination of weed seeds) are significantly minimized if heat-dried or composted sludge is used.

Since Fort Eustis has its own sewage treatment plant which accepts only domestic waste, the conversion of wastewater and sludge into usable fertilizer supplements for the golf course is a viable option and well worth further investigation. Depending on the technologies selected and the additional equipment needs (if any), it is likely that long-term cost savings could be achieved. Detailed cost analyses were not undertaken for this report because all of the necessary background information was not available.

Several planning studies must be undertaken before Fort Eustis can fully investigate the feasibility of using their wastewater and sludge as a fertilizer supplement on the golf course. The planning processes for wastewater and sludge applications are outlined in Figures 1 and 2, respectively. Of prime importance

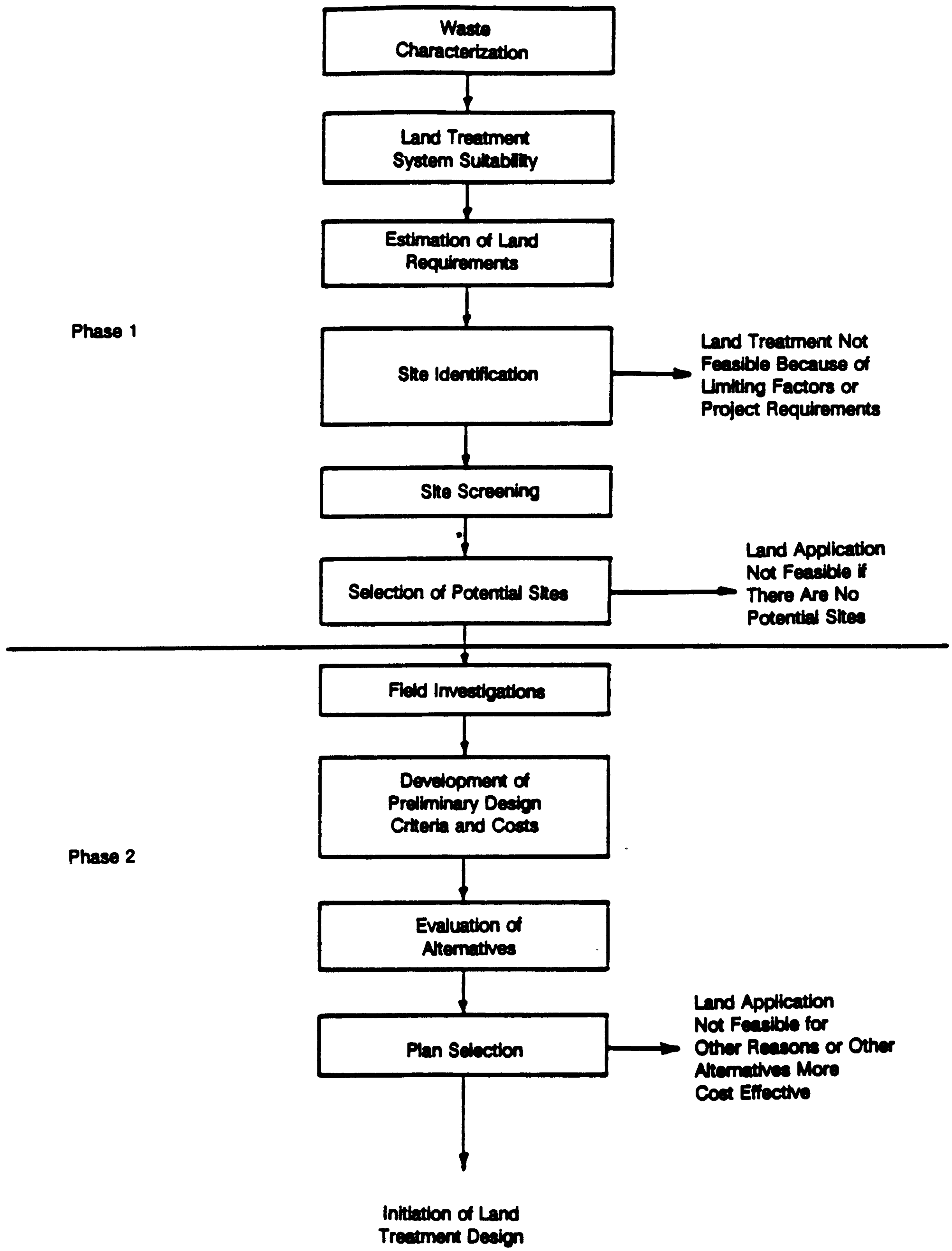

Figure 1. Planning Process for Wastewater Application (USEPA, 1981).

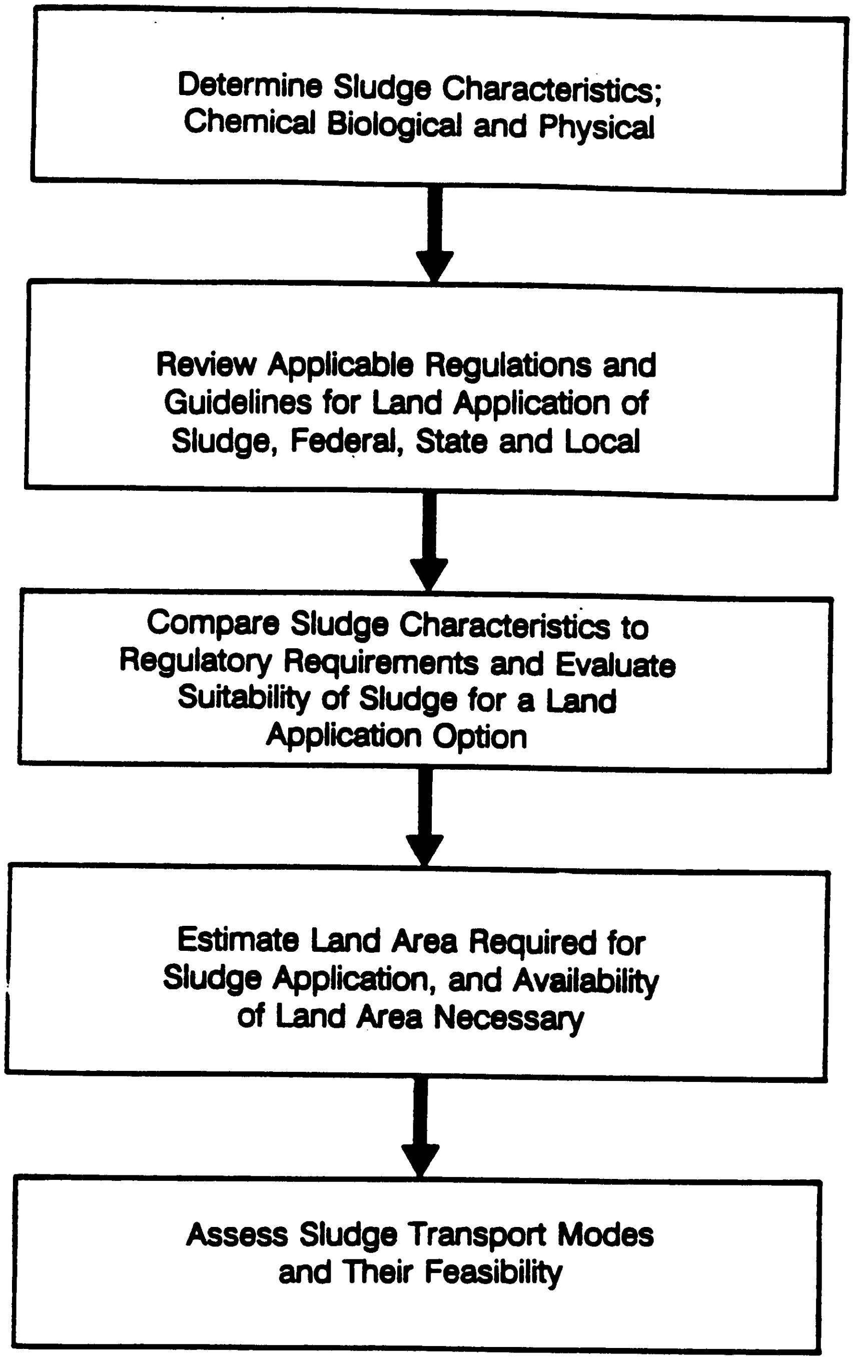

Figure 2. Planning Process for Sewage Sludge Application (USEPA, 1983).

in these planning studies are a chemical/physical characterization of the wastewater and sludge and an evaluation of the land for suitability. Also important is the evaluation of the various techniques that can be used to apply and use the wastewater and/or sludge. These evaluations should be based on capital costs, operation and maintenance costs (including energy consumption), and other nonmonetary factors such as public acceptability, ease of implementation, environmental impacts, treatment consistency, and reliability. Two Environmental Protection Agency documents (Process Design Manual: Land Treatment of Municipal Wastewater and Process Design Manual: Land Application of Municipal Sludge) provide detailed information on the various technologies and design/cost considerations for using wastewater and sludge.

FEASIBILITY

A feasibility analysis was conducted for each component of the pollution prevention options using a modified Worksheet Number 13. Each option was rated qualitatively for a number of different criteria because quantitative data were not available (Table 7). A brief discussion of each option is presented below. Table 4, presented earlier in this report, provides further descriptions and limited cost information for some of the components of the Watershed Nutrient Control Standards.

Nutrient Source

Slow-release fertilizers have a lower leaching potential than water soluble fertilizers and, therefore, pose less risk to ground water. Slow-release formulations will also reduce surface losses if time of release is synchronized with plant uptake and does not coincide with runoff producing events. Slow-release fertilizers offer additional benefits, including: labor saving benefits since fewer applications are needed, reduction in the risk of foliar burn, and a more even supply of nitrogen. Certain types of slow-release formulations may have only a moderate to poor response in cool weather, while other slow-release formulations are not affected by cooler temperatures; care must be taken to select the best formulation for local climate conditions. Slow-release formulations may be slightly more expensive than water-soluble sources, but the added cost may be offset by needing fewer applications. Use of split applications for water-soluble formulations reduces waste by better matching fertilizer amount to actual plant needs, thus reducing the leaching potential. Since phosphorus has the greatest potential for contributing to the eutrophication of surface water, efforts should be made to reduce its application to the lowest amount indicated through nutrient management planning.

Pesticide Source

The above principles also apply to pesticides. Pesticides with low mobility, high adsorption, and low persistence have a reduced potential for leaching and runoff. Therefore, effort should be made to use brands of pesticides with these characteristics.

Application Rate

Efficient fertilizer use can be determined through comprehensive nutrient management planning. Using the minimum amount of fertilizer/pesticide needed reduces opportunities for water contamination by surpluses. Reducing fertilizer and pesticide quantities also reduces costs and provides labor saving benefits. If needs are estimated based on comprehensive nutrient management planning (e.g., soil testing, awareness of plant requirements) and an assessment of pesticide damage potential and extent, there should be no change in turfgrass quality.

TABLE 7. QUALITATIVE ASSESSMENT OF POLLUTION PREVENTION OPTIONS FOR THE FT. EUSTIS GOLF COURSE

	Nutrient Source		Application Rate		Timing of Application	
Criteria	Use Slow-Release Fertilizers	Use No- or Low-Phosphorus Fertilizers	Avoid Applying Excess Fertilizer	Prepare Comprehensive Nutrient Management Plan	Apply Fertilizer Near Time of Maximum Plant Uptake	Time to Minimize Leaching Losses from Rainfall or Irrigation
Effect on Turf-grass Quality	No effect	No effect if done with nutrient management plan to ensure phosphorous needs are met	Positive effect	Positive effect	Positive effect	Positive effect
Waste Reduction	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect
Compatibility with Existing Operating Procedures	Fully compatible	Partially compatible; will require nutrient management planning and identification of appropriate fertilizer sources	Fully compatible	Compatible; will require research and working with VCES	Compatible; will require re-evaluation of fertilizing schedules	Fully compatible
Cost Requirements Compared to Current Costs	No additional costs unless evaluation suggests brand should be changed	Unsure; may result in slight cost increase; further evaluation needed	Cost saving	Low to no cost to prepare NMP; cost savings after plan implementation	Will not affect cost	Cost saving
Additional Labor Requirements	None	None	Reduced	Additional labor to complete plan; should result in labor savings	None	None
Implementation Period	Immediate implementation, unless evaluation shows that new supplies should be obtained	Implementation requires evaluation of plant phosphorous needs and alternative fertilizers	Immediate implementation pending completion of nutrient management plan	Immediate implementation; will require some research (e.g., soil testing)	Immediate implementation	Immediate implementation
Ease of Implementation	Easy to implement	Requires evaluation of actual plant phosphorus needs and identification of alternative fertilizer sources	Easy to implement	Easy to implement	Easy to implement	Easy to implement
Adverse Environmental Impacts	None; positive benefits	None; positive benefits	None; positive benefits	None; positive benefits	None; positive benefits	None; positive benefits

TABLE 7. (continued)

Criteria	Water Conservation	Leave Vegetative Buffers	Proper Mowing Techniques	Leave Grass Clippings	Aerate Turf-grass	Alternatives to Nitrogen	Equipment Calibration
Effect on Turf-grass Quality	Should have no effect if sensors are used to determine irrigation needs	No effect	Positive effect	Positive effect	Positive effect	Positive effect if proper alternatives are selected	Positive effect
Waste Reduction	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect
Compatibility with Existing Operating Procedures	Partially compatible; current irrigation practices must be evaluated, it may be necessary to install sensors to accurately determine irrigation needs	Partially compatible; may require planning to preserve areas and rehabilitation efforts for damaged areas	Compatible; requires evaluation of current mowing procedures	Fully compatible	Fully compatible	Partially compatible; requires further research	Fully compatible
Cost Requirements Compared to Current Costs	Unknown; depends on the need for sensors	May add cost, espec-ially if rehabilitation must occur	Will not affect cost; may have cost savings	Long-term cost savings	Will not affect cost; may have cost savings	Unknown	Will not affect cost; may have cost savings
Additional Labor Requirements	None	Labor increase if rehabilitation must occur	None or reduced	None	None	None	None
Implementation Period	Unknown; need to evaluate current system and feasibility of using sensors	Could be long if rehabilitation must occur; immediate implementation for preservation	Immediate implementation	Immediate implementation	Immediate implementation	Requires additional research	Immediate implementation
Ease of Implementation	Unknown; pending evaluation of current system	May be difficult if rehabilitation must occur	Easy to implement	Easy to implement	Easy to implement	Requires additional research	Easy to implement
Adverse Environmental Impacts	None; positive benefit	None; positive benefit	None; positive benefit	None; positive benefit	None; positive benefit	None; positive benefit	None; positive benefit

TABLE 7. (continued)

Criteria	Pesticide Source Use Low Mobility, High Adsorption, Low Persistence	Spot Treat with Pesticides	Use IPM	Keep Records	Work with VCES	Use Wastewater and Sludge as Supplemental Fertilizer
Effect on Turf-grass Quality	Should have no effect	Should have no effect	Positive effect	Positive effect	Positive effect	Should have no effect if tied in with comprehensive nutrient management planning
Waste Reduction	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect
Compatibility with Existing Operating Procedures	Compatible; requires further evaluation of existing sources	Fully compatible	Compatible; requires additional education and research	Compatible; will require creation of a record-keeping system	Compatible; VCES offers many free and low-cost assistance/education programs	Cannot be evaluated until preliminary planning studies are done
Cost Requirements Compared to Current Costs	Unknown	Cost savings	Unknown, but likely cost savings	Short-term cost to establish recordkeeping system; long-term cost savings through better management	Will not affect costs; may have cost savings	Cannot be evaluated until preliminary planning studies are done
Additional Labor Requirements	None	None	None	Additional time will be required; additional labor probably not necessary	None	Cannot be evaluated until preliminary planning studies are done
Implementation Period	Unknown; depends upon evaluation of suitability of existing supplies	Immediate implementation	Some aspects may be implemented quickly; additional research/ education is needed to fully understand IPM concepts	Requires some time to develop recordkeeping system	Immediate implementation	Cannot be evaluated until preliminary planning studies are done
Ease of Implementation	Unknown; depends upon evaluation of suitability of existing supplies	Easy to implement	Some aspects are easy to implement; additional research/education is needed to fully understand IPM concepts	Requires development of recordkeeping system	Easy to implement	Cannot be evaluated until preliminary planning studies are done
Adverse Environmental Impacts	None; positive benefits	None; positive benefits	None; positive benefits	None; positive benefit	None; positive benefits	If wastewater and sludge are not properly characterized, or if treatment if faulty, negative impacts could occur

Timing of Application

Proper timing of fertilization and pesticide application can improve efficiencies at no added cost or labor requirement. By withholding pesticide applications until inspections suggest a problem has occurred, savings in the amount (and cost) of pesticides used could be realized.

Spot Treat

Spot treating pest problems rather than treating large areas will reduce the amount of pesticides used, as well as labor and costs. There should be no adverse benefit to the turfgrass.

Leave Vegetated Buffers Around Water Bodies

Vegetative buffer areas serve to slow the flow of surface runoff and act as a filter for pollutants contained in that runoff. Having buffers can actually reduce the amount of nutrients and pesticides entering water bodies by secondary infiltration, sediment deposition, reducing flow, and uptake by buffer strip vegetation. Preserving existing buffer areas does not require additional costs. Rehabilitation of damaged or absent buffer areas will involve additional costs; amounts vary depending on site-specific conditions.

Practice Water Conservation

By reducing the amount of water used for irrigation, cost and labor benefits can be realized. Reduced water also lessens the potential for surface runoff or subsurface infiltration. If irrigation is determined using sensors to determine crop needs, there should be no negative impact on vegetation. Additional costs (unknown) may be incurred if sensors are not already in place, but these should be offset by savings in water usage.

Proper Mowing Techniques

Mowing is a stress-creating management activity for turfgrass. If grass is mowed too short, its productivity is decreased, there is less growth of roots and rhizomes, and the turf becomes less tolerant of environmental stresses, more disease prone, and more reliant on outside means (e.g., pesticides, fertilizers, water) to remain healthy. By setting the mowing height as high as is acceptable and mowing at times and intervals designed to minimize stress on the turfgrass, a healthier grass will result. This can result in cost savings as mowing frequency and associated labor requirements may decrease. The need for pesticides, fertilizers, and irrigation water may also decrease.

Leave Grass Clippings in Place

Research has shown that grass clippings can contribute nutrients to soil, thereby reducing fertilization need. The reduction in fertilizer would result in comparable cost savings.

Aerate the Turfgrass

Aeration is an effective means of improving turfgrass quality. It increases air exchange, water infiltration rates, water retention, root development, and thatch decomposition. By improving water infiltration, water use efficiency is increased. This can result in a reduction in irrigation requirements. Aeration does involve additional labor and equipment, but the benefits can result in healthier turfgrass and reduced need for chemical inputs and irrigation.

Investigate Alternatives to Nitrogen

Any techniques which result in a reduced need for nitrogen fertilization can result in water quality benefits, as the best way to reduce the threat of surface or ground water contamination by fertilizer-derived nitrate is to reduce the quantity of nitrogen fertilizer applied. Cost savings may be realized by reducing overall fertilizer requirements, depending on the relative costs of the alternatives.

Ensure Application Equipment Works Properly

Properly calibrated and functioning equipment will ensure accurate delivery and placement of materials and will minimize the chances of over- or under-fertilizing. Steps to check calibration and equipment function do not require much extra labor or cost. Cost savings may be realized as properly functioning application devices will reduce waste.

Keep Detailed Records

Written records of fertilizer/pesticide application rates, times, etc. are essential in monitoring use and to help ensure that overuse does not occur. The paper work will require a minimal amount of extra time and start up costs to establish a record-keeping system, but will greatly reduce the risk (and, therefore, cost) of over-applying.

Work With the Virginia Cooperative Extension Service

The VCES has extensive expertise and educational materials aimed at environmentally-sound turfgrass maintenance. Using VCES to develop golf course management programs involves low cost (the VCES typically does not charge for these services) and substantial cost savings may be realized through reduced fertilizer and pesticide needs.

Integrated Pest Management

Integrated pest management (IPM) uses a variety of management techniques with the goal of improving plant health and productivity while minimizing environmental impacts. Many of the pesticide management techniques identified in Exhibit 2 are components of IPM. Additional time should be invested by the appropriate Fort Eustis personnel to learn more about IPM (e.g., attendance at training sessions, working with VCES). Many of the goals of IPM involve reducing pesticide inputs. Therefore, integrating IPM techniques into the golf course management program should result in long-term cost savings by reducing inputs.

Use of Wastewater and Sludge as Fertilizer Supplement

Sewage treatment plant sludge and wastewater is nutrient-rich and can serve as an excellent supplemental organic fertilizer source. As an organic fertilizer, it has the advantage of being slow-release. Also, it is readily available at Fort Eustis and could be used to reduce reliance on chemical fertilizers. As discussed in the Assessment section of this report, the potential negative impacts of wastewater and sludge can be ameliorated through treatment technologies. Prior to making any decisions regarding using the wastewater and sludge, Fort Eustis must undertake planning studies. The types of studies needed were briefly outlined in the Assessment Section of this report (principally in Figures 1 and 2). Upon completion of these planning studies (especially the sludge/wastewater characterization and site assessment) and review of the existing wastewater evaluation report, Fort Eustis will be in a better position to evaluate the feasibility of using wastewater and sludge as a fertilizer supplement. Until then, it is difficult to make judgements about costs and/or savings from this pollution prevention option.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

The golf course nutrient and pesticide management activities described in this report could easily be implemented at other golf courses. Implementation of the second pollution prevention option - use of sewage treatment plant wastewater and sludge could also be implemented at other facilities if a sewage treatment plant handling domestic sewage (i.e., not industrial wastes) is located onsite. As in the case of Fort Eustis, a number of planning studies would have to be completed before the full feasibility of Option 2 could be evaluated.

MEASUREMENTS OF POLLUTION PREVENTION

Measuring the impacts of pollution prevention activities requires baseline data on wastes and operating costs, as well as water quality information. Much of this background data were not available from the Fort Eustis golf course. By immediately implementing a record-keeping system, Fort Eustis could begin acquiring the needed cost and waste data. Water quality data could be obtained from a carefully designed monitoring program to include surface and ground water. If monitoring stations were established prior to implementing the pollution prevention options described in this paper, baseline data could be obtained from which future changes in water quality could be measured.

A further measure of the impacts of pollution prevention activities on the golf course could be obtained from a qualitative evaluation of the condition of the golf course grounds before and after implementing the pollution prevention options. Some factors to include in the evaluation are: overall growth and health of the turfgrass, weed and pest populations, and disease incidents. Changes in the amount of noxious aquatic vegetation in surface water ponds on the golf course could serve as another measure of nutrient pollution prevention results.

IMPLEMENTATION

Most of the measures described under Option 1 - Nutrient and Pesticide Management can be implemented with few barriers. As described in the Assessment Section of this report, Fort Eustis staff already employ a number of the recommended nutrient/pesticide management approaches. Some of the measures that are not currently employed involve simple modifications in current approaches and are readily implementable. These include: avoid applying excess fertilizer, wise mowing, equipment calibration, and working with the VCES. Other measures are easily implemented after an evaluation of current practices and/or research on alternative approaches is completed (see Table 2 for a more detailed description of needed additional activities). These measures include: preparing a comprehensive nutrient management plan; applying fertilizer near time of maximum plant uptake; timing to avoid leaching losses from rainfall or irrigation; use of low- or no-phosphorous fertilizers; alternatives to nitrogen; use of low mobility, high adsorption, and low persistence pesticides; IPM; recordkeeping; and water conservation. The preservation and maintenance of vegetative buffer strips may present few, or many, implementation barriers depending on the existing condition of these buffers. An initial evaluation of existing buffer areas should be undertaken to determine the extent of healthy buffer areas and those needing rehabilitation. If significant amounts of rehabilitation are needed, barriers to implementation would occur from cost, time, and labor to rebuild the buffer areas.

The above approaches could be implemented all at once, or phased in on various sections of the golf course. For example, one green could be fertilized with a reduced phosphorus fertilizer, another green could receive reduced levels of nitrogen fertilizer, and the remaining greens could continue to receive the current treatment. By phasing in some of the above recommendations on a limited basis, the effects of the changes in management approach could be monitored in a controlled fashion. This would allow time for any modifications or fine-tuning prior to using the measure course-wide.

Option 2 - Use of Wastewater and Sludge as a Supplemental Fertilizer offers the most potential barriers to the proposed pollution prevention options. It is difficult to fully estimate the extent of these barriers without having the results of the initial planning studies described in the Assessment Section of this report. The extent of barriers depends on the quality of the wastewater and sludge, as well as transportation and application techniques. If sludge quality is good and requires little treatment, or if existing equipment can be used for application, then the barriers to Option 2 are few. As treatment demands or equipment needs increase, so do the barriers; this cannot be determined without the initial planning studies. One barrier to using wastewater and sludge relates to the public perception of these materials. This barrier can be overcome through effective public education and outreach programs.

RESEARCH, DEVELOPMENT AND DEMONSTRATION NEEDS

In order to make its golf course management program truly effective, and to provide the necessary information to make decisions on pollution prevention approaches and performance, Fort Eustis should undertake a few R&D studies. These are briefly outlined below:

- Nutrient and Pesticide Management - Fort Eustis should work with VCES to develop a comprehensive nutrient management plan for the golf course. Some of the major goals of this plan should be to reduce fertilizer inputs to the lowest possible level based on a full understanding of all nutrient sources (e.g., grass clippings, soil nutrients) within the golf course system compared to actual turfgrass nutrient needs. After determining actual nutrient needs, Fort Eustis should examine its current fertilizer sources to see if more environmentally-sound supplies could be used. This same type of product evaluation should occur for the current pesticide program with the goal of selecting the product that best meets the recommendations given in this report.

- Use of Wastewater and Sewage Sludge as a Supplemental Fertilizer - A number of planning studies must be undertaken before this option can be fully explored. These studies are described more fully in the Assessment Section of this report.

- Test Plots - If Fort Eustis golf course personnel are wary about trying a new approach (e.g., using low-phosphorous fertilizer or using sewage sludge), they could establish various test plots on the golf course to implement these approaches and monitor the results on a small scale.

- Reduce Reliance on Aqua-shade - Currently, Fort Eustis golf course personnel use an herbicide, aqua-shade, to reduce algal growth in the golf course ponds. This practice masks signs of nutrient-enrichment (e.g., eutrophication). In order to determine if eutrophic conditions exist on the golf course, the use of aqua-shade should be suspended in at least a few of the ponds. This will provide a qualitative means of assessing the extent of nutrient loadings to surface water from the golf course.

RECOMMENDATIONS/CONCLUSIONS

A pollution prevention opportunity assessment was performed on the golf course at Fort Eustis in September, 1991. More specific data on the types of management practices currently used, especially fertilizer and pesticide formulations and application rates/loadings, is needed to refine the pollution prevention activities proposed in this report. Two broad based pollution prevention options were identified:

Option 1 - Nutrient and Pesticide Management; and Option 2 - Adoption of Option 1 and Substitute an Organic Fertilizer. Option 1 consists of afdopting guidelines prepared by the USGA and VCES and enhancing them with the "Watershed Nutrient Control Standards." Option 2 consists of substituting fertilizer derived from the Fort Eustis Sewage Treatment Plant (i.e., sludge and wastewater).

Fort Eustis already employs a number of recommended nutrient and pesticide management practices and is encouraged to continue these practices. A number of additional nutrient and management practices were also identified which could be easily implemented or considered by Fort Eustis as a supplement to the on-going program. The only recommended pollution prevention option that requires significant additional study prior to implementation is Option 2 - Substitute Organic Fertilizer (i.e., sludge and wastewater) Derived From the Fort Eustis Sewage Treatment Plant. The feasibility of this option should definitely be explored, as wastewater and sewage sludge offer viable alternatives to chemical fertilizers and can be obtained relatively easily onsite. Using wastewater and sludge from the sewage treatment plant would also greatly reduce thekamount of waste needing to be disposed or discharged from that facility. Depending on the results of the feasibility study (e.g., equipment needs), it is very likely that a cost savings (from reduced chemical fertilizer needs and/or reduced treatment/disposal expenses) could occur. The other added benefit of using wastewater and sludge is that its use could extend beyond the golf course to other areas of the grounds maintenance program (e.g., fertilizer for landscaping projects).

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

ROADS AND RUNWAYS AT LANGLEY AIR FORCE BASE

by

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INTRODUCTION

A pollution prevention opportunity assessment (PPOA) was conducted on the runway and road operations at Langley Air Force Base. The assessment was conducted for the EPA's Risk Reduction Engineering Laboratory under the purview of the WREAFS program to support the Tidewater Interagency Pollution Prevention Program (TIPPP). A procedure described in the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003) was used to conduct the study. The manual provides detailed worksheets and a process/option evaluation method for use in industrial settings.

A PPOA consists of four systematic steps: Planning and Organization, Assessment, Feasibility Analysis, and Implementation. Of the 19 worksheets in the manual, none were used in this PPOA; a questionnaire was prepared and used to obtain data from Langley (see Appendix A). The implementation of the recommended options presented in this report is at the discretion of the host facility.

PROCESS REVIEW

This section describes road and runway operations conducted at Langley Air Force Base and the associated waste streams from these operations.

Runway Operations

The runway area includes the active runway as well as the runway apron and associated areas where aircraft fueling, taxiing, parking, servicing, and washing occurs. All areas are paved. The active runaway dimensions are approximately 3,048 meters by 46 meters. The major operations are aircraft fueling, aircraft washing, runway maintenance, and runway de-icing. Aircraft and support vehicle maintenance and repair do not take place on the runway area and were not evaluated as part of this assessment. The large expanse of paved area generates large volumes of stormwater runoff. Stormwater from the runway drains directly to storm sewers. A brief description of runway operations and associated wastes follows.

Aircraft Fueling

Aircraft are fueled with JP-4 by tank trucks or fixed fueling stations. JP-4 is one type of petroleum, oil and lubricant (POL) product used at Air Force bases. All POL materials have the potential to contaminate the environment if improperly used or managed. Potential waste streams from fueling operations are fugitive emissions during fueling and fuel spills. Stormwater can become contaminated by fuel spilled on exposed paved surfaces and from fuel dripped from aircraft due to overfills.

Aircraft Washing

Aircraft are washed in a designated area designed with wash racks that allow easy access to the aircraft and permit drainage of washwater. Aircraft are washed with pressurized water and Citri-Kleen®, an alkali cleaning agent, and then rinsed with fresh water. Washwater is collected in a sump, passes through an oil/water separator, and is discharged to the storm sewer. The washwater has not been characterized (ECAMP/NPDES) but may contain oil, grease, Citri-Kleen®, detergents, and surfactants. It is unknown whether organic solvents, such as 1,1,1-trichloroethane, are used to spot clean aircraft.

Runway Maintenance

Routine maintenance is performed to keep the active runway and runway area operational. Runways are repaired with concrete and asphalt. Concrete and asphalt are lost from runways due to wear-and-tear from weather conditions and vehicular traffic. Annual concrete use is 70 yds^3 of 3000 psi concrete and 30 yds^3 of 5000 psi concrete. Annual asphalt usage is 200-300 tons per year. Runway joints are sealed with a self-leveling rubberized sealant. How much of the concrete and asphalt is actually lost into stormwater discharges is unknown. Wear of vehicular tires may result in some particulate rubber being discharged into stormwater runoff.

De-icing

An electronic ice detection system is used to detect icy conditions on the active runway. Runways are de-iced using urea. The urea de-icing agent can contaminate ice melt or stormwater runoff with potentially high concentrations of nitrogen, an aquatic plant nutrient and one of the major pollutants of concern for the Chesapeake Bay system.

Aircraft Taxiing, Takeoff and Landing

Aircraft taxiing, takeoff, and landing generate engine emissions. Particulate emissions deposited on paved surfaces can contaminate stormwater.

Support Vehicle

Support vehicles such as trucks are operated in the runway area. Support vehicles can leak automotive fluids onto paved areas where such fluids may contaminate stormwater.

Roadway Operations

Langley Air Force Base is served by a network of roads. The area covered by paved or unpaved roads is unknown. The major operations investigated are road de-icing and road maintenance.

Roadway De-icing

Sand is spread on roadways as a de-icing agent. Sand can be transported as suspended solids in ice melt runoff or stormwater runoff to surface waters. High suspended solid concentrations can degrade water quality and harm aquatic biota by physically covering aquatic habitats and reducing availability of light to aquatic vegetation.

Roadway Maintenance

Roads are paved and unsealed. Maintenance operations include periodic surface maintenance, filling potholes, and line painting. The specific type of paint used on roads was not known to the Air force staff interviewed for this assessment. Stormwater runoff from roads can be contaminated with oil and grease and toxic metals from routine vehicle traffic. Some roadway paints contain lead which, when eroded due to weather and traffic, may contaminate stormwater.

ASSESSMENT

An inspection of runway and road processes was conducted by the assessment team in September 1991. Pollution prevention worksheets found in the ORD Waste Minimization Opportunity Assessment Manual were not appropriate for this assessment. Instead, Air Force personnel were requested to provide process and facility information by completing a pre-assessment questionnaire. A copy of the pre-assessment questionnaire is found in Appendix A.

Data Gaps

Sufficient quantitative data on processes and the facility were not available. Air Force personnel did not initially provide the information requested in the pre-assessment questionnaire. Available data were collected through interviews with Air Force personnel during the site visit. The assessment team did not fully tour the runway nor associated runway areas due to security and safety concerns raised by Air Force personnel. The lack of a complete set of quantitative data does not allow the most basic questions to be answered, such as:

- Which wastes are of most concern?
- What are waste management costs?
- Which processes or wastes should be targeted for pollution prevention?

Particular data that need to be collected to answer these questions are:

- Identification of all operations generating wastes
- Identification of all existing waste management and pollution prevention practices
- Chemical composition of input materials that generate wastes
- Amount of raw materials used
- Costs of raw materials
- Quantity of raw materials lost
- Mechanisms or pathways by which the material is lost
- Quantity of waste generated
- Chemical components in each waste stream
- Cost of waste management
- Which wastes are classified as hazardous or nonhazardous
- Quantity of input material(s) entering each waste stream

Current Waste Management Practices

Runways are vacuumed daily using a Tempo™ sweeper. The runway border areas are vegetated and reseeded to prevent erosion and slow stormwater runoff to allow settling of suspended contaminants and biological uptake of nutrients. Washwater discharges from aircraft washing passes through an oil/water separator before being discharged to the storm sewer. The oil/water separator may be ineffective in removing oil because surfactants in detergents chemically stabilize free and dispersed oil. Fuel spills are contained using vacuum skimmers and booms. A Spill Prevention and Response Plan is in place. A leak detection system exists for underground fuel storage tanks. An oil boom is installed at the stormwater sewer outlet to absorb floating oil and grease from stormwater discharged from the runway area. The oil boom may be ineffective during periods of high stormwater flow. It is also not known whether the boom is periodically replaced when the capacity to absorb oil is diminished.

Pollution Prevention Options

A number of potential pollution prevention options were identified for runway and road operating processes.

Reduce fugitive VOC emissions during aircraft fueling by:

- Installing vapor recovery systems on fuel delivery equipment

Reduce contamination of stormwater from aircraft washing by:

- Evaluating washing frequency
- Recycling and reusing washwater

Reduce contamination of stormwater from de-icing operations by:

- Using alternative de-icing material
- Installing heating elements under the runway

Reduce contamination of stormwater from dripping or leaking engine fuel and liquids from aircraft and support vehicles by:

- Routinely checking for leaks
- Placing drip pans under leaking engines until the leak is fixed
- Installing overfill protection pans

Reduce emissions from aircraft engines by:

- Using natural gas or electric powered tugs to move planes out to runways

No options were identified for roadway operations due to the lack of data. Installing a heating element system under the runway was not considered further given the high capital costs, disruption to runway activities during installation, and low number of days per year the system would be needed. All of the other options were further evaluated for feasibility.

FEASIBILITY

A feasibility analysis for each pollution prevention option was conducted using a modified Worksheet Number 13 (see Table 1). Each option was rated qualitatively for a number of different criteria since quantitative data were not available. The feasibility analysis results identified these pollution prevention options as promising areas for reducing or eliminating wastes. A more rigorous feasibility analysis, based on the data described in the Data Gaps section, should be completed for each option prior to implementation. A brief description of each pollution prevention option is presented below.

Fueling Vapor Recovery

Installing an emission recovery system on the second stage fuel delivery equipment would reduce fuel loss from fugitive emissions. The system prevents emissions by sealing the fuel nozzle and the fuel tank.

Aircraft Washing

The frequency of aircraft washing should be evaluated to ensure that aircraft are only washed when required. Washing aircraft on an as-needed will reduce the amount of water and cleaning agent required and limit wastewater generation.

Washwater could be collected, filtered, and reused for aircraft washing. New cleaning agent and water would be added as needed. Recycling washwater will reduce the amount of water and cleaning agent used and eliminate the discharge of washwater to the storm sewer.

TABLE 1. QUALITATIVE ANALYSIS OF POLLUTION PREVENTION OPTIONS

Criteria	Fuel Vapor Recovery System	Recycle Aircraft Washwater	Alternative De-icing Material	Tugs to Move Aircraft
Additional space required	No	Possibly	Possibly	Yes- Tug storage
Waste reduction	High	High	Eliminate nitrogen	Yes
Safety hazard reduction	Yes	N/A	N/A	Unknown
Input material cost reduction	Yes	Yes	Undetermined	Unknown
Extent of current use in industry	High	High	Moderate	Moderate
Personnel training	Required	Required	None	Required
Additional labor requirements	No	No	No	No
Utility requirements/ availability	None	Electricity	None	None
Special expertise requirements	None	None	None	None
Adverse environmental impacts	None	Potential sludge disposal issues	NaCl - salinity Sand - turbidity	Unknown

Alternative De-icing Material

An alternative de-icing material will eliminate the nitrogen contamination of stormwater. Alternatives to urea include road salt (NaCl), ice-melt (CaCl), and sand. These alternative materials are widely used as de-icing agents on roads. However, they have potential environmental drawbacks. Road salt increases the salinity of ice melt water or stormwater runoff. High salinity is harmful or fatal to certain types of vegetation and freshwater organisms. CaCl increases the chloride content of stormwater runoff. Both NaCl and CaCl can have adverse impact on paved surfaces. Sand can be transported as suspended solids in ice melt runoff or stormwater runoff to surface waters. High suspended solid concentrations can degrade water quality and harm aquatic habitats. However, a settling tank can be installed before discharging stormwater to surface water to minimize suspended solids.

Eliminating Engine Drips and Leaks

Eliminating engine drips and leaks involves visually checking aircraft and support vehicles for leaking fluids. Drip pans should be placed to catch dripping fluids for recycling or proper disposal until the leak can be fixed. This simple option will eliminate potential sources of stormwater contamination unless the drip pan is allowed to overflow in a thunderstorm. The option can be implemented without additional staffing, special training, or increased capital investment or operating costs. This option was not evaluated using Table 1 criteria.

Aircraft Engine Emission Reduction

Using natural-gas-powered tugs to move planes out to runways instead of taxiing will reduce localized air emissions and dry deposition of combustion particulates that can contaminate stormwater. Various energy-efficient innovations are currently being explored that will warm engines while reducing air emissions.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

A fuel recovery system and recycling of washwater could be applicable to other TIPPP operations that have fueling or vehicle washing operations. Other recommendations may be applicable to some of the other TIPPP sites.

MEASUREMENT OF POLLUTION PREVENTION

Measuring the impact of pollution prevention requires baseline data on wastes and operating costs. These data were not available.

IMPLEMENTATION PLAN

Inspecting aircraft and vehicles for leaks and placing drip pans to prevent engine fluids from contaminating stormwater should be implemented immediately. The decision to implement the other options should be made after a more formal feasibility analysis based on quantitative process and waste data. The major questions that should be answered prior to implementing each option are:

- Compatibility of the option with existing operating procedures
- Capital cost and operation and maintenance costs
- Production switchover interval

Specific implementation issues for three options follow.

Recycling Aircraft Wash Wastewater

- Testing the cleaning effectiveness of washwater after multiple uses
- Testing wastewater sludge to determine its chemical composition and disposal or recycling options

Alternative De-icing Agents

- The effectiveness of alternative de-icing materials; investigate if switching material requires changing Standard Operating Procedures

- Determine if new delivery equipment is required

Tug System

- Space requirements for tug storage
- Special training or personnel expertise required for maintenance
- Alternative auxiliary equipment for tugs such as natural gas fueling systems or battery charging equipment

RESEARCH DEVELOPMENT AND DEMONSTRATION NEEDS

The options presented in the preceding section will require onsite testing, refinement, some improvisation, and a desire to integrate the options into the procedures of the base. Little or no major research development and demonstration (RD&D) barriers have to be overcome, since the options are commercially available and simply need to be proven and accepted at Langley.

RECOMMENDATIONS/CONCLUSIONS

The aircraft and support vehicle leak detection program should be implemented immediately. A thorough analysis of the other four pollution prevention options should be performed. A follow up pollution prevention opportunity assessment supported by quantitative data should be conducted to identify other pollution prevention options.

A pollution prevention opportunity assessment was performed on runway and road operations at Langley Air Force Base. The lack of data on wastes, input materials, and operations limited the options identified by this assessment. Five potential pollution prevention options were identified:

- Aircraft fuel vapor recovery system
- Recycling aircraft washwater
- Alternative de-icing material
- Tug system to move aircraft
- Aircraft and support vehicle leak detection program

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

SOLID WASTE SOURCE REDUCTION
AT THE FT. EUSTIS COMMISSARY

by

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INTRODUCTION

Solid waste management is a pressing issue in most communities. Many concerned citizens want to do their part to alleviate the landfill crisis, but they are often confused about how to act. With an abundance of advertising claims, a lack of information about what is recyclable and where it can be recycled, and a lack of alternatives to heavily packaged products, consumers understandably have become frustrated. They want to use their consuming dollars to show their commitment to the environment, but they are unsure of what to buy. To alleviate this confusion, facilities such as the Ft. Eustis Commissary need to take the lead in helping consumers to act on their desire to purchase more environmentally sound products.

This report outlines a suggested strategy for making the Ft. Eustis Commissary a model "green" commissary. The strategy focuses on minimizing the commissary's generation of in-house waste and offering consumers a choice of products that contain fewer toxic materials and/or less packaging. As part of this strategy, it is recommended that the commissary also function as a community recycling center where recyclable materials, such as glass bottles and aluminum cans, are collected.

On September 17, 1991, the U.S. EPA performed a pollution prevention opportunity assessment of the Ft. Eustis Commissary. EPA was supported in this effort by Lt. Col. James Howell (Food and Safety and Quality Assurance, Ft. Lee) and Mr. Fisher (Ft. Eustis Commissary Director) at Ft. Eustis. Following the assessment, it was decided that, as part of the Tidewater Interagency Pollution Prevention Program (TIPPP), the Ft. Eustis Commissary would participate in a demonstration project showing how commissaries can become "green" without decreasing profitability. (In some cases, waste education activities may actually increase profitability.) The program can be implemented in incremental stages, so that the normal operations of the commissary are not disrupted.

In an effort to assist the Defense Commissary Agency in using the Ft. Eustis Commissary as a test case for developing a model "green" commissary, the following pollution prevention activities are proposed:

- minimize the amount of in-house waste generated by the commissary;
- work with distributors to reduce the amount of packaging used to ship products to the commissary;
- implement/test product classifications that might allow the commissary to rank the environmental "greenness" of products;
- identify marketing/display strategies to encourage customers to purchase "green" products;
- identify activities to eliminate, reduce, or properly dispose of, household hazardous waste;
- support existing installation recycling programs by: (1) informing patrons about these programs; (2) establishing centralized collection areas for consumers who live outside of the installation; and (3) helping to develop markets by selling products made from, or packaged in, recycled materials.

The implementation of these activities is discussed in greater detail in the sections following "Process Reviews," which describe the pattern of waste generation associated with the normal operations of the Ft. Eustis Commissary.

PROCESS REVIEWS

The municipal solid waste (MSW) generated by the Ft. Eustis Commissary can be divided into two distinct waste streams: waste that is a by-product of the normal operations of the commissary and waste that is generated by the commissary's customers.

Commissary Wastes

The operation of the Ft. Eustis Commissary can be divided into four process areas:

- loading dock/delivery area
- fresh food processing area
- check-out lanes
- commissary office

Loading dock/delivery area

All products that are sold at the commissary are received and unpacked at the loading dock. Wastes generated in this area include: coated and uncoated cardboard, shrinkwrap, plastic strapping, broken pallets, damaged crates and broken glass containers. The Food Marketing Institute (FMI) estimates that corrugated cardboard comprises 84 percent of the waste stream of large supermarket chains and 46 percent of the waste stream of small supermarket chains. One supermarket chain, Hannaford Bros. Co., estimates that 30 percent of its corrugated cardboard is unrecyclable because it is either waxed (6.5 percent) or wet (23.4 percent).

Fresh food processing area

All fresh foods must be inspected, and in some cases packaged, before they are put on display. Wastes generated as a consequence of preparing fresh fruits, vegetables, meats, poultry, fish, deli items, and bakery products include: produce wastes; meat trimmings; unsold prepared foods like salads; stale bread and other outdated bakery products; used cooking oil; and plastic waste such as shrink wrap, polystyrene trays and plastic containers. Other wastes generated in this area include used cleaning products such as paper towels, sponges, and containers for cleaners like ammonia and window cleaner. If the commissary sells flowers, floral wastes are also generated in this process area. . . . .

Check-out lanes

Customer purchases are registered, paid for, and bagged in the check-out lane. The check-out lane also provides customers with the opportunity to pick up some last minute items like magazines and snack foods.

Commissary office

The office is where paper work pertaining to the operation of the commissary is accomplished. Typical office wastes such as waste paper, laser printer and photocopier cartridges, aluminum cans, bottles and newspapers are generated in the commissary office.

Consumer Wastes

All of the products purchased at the commissary ultimately become part of the wastes generated by consumers at home. The consumer waste stream contains considerably less produce and meat wastes and more packaging wastes, than the commissary waste stream. According to the U.S. EPA, 30 percent of all MSW (by weight and by volume) is packaging. This includes paper, paperboard, plastic bags, and containers, film plastics, aluminum and bi-metal cans, glass, register tape, magazines, and the packaging from single serving size products (e.g., potato chips, chewing gum). Food wastes comprise just 7 percent by weight, and 3 percent by volume, of the municipal solid waste stream.

To more precisely measure the amount of municipal solid waste generated by the commissary's customers, a standard per capita generation rate can be applied to the number of people living at Ft. Eustis and/or near the installation. In 1988, the U.S. EPA estimated the per capita generation rate in the U.S. to be 4.0 pounds per person per day of MSW. This rate is expected to increase to 4.2 pounds per person per day by 1995.

Part of this 4.0 pounds per person per day is household hazardous wastes that are supplied by the commissary and eventually become part of the municipal solid waste stream. Typical household hazardous wastes are shown in Table 1.

TABLE 1. HOUSEHOLD HAZARDOUS WASTES FROM ITEMS SOLD AT THE COMMISSARY

• furniture polishes	• aerosols
• furniture stains	• shoe polishes
• floor waxes	• self-lighting charcoal
• car waxes	• charcoal lighter fluid
• spray dust cleaners	• butane lighters
• drain cleaners	• motor oil
• toilet bowl cleaners	• paints
• oven cleaners	• glues
• spot and stain removers	• batteries

ASSESSMENT

The Ft. Eustis Commissary is located on a military installation in eastern Virginia. This new commissary became fully operational in September 1991. The facility is very large, and currently uses only one third of its warehouse space. The Ft. Eustis Commissary is used by Ft. Eustis residents and military personnel that live near the installation. This clientele may be more receptive to pollution prevention efforts than other supermarket shoppers. Ft. Eustis residents are accustomed to recycling, since the installation already has an established collection program (as required by DoD directive) for cardboard, paper, metals, aluminum cans, and glass.

The commissary purchases its goods through commercial food distributors and manufacturers. The deli and bakery at the Ft. Eustis Commissary are controlled by operators.

Data Gaps

Except for the amount of fruit and vegetable wastes generated daily at the Ft. Eustis Commissary, very little hard data on the facility's waste generation was available. Consequently, the following pollution prevention analysis is based on a general understanding of supermarket and consumer wastes

and some specific statistics compiled by the U.S. EPA and the Grocery Industry Committee on Solid Waste.

Pollution Prevention Activities

The commissary is already engaged in several on-going and planned pollution prevention activities.

<u>On-going activities</u>

- *Reusable plastic crates.* The commissary already receives some products, such as cartons of milk, in reusable plastic crates.

- *Cardboard recycling.* The commissary is baling its uncoated corrugated cardboard boxes and selling them to a local recycler.

- *Discourage double-bagging.* The commissary is discouraging double-bagging unless specifically requested by the customer.

<u>Proposed activities</u>

- *Cardboard boxes made from recycled paper.* The commissary is planning to request that its distributors use cardboard boxes with recycled content to ship products to the commissary.

- *Paper bags made from post-consumer waste paper.* The commissary is planning to request that its distributor supply brown kraft paper bags with recycled content.

Following an on-site visit to the Ft. Eustis commissary in September 1991, several additional activities for reducing commissary and consumer wastes were identified.

For commissary wastes:

Reduce the amount of in-house waste generated at the commissary by:

- using less packaging to ship products to the commissary.
- using reusable shipping containers.

Recycle commissary wastes by:

- recycling shrinkwrap.
- recycling plastic strapping.
- recycling used pallets and wood vegetable crates.

- composting food wastes.
- recycling meat scraps.

For consumer wastes:

Reduce the amount and toxicity of wastes generated by consumers at home by:

- stocking the largest container size of popular products.
- stocking alternative non-toxic cleaning products.
- installing bulk distribution units for some products.
- selling fruits and vegetables loose, not packaged.

- selling meats, poultry and fish "deli-style," not packaged.
- selling reusable canvas bags.

Encourage consumers to recycle and to buy products that are recyclable and/or that come in packaging with recycled content by:

- establishing a drop-off center at the commissary.

- offering consumers a choice between paper and plastic bags, and an option to return either to the store.

FEASIBILITY

A feasibility analysis for each pollution prevention option was conducted using a modified worksheet Number 13. Each option was rated qualitatively (see descriptions below), then evaluated quantitatively according to 14 criteria (see Tables 2 and 3). The following pollution prevention activities are listed in descending order of importance.

For commissary wastes:

- *Reduce the amount of packaging used to ship products to the commissary.* Distributors use large amounts of corrugated cardboard and plastic shrinkwrap to package products for shipping. For many items, such as cartons of milk and fruit, it is possible to use reusable plastic crates or baskets instead. The commissary should encourage its distributors to ship other products in reusable containers.

- *Return used crates and pallets to the distributor for reuse.* This is very easy to do, since distributors are always in a position to backhaul materials from the commissary. Given the large amount of available storage space at the Ft. Eustis Commissary, it should be possible to store enough pallets to fill a distributor's truck for backhauling. Not all pallets can be reused or repaired. These used pallets should be returned to the distributor for recycling or sent to a local end-user, such as a wood chipping operation. Doing so will reduce the commissary's landfill tipping fees.

- *Recycle coated corrugated cardboard.* Corrugated cardboard is one of the most highly sought after recyclables. Therefore, it is likely that end-users exist for even the lower grade coated cardboard. Finding a market for the coated cardboard would save money by reducing the amount the commissary pays in landfill tipping fees.

- *Recycle shrinkwrap.* In recent years, shrinkwrapping products together rather than boxing them has become very popular. It is easy to do and saves in shipping costs, since the plastic wrap is much lighter than corrugated cardboard. Shrinkwrap is also used to wrap pallet loads of products to contain them during shipping. This plastic material represents a significant part of the commissary's waste stream. It is recyclable, as evidenced by the shrinkwrap recycling programs in place at other supermarkets, including Giant (Maryland) and Hannaford Bros. Co.'s Shop 'n Save (Portland, ME).

- *Recycle plastic strapping.* Plastic strapping is commonly used to attach stacked corrugated boxes to pallets. It should be collected separately and sent to a plastic resin recycler, who may turn it back into plastic strapping.

TABLE 2. QUALITATIVE RANKING OF ACTIVITIES AFFECTING COMMISSARY WASTESTREAMS

Criteria	Option #1 Reduce packaging for shipments	Option #2 Reuse or recycle crates and pallets	Option #3 Recycle corrugated cardboard	Option #4 Recycle shrinkwap	Option #5 Recycle plastic strapping	Option #6 Compost fruit and vegetable scraps on-site	Option #7 Composite fruit and vegetable scraps off-site
Effect on product or operation quality	2	3	3	3	3	2	3
Space requirements	4	2	2	2	2	1	3
Compatibility with existing operating procedures	2	2	2	2	2	1	2
Treatment/disposal cost reduction	5	5	5	4	4	5	5
Input material cost reduction	4	4	4	4	4	3	3
Extent of current use in industry	4	2	3	2	2	1	1
Capital cost	2	3	3	3	3	1	3
O&M cost	3	2	2	2	2	1	2
Additional labor requirements	3	2	2	2	2	1	2
Implementation period	4	3	2	2	2	1	2
Ease of implementation	5	2	3	3	3	1	2
Utility requirements and availability	3	3	3	3	3	2	3
Special expertise requirements	3	3	3	3	3	1	2
Alternative's adverse environmental impacts	3	3	3	3	3	3	3
TOTAL	47	39	40	36	38	24	36

The qualitative ranking system is based on the assumption that each option will have either a positive, a negative or no effect on current operating procedures. Using a system of 1 through 5, with 3 as a neutral or middle point , each option was ranked as either positive (more efficient, more cost-effective, more material-conserving, etc.), negative (more labor intensive, more expensive, more incompatible, etc.), or neutral. The scores were added, and an overall ranking was determined for each option. The options with the highest scores are those that best balance feasibility and accomplishment.

1 = very negative
2 = negative
3 = neutral
4 = positive
5 = very positive

TABLE 3. QUALITATIVE RANKING OF ACTIVITIES AFFECTING THE CONSUMER WASTESTREAM

CRITERIA	Option #1 Stock large sizes of popular products	Option #2 Stock alternative non-toxic cleaners	Option #3 Bulk distr. units with reusable containers	Option #4 Loose products	Option #5 Deli-style meats, etc.	Option #6 Sell canvas bags	Option #7 Establish drop-off center and waste exchange	Option #8 Offer paper versus plastic option	Option #9 Distribute Green commissary brochures
Effect on product or operation quality	3	3	2	3	4	3	2	3	5
Space requirement	2	2	1	3	4	2	1	3	3
Compatibility with existing operating procedures	3	2	1	3	2	2	1	3	2
Treatment/disposal cost reduction	4	5	5	4	4	5	5	3	4
Input material cost reduction	5	3	5	4	4	3	1	3	2
Extent of current use in industry	5	2	2	4	3	2	1	4	1
Capital cost	2	3	1	4	2	3	1	3	2
O&M cost	2	3	1	4	2	3	1	3	3
Additional labor requirements	2	2	1	3	3	3	1	3	2
Implementation period	3	2	1	3	2	2	1	3	2
Ease of implementation	4	2	1	5	2	5	1	5	4
Utility requirement and availability	3	3	3	3	3	3	1	3	3
Special expertise requirement	3	2	1	3	3	3	1	3	1
Alternative's adverse environmental impacts	3	3	2	3	3	2	1	3	2
TOTAL	44	37	27	49	41	41	19	45	36

The qualitative ranking system is based on the assumption that each option will have either a positive, a negative or no effect on current operating procedures. Using a system of 1 through 5, with 3 as a neutral or middle point , each option was ranked as either positive (more efficient, more cost-effective, more material-conserving, etc.), negative (more labor intensive, more expensive, more incompatible, etc.), or neutral. The scores were added, and an overall ranking was determined for each option. The options with the highest scores are those that best balance feasibility and accomplishment.

1 = very negative
2 = negative
3 = neutral
4 = positive
5 = very positive

- *Compost food wastes.* Food wastes include fruit and vegetable scraps, stale bakery products and unsold prepared foods. These wastes are valuable and should be recycled into a soil amendment whenever possible. Food contaminated paper products such as paper towels and napkins can be composted along with these wastes. The commissary generates a significant amount of food wastes. Composting these wastes would result in a savings in the form of avoided landfill disposal costs.

  Supermarkets around the country are involved in food waste composting programs, including Star Market (Boston, MA) and Hannaford Bros. Co.'s Shop 'n Save (Portland, ME). Star Market is working with the Massachusetts Department of Environmental Protection on an experimental composting program; food wastes are collected from the stores once or twice a week and brought to a nursery where they are composted and used for potting soil. Shop 'n Save has found two agricultural composting sites near its Portland store that are willing to take food wastes as long as the store absorbs the cost of transportation. Shop 'n Save claims that composting its food scraps has resulted in a 50 percent decrease in the amount of waste that it sends to the local landfill.

  In contrast to Star Market and Shop 'n Save, Puget Consumers Co-op (Seattle, WA) operates a composting facility behind one of its stores. This is a good option for Ft. Eustis, since the resulting compost could be used for landscaping at the installation and/or offered to customers.

- *Recycle meat scraps.* Meat trimmings, bone and outdated fish can be sent to a local rendering plant. Meat fat and bone contain tallow which is used in the manufacture of soap.

For consumer wastes:

- *Stock the largest size container of popular products.* This gives customers the option to reduce the amount of packaging waste that they generate at home. Single-serving containers and other small packages are a major source of packaging waste. Many products are available in large sizes and can be easily supplied by a distributor.

- *Stock alternative, non-toxic cleaning products.* This will help to reduce the amount of household hazardous waste generated by the installation and local community. By accompanying displays of alternative cleaning products with explanatory brochures, this activity will also serve an important public education function. Several ordinary supermarket products can be used for cleaning, such as baking soda and vinegar.

- *Install bulk distribution units for certain products such as cereals and laundry detergent.* This will reduce the amount of packaging waste generated by customers at home. Several products, such as coffee beans and nuts, are already sold in bulk in most stores. Although it should not be difficult to find a distributor that can provide the necessary dispensers and an array of products suitable for bulk distribution, customer generally do not like bulk for many foods. Army personnel also believe that buying in such larger quantities could create a sanitation problem.

- *Sell fruits and vegetables loose, not packaged in polystyrene and plastic wrap.* This will reduce the amount of packaging waste generated by customers at home. Since many fruits and vegetables are already sold both in bulk and packaged, this activity simply requires the elimination of the packaging option. This may save money by reducing the amount of time commissary employees spend wrapping fruits and vegetables.

- *Sell meats, poultry and fish "deli-style;" that is, upon request, rather than packaged and set out in a display.* This will reduce the amount of plastic packaging discarded; however, it may increase the amount of unrecyclable paper discarded by customers at home, since paper will be used to package meats for transporting home. Another problem that may arise is the possible inability to meet customer demand at lunch for meats and poultry.

- *Sell reusable canvas bags that customers can bring to the commissary to be used instead of paper or plastic bags.* This is being done in supermarkets throughout the U.S. There are many manufacturers of canvas bags, thus it should be easy to acquire them at a reasonable price. However, before this can be implemented it must be authorized.

- *Offer customers a choice between paper and plastic bags.* Such a choice mirrors those that customers face throughout the commissary. Offering a choice between paper and plastic bags draws the customer's attention to the fact that they are choosing a form of packaging for their groceries. Presenting this choice may remind consumers that it is more environmentally sound to bring their own canvas bags. There are no costs associated with this pollution prevention activity.

- *Stock and label products packaged in recycled or recyclable packaging.* It is more difficult to accurately identify recycled packaging, thus this activity would require some research. However, it would be of enormous benefit to the commissary's customers, who need assistance in sorting through the numerous and contradictory packaging claims made by manufacturers.

- *Establish a drop-off center for recyclables at the commissary.* This activity involves the collection of recyclables at the commissary, either in the warehouse or outside in the parking lot. It would enhance Ft. Eustis' recycling program by providing a drop-off center at a frequently visited location. To do so requires adequate space, staffing, and promotion. Many supermarkets in the United States have drop-off centers for newspapers, bottles and cans in their parking lots.

CROSSFEED TO OTHER TIPPP INSTALLATIONS

The commissary and consumer pollution prevention activities described above could be implemented at other commissaries that are interested in reducing the amount of solid and household hazardous waste that they and their customers generate. Some of the options could also be applied to other facilities that deal with food products, such as cafeterias and hospitals.

MEASUREMENT OF POLLUTION PREVENTION

Measurement of the efficacy of pollution prevention methods is very important in demonstrating success and gaining support and funding for follow-up projects. A system of recordkeeping, for example to detail customer preference for paper versus plastic bags and how many of each were returned to the store form recycling, is a necessary part of quantifying waste reduction.

Several options presented in this report will be successful only if consumers participate in the program and continue to buy the product. Quantifying recycling programs and negotiating specific packaging options from the suppliers to the commissary are relatively easy.

IMPLEMENTATION

This section reviews the pollution prevention strategies discussed above in terms of any barriers to their implementation.

No Barriers

- *Offer customers a choice between paper and plastic bags.* This pollution prevention activity should be implemented immediately, as there are no costs associated with it and it requires virtually no change in current commissary operating procedures.

- *Discourage the practice of double-bagging unless it is specifically requested by the customer.* This pollution prevention activity should be implemented immediately, as there are no costs associated with it and it requires virtually no change in current commissary operating procedures.

- *Sell reusable canvas bags that customers can bring to the commissary to be used instead of paper or plastic bags.* There are so many different types of canvas bags on the market, that it should be easy to find a suitable bag at a reasonable price. Several manufacturers should be contacted and samples requested. If the commissary chooses to implement this option, they should consider selling the bags at cost to encourage consumers to buy and use them. Although the commissary would not make any money in such an enterprise, savings would result from not needing to purchase as many paper and plastic bags.

- *Sell fruits and vegetables loose, not packaged.* This option should be implemented immediately for all produce items that have not been packaged prior to delivery. There are no capital costs associated with this activity, which should save money by no longer requiring that commissary employees spend time wrapping fruits and vegetables.

- *Stock the largest size container of popular products.* Making more shelf room for larger packages should not be a problem, since the Ft. Eustis commissary has more space than it can currently use. A potential problem with implementing this pollution prevention strategy is consumer acceptance. Often, large product sizes do not sell well because people find them cumbersome and difficult to use. This could be remedied by stocking large sizes that come with built in handles and allowing customers to take their shopping carts all the way to the car.

Few Barriers

- *Reduce the amount of packaging used to ship products to the commissary.* This may be difficult now that procurement for all commissaries is arranged through the American Logistics Agency, so that any change in distribution will affect more stores than just the Ft. Eustis Commissary. However, it is should be pursued since it is one of the pollution prevention activities that is likely to have the greatest impact on reducing the amount of in-house waste generated by the commissary.

- *Return used crates and pallets to the distributor for reuse.* Storing pallets and crates until a sufficient number have accumulated to justify the distributor's backhauling them could pose some problems. Although Ft. Eustis has ample storage space, standard commissary operating procedures may prohibit the accumulation of items inside the facility. If so, an arrangement should be worked out with the distributor whereby the pallets and crates are taken back each time a new shipment of goods is delivered. Used pallets that cannot be reused or repaired should be recycled. Used pallets can be made into wood chips or burned for fuel. Therefore, implementing this activity will require some research to find a local end-user for the pallets and/or some time to set up a system for distributing broken pallets to the commissary's customers who can take them home to burn in their fireplaces or stoves.

- *Recycle coated corrugated cardboard.* The mechanisms for collecting and baling cardboard are already in place at the commissary. Thus, the only hurdle to implementing this pollution prevention activity is finding a market for the coated cardboard. This will take some time, but should be possible given the commissary's location in the Southeast (where many of the recycled linerboard manufacturers are located).

- *Recycle shrinkwrap.* Finding a mechanism for collecting the plastic wrap should be easy, given the commissary's experience with collecting cardboard and the installation's experience with collecting other recyclables such as bottles and cans. What may prove difficult is finding a market for the collected shrinkwrap. Before this activity is implemented, a thorough investigation of local markets for recycled film plastics should be made.

- *Recycle plastic strapping.* Plastic strapping can be collected at the same time that corrugated cardboard and shrinkwrap are collected for recycling. Finding a market for recycled plastic strapping is likely to be more difficult than for the other two materials. If an end-user for shrinkwrap is found, they may also be able to take the strapping.

- *Stock alternative, non-toxic cleaning products.* This strategy requires some creativity and supporting literature. Alternative products, such as baking soda and vinegar, need to be displayed beside common household cleaners, with pamphlets explaining their use. Other non-toxic cleaners should be ordered, which will require approval from the American Logistics Agency.

- *Stock and label products packaged in recycled or recyclable packaging.* Industry is presently packaging and marking materials that have recycled content which greatly aids in stocking.

- *Establish a drop-off center for recyclables at the commissary.* This option should be viewed as an extension of the installation's recycling program, with the commissary being a new drop-off location. Maintaining the drop-off will require a small investment in containers and some staffing, but these costs should not be prohibitive.

Several Barriers

- *Install bulk distribution units for certain products such as cereals and laundry detergent.* Due to the large size of Ft. Eustis' new commissary, finding aisle space to house bulk distribution units should not be difficult. However, retrofitting shelves to accommodate the units could be costly. Thus, the implementation of this pollution prevention activity depends on the availability of funds. Another important consideration is consumer acceptance. The supermarket chain Shop 'n Save (Portland, ME) tried bulk distribution for a wide range of products from jello to detergent, but found that consumers did not like it. Changing negative customer attitudes regarding buying in bulk will also be necessary in order to implement.

- *Sell standard size reusable containers for use in conjunction with a bulk distribution system.* The primary barrier to the implementation of this option is cost. Having containers specially made and possibly selling them at cost to customers (to encourage them to use the bulk distribution system) could be expensive. In addition, consumers might not like the containers and/or find it troublesome to remember to bring them to the commissary.

- *Sell meats, poultry and fish "deli-style;" that is, upon request, rather than packaged and set out in a display.* Implementation depends on the willingness of the meat contractor to change the way these foods are sold. It also may require extra staffing, although this should be balanced by the time saved by not wrapping all meat products.

- *Compost food wastes.* It is easier to implement this pollution prevention option if the food wastes are collected and taken to an off-site composting facility. Ft. Eustis is located in a rural area where it should be possible to find an agricultural establishment interested in using their food wastes (if not to compost, then perhaps to feed to animals like pigs). The alternative is to establish an on-site composting facility at the commissary. This would require considerably more time and effort since an appropriate composting pad would need to be built and the process would have to be monitored. In addition, the commissary would need to obtain a permit from the State of Virginia to operate a composting facility.

RESEARCH DEVELOPMENT & DEMONSTRATION NEEDS

To make the model commissary program truly effective, more research and data gathering should be done regarding the generation of wastes by the Ft. Eustis commissary and its customers. Once this has been accomplished, there are two other research efforts that would facilitate the implementation of the pollution prevention strategies. These efforts are listed below:

- *Perform a customer survey.* Before implementing a bulk distribution system, do a survey of commissary customers to find out whether or not they would like the opportunity to purchase foods in bulk. Ask customers what products they think are good candidates for bulk distribution.

- *Energy efficiency assessment.* In any follow-up evaluation of pollution prevention opportunities at the Ft. Eustis Commissary, include an energy efficiency assessment that evaluates the facility's lighting, refrigeration, cooling and heating systems.

RECOMMENDATIONS/CONCLUSIONS

A pollution prevention opportunity assessment was performed on the commissary at Ft. Eustis on September 17, 1991. More specific data on the generation of wastes by the commissary and its customers is needed to refine the pollution prevention activities proposed in this report. Four broad pollution prevention options were identified:

- reduce the amount of in-house waste generated at the commissary.

- recycle commissary wastes.

- reduce the amount and toxicity of wastes generated by customers at home.

- encourage customers to recycle, and to buy products that are recyclable and/or that come in packaging with recycled content.

The five pollution preventions options that were identified as having no barriers should be implemented immediately:

- offer customers a choice between paper and plastic bags.
- discourage double-bagging.
- sell reusable canvas bags.
- sell fruits and vegetables loose, not packaged.
- stock the largest size containers of popular products.

The other eighteen pollution prevention options should be thoroughly analyzed. In particular, Ft. Eustis should seriously consider implementing the following long-term options that could significantly reduce the amount and toxicity of wastes generated by the commissary and its customers:

- compost food wastes.

- ship products to the commissary in reusable containers.

- install bulk distribution units for dry products.

- establish a recyclables drop-off center.

- stock alternative, non-toxic cleaning products.

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POLLUTION PREVENTION OPPORTUNITY ASSESSMENT

PAINTING PROCESS AT THE FT. EUSTIS ARMY FACILITY

by

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INTRODUCTION

Purpose

The purpose of this project was to conduct a Pollution Prevention Opportunity Assessment (PPOA) for painting processes at the Ft. Eustis Army Base near Norfolk, Virginia. The assessment was conducted for the EPA's Risk Reduction Engineering Laboratory under the purview of the Waste Reduction Evaluation at Federal Sites (WREAFS) of the Pollution Prevention Research Branch. A procedure described in the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003) was used to conduct the study. The manual provides detailed worksheets and a process/option evaluation method for use in industrial settings.

Approach

The PPOA consisted of four systematic steps: Planning and Organization, Assessment, Feasibility Analysis, and Implementation. Figure 1 presents the Waste Minimization Opportunity Assessment (WMOA) process. Of the 19 worksheets in the WMOA manual, selected sheets were completed for the processes and pollution prevention options considered. The detailed worksheets used are presented in Appendix A. The implementation of the recommended options presented in this report is at the discretion of the host facility.

PROCESS REVIEW

The U.S. Army's large transportation vehicles undergo overhaul and refurbishment at Fort Eustis. This overhaul and refurbishment is the responsibility of a contractor, Northrop Worldwide Aircraft Service's Fort Eustis Division (Northrop). The operation is conducted under the Directorate of Logistics (DOL) by the Maintenance Department of the Installation Maintenance Office in the Tactical Vehicle Shop (Building 1411). The focus of this assessment is on the painting operations conducted as part of the overhaul and refurbishment of vehicles for continued service.

Personnel and Work Load

The painting operation employs four persons continually: one painter and three persons who do the sanding and masking. Generally painting is done five days per week in a single shift per day. Occasionally work is done on Saturday if there is a need to catch-up on the work load. During times of heavy work loads additional personnel are employed in the painting operation (up to nine persons total).

A total of 1400 vehicles are painted on a rotating basis in this painting operation. Approximately 20 to 30 vehicles are painted per month for a total of 240 to 360 vehicles painted per year. Just prior to Desert Shield/Desert Storm there was an increase in the amount of painting done because vehicles were being prepared for shipment overseas. Currently vehicles that have come back from Desert Storm are being stripped and repainted.

Spray Painting Operation

The paint booth is approximately 50 feet long, 20 feet wide, and 25 feet high and is believed to be 38 years old (the building was constructed in 1953 and all sources indicate that the paint booth was installed when the building was constructed). Almost all of the painting is done within the paint booth which is equipped with a water curtain to capture paint overspray. Touch-up painting is occasionally done outside of Building 1411 with a paint brush (prior approval must be obtained for this procedure). The booth is totally enclosed because the painting operation is hazardous. The paint that is used is a Chemical Agent Resistant Coating (CARC). The CARC paint is extremely hazardous in liquid form but is non-hazardous when dry.

The CARC paint is solvent-based and is applied using standard spray painting methods. The paint is mixed with paint thinner (cellulose nitrate) in the paint pot and then applied with hand-held spray guns and pressure. There are two spray guns in use in this painting operation. One is a large paint gun that is operated at 20 to 25 psi and the other is a small paint gun that is operated at 40 to 55 psi.

All of the painting is done in either the desert sand or jungle green camouflage colors. Cleaning of the painting equipment between colors is not necessary because of this camouflage pattern. Cleaning of the painting equipment and lines is performed at the end of the shift with the paint thinner recommended for use with CARC paint by the manufacturer.

The raw materials used in the CARC painting operation include CARC paint, paint thinner, municipal water, and personal protective equipment. Due to the hazardous properties of the CARC paint (Material Safety Data Sheets (MSDS's) were provided) personal protective equipment must be worn while painting. Personal protective equipment consists of airline respirators, half-mask respirators, disposable coveralls, rubber gloves, and industrial footwear. Table 1 lists the raw materials used in the CARC painting operation, annual consumption rates, and costs (all costs have been rounded to the nearest whole dollar amount).

In preparation for the paint application, the vehicle is sandblasted to remove heavy corrosion or surface sanded by hand. Sandblasting is currently conducted outside of Building 1411 in an open area and the blasted material is deposited on the ground. Soil sampling conducted by the facility in September 1990 indicated high levels of lead and chromium in the soil surrounding building 1411 where the sandblasting is conducted. Toxicity Characteristic Leachate Procedure (TCLP) tests were also conducted and it was determined that the soil would not be considered a hazardous waste at the present time. Measures to prevent further contamination have been instituted by the Fort. An indoor sandblasting facility should be installed and operational by June of 1992.

Following the sanding procedure the vehicle is masked by hand with standard masking tape and brown paper. Then the vehicle is driven into the paint booth, painted with a base coat and additional colors to form the camouflage pattern, is allowed to air dry and the masking removed. During the spray painting operation, paint overspray is captured by the water curtains in the paint booth and the floor of the booth is covered with paper to keep it from being coated with paint. Figure 1 is a work flow diagram of the CARC painting operation.

Wastes generated at Fort Eustis are handled in two ways. Non-hazardous wastes are placed in dumpsters located throughout the base and are picked up and taken to the city landfill. Hazardous wastes are handled by the Defense Reutilization and Marketing Office (DRMO). The DRMO collects hazardous wastes from operations throughout the Fort and holds them at the Hazardous Waste Disposal Accumulation Facility (Building 1637) to await disposal. The DRMO contracts with a Treatment, Storage and Disposal Facility (TSDF) in Alabama to dispose of these wastes. The wastes are shipped in bulk whenever sufficient quantity has been collected but always within 90 days of generation.

Waste Generation in the Spray Painting Operation

The CARC painting operation generates numerous hazardous and non-hazardous wastes. This assessment focused on the hazardous wastes generated in the CARC painting operation including wastewater, liquid CARC paint, CARC paint residue, used paint thinner, and contaminated trash. Table 2 lists the hazardous wastes generated in the CARC painting operation, annual generation rates and disposal costs. The method of generation of each waste stream is described in the remainder of this section.

The paint booth contains two water curtains, one on each side of the booth opposite the booth entrance. They operate continuously during the work shift. Each water curtain circulates 1200 gallons of water. Approximately 500 gallons of water is added on a weekly basis to make up for evaporation losses.

TABLE 1. RAW MATERIALS USED IN THE CARC PAINTING OPERATION[a]

Raw Material	Cost	Annual Consumption Rate[b]	Total Annual Cost
CARC Paint	$34.94/gallon	480 gallons	$16,771
Paint Thinner	$5.87/gallon	336 gallons	$1,972
Municipal Water	$1.49/100 ft^3	46,800 gallons	$83
Personal Protective Equipment			
Airline Respirators	$300/item	2	$600
Half-mask respirators	$85/item	0	$0
Disposable Coveralls	$3.57/item	324	$1,157
Rubber Gloves	$0.80/item	384	$307
Industrial Footwear	$54/item	2	$108
Total Annual Cost	--	--	$20,968

a All costs have been rounded to the nearest whole dollar amount.

b Consumption rates were provided for 1991 year-to-date and the assessment was conducted in September. The figures shown have been adjusted to include the remaining months of 1991.

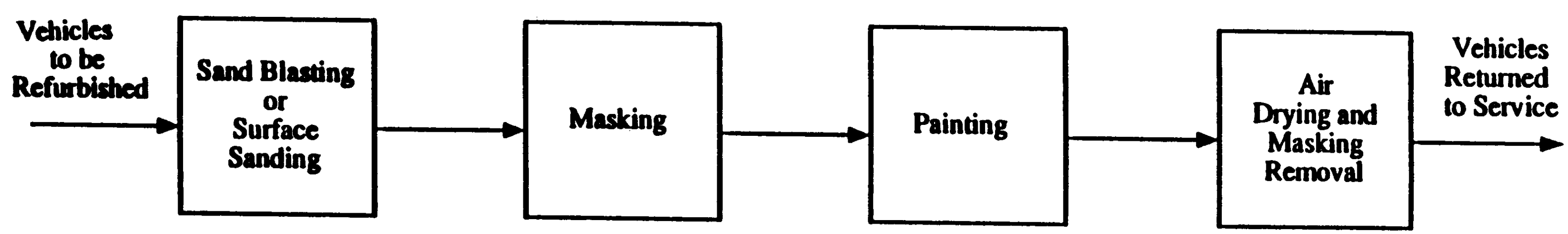

Figure 1. Work Flow Diagram of the CARC Painting Operation.

TABLE 2. HAZARDOUS WASTES GENERATED DURING THE CARC PAINTING OPERATION

Waste stream	Annual Generation Rate (gallons)[a]	Disposal Cost ($/lb)	Annual Disposal Cost[b]	Priority Rating Score	Priority Ranking
Waste water	28800	$0.15	$36,029	333	1
Liquid CARC paint	660	$0.46	$3,038	239	2
CARC paint residue	2880	$0.45	$12,970	220	3
Used paint thinner	660	$0.46	$2,162	239	2
Contaminated trash[c]	960	$0.45	$5,404	64	4
Total Annual Disposal Cost	--	--	$59,694	--	--

a Consumption rates were provided for 1991 year-to-date and the assessment was conducted in September. The figures shown have been adjusted to include the remaining months of 1991.

b The facility reported the generation rate of the waste streams in quantities of drums but disposal costs were reported in lbs. A conversion between volumetric units and mass units was made in order to calculate the disposal cost. The density of the material was taken into account when it was available.

c Contaminated trash is disposed as a hazardous waste at the present time but toxicity tests are being performed that may indicate that this waste stream is non-hazardous.

Once per month, the water curtains are thoroughly cleaned. This procedure involves draining the water, scraping out the accumulated paint residue, and refilling the water curtain. The used water is pumped into a wastewater holding tank (336 gallon capacity) outside of Building 1411. From this tank, the water is immediately transferred to 55 gallon drums and taken to Building 1637 to await disposal.

The CARC paint residue (scraped off during the monthly cleaning of the booth) is the result of paint overspray which has built up as a hard coating on the surfaces of the water curtain. The CARC paint residue is drummed along with any contaminated trash (paper, wood or rubber that has been contaminated during the CARC painting operation) and taken to Building 1637 to await disposal.

At the end of the day, unused paint consisting of 60 percent paint and 40 percent paint thinner is emptied into a 55 gallon drum stored in a three-sided enclosure outside of building 1411. In addition, the spray painting equipment is cleaned with paint thinner and this waste consisting of 75 percent thinner and 25 percent paint is also emptied into a 55 gallon drum outside of Building 1411. When a drum becomes full it is removed to Building 1637 to await disposal. Wastes were prioritized during this assessment based on regulatory compliance, the quantity of waste generated, the disposal cost, potential liability, waste hazards, safety hazards and the availability and viability of an option to reduce or eliminate the waste. The waste with the highest priority (shown in Table 2) is the wastewater, followed by the liquid CARC paint, the used paint thinner, CARC paint residue, and the contaminated trash.

ASSESSMENT

Options were identified in this assessment that would reduce or eliminate the hazardous wastes generated in the CARC painting operation. The options identified are:

- Option 1 - Booth Maintenance System;
- Option 2 - Improve Transfer Efficiency;
- Option 3 - Recovery of Paint Thinner;
- Option 4 - Installation of a New Paint Booth.

Each option is described briefly in the next section. Table 3 is a comparison of all four options including the waste streams and raw materials affected as well as the requirements of each option. Additional options may be applicable to this painting operation but due to scope limitations only four options were identified.

FEASIBILITY

Option 1 - Booth Maintenance System

The water circulated in the water curtains is municipal water with no additional chemicals added. When overspray is captured by the water curtains, it immediately adheres to the surfaces and builds up a coating of paint. There are chemicals available that can be added to the water in the water curtains that will keep the paint from adhering to the surfaces by dispersing it in the water. Then at the time of the monthly cleaning, additional chemicals may be added that will flocculate the paint enabling it to be removed easily. The water may then be reused instead of being discharged after additional dispersant is added.

Option 2 - Improve Transfer Efficiency

Transfer efficiency refers to the percentage of paint that leaves the paint gun and is actually deposited on the vehicle's surface. A higher transfer efficiency means more paint is reaching the surface of the vehicle. High volume-low pressure (HVLP) spray painting equipment can achieve transfer efficiencies

TABLE 3. OPTIONS IDENTIFIED FOR THE CARC PAINTING OPERATION

Pollution Prevention Options	Waste Streams Affected	Raw Materials Affected	Requirements
Option 1 - Booth Maintenance System	• Waste water	• Municipal water	• Additional raw materials • Operator training
Option 2 - Improve Transfer Efficiency	• CARC paint residue	• CARC paint • Paint thinner	• Modifications to painting equipment • Monitoring of air pressures
Option 3 - Recovery of Paint Thinner	• Used paint thinner	• Paint thinner	• Purchase and installation of a recovery still • Operator training
Option 4 - New Paint Booth	• Waste water • CARC paint residue	• Municipal water	• Installation of a new paint booth • Operator training

up to 90 percent and is currently in use in many industrial applications. The facility currently uses standard spray painting equipment and operates in a pressure range from 20 to 55 psi. By converting to a HVLP spray painting system improved transfer efficiencies may be achieved. An improved transfer efficiency would decrease raw material usage, decrease CARC paint residue resulting from overspray, and decrease the time spent in cleaning out the water curtains.

Transfer efficiencies of spray painting operations are also operator dependent and this is related to the air pressure used. High pressures generally reduce the transfer efficiency and operators will increase the pressure to reduce the painting time. Operators should be instructed to use specific air pressures in the painting operation.

Option 3 - Recovery of Paint Thinner

Currently, used paint thinner consisting of 75 percent thinner and 25 percent paint is disposed of as a hazardous waste. Recovery of this paint thinner can be achieved with the installation of a recovery still. Used paint thinner can then be distilled for reuse. The waste stream would not be totally eliminated because the still would generate still bottoms that would need to be disposed. However, the generation rate of still bottoms would be less than the current generation rate of used paint thinner. This would reduce the amount of used paint thinner disposed and decrease the amount of virgin paint thinner used in the painting operation. In addition, the cleaning equipment cleaning procedures can be modified to reduce the generation of used paint thinner.

Option 4 - Installation of a New Paint Booth

The current paint booth system is used for operations up to truck-sized pieces of equipment. The current system, as discussed previously, is inadequate to protect workers as well as meet minimum air emissions standards. In addition, the current facility is not of sufficient size to accommodate the large pieces of field equipment (e.g., cranes, trailers, artillery pieces, etc.) that are routinely painted at Ft. Eustis. As such, Ft. Eustis personnel currently paint such equipment in an uncontained but well ventilated area. Releases to the environment are thus uncontrolled and unmonitored. Thus, in considering reduction alternatives for painting operations, Ft. Eustis must focus on two similar operations: routine small-scale painting operations and large-scale painting.

With respect to small-scale painting operations, Ft. Eustis has several opportunities to reduce emissions. the simplest of which may be to replace the current waterfall paint booth system with a dry filtration booth. One specific opportunity exists in that Langley Air Force Base currently has a dry booth (of comparable size to Eustis's wet system) that might be moved to Ft. Eustis to replace its current system. This is technically feasible since the booth at Langley is a building insert that can be disassembled and moved. Further, at this time, both installations seem willing to discuss the concept but have not formerly identified what conditions would have to exist to accomplish such a property transfer. Further, the Langley AFB staff who currently hold the paint booth, would need a substitute technology for their small-scale operations.[1] If such a transfer could be accomplished, the paint booth could remedy some, but not all, of Ft. Eustis waste generation and release issues associated with painting operations.

Specifically, even if Ft. Eustis had a functional dry system to replace the current waterfall technology, they would still need a larger system to accommodate large-scale painting operation. as such, even though replacement of the current would resolve some problems it would do nothing to ease or eliminate the

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1 Langley AFB currently uses the booth for very small-scale painting operations (wood work, small pieces of equipment, etc.). The current booth is oversized for current uses.

CROSSFEED NEEDS TO OTHER TIPPP INSTALLATIONS

Painting operations are conducted to some extent by all four TIPP participants. Improving paint transfer efficiency and examination of the booth maintenance program and waterfall curtain systems are directly relevant to any other painting operation of similar or larger size.

The Langley Air Force Base painting hanger provides tangible evidence of improvements in painting systems and overspray controls and a state-of-the-art system that should be evaluated at the other three bases. Further, depending on the workload and frequency of use, the new Langley paint hanger might be used to schedule some work from the TIPPP participants to overall reduce generation of wastes.

IMPLEMENTATION PLAN

The four options identified in this assessment to reduce/eliminate the wastes generated in the spray painting operation have all been used in other industrial applications. Therefore, they can be readily implemented once a particular option is chosen. Options with low capital costs that reduce waste generation and raw material usage are usually chosen immediately for implementation. Table 4 lists the advantages and disadvantages of each option.

Implementation procedures for the pollution prevention options can be conducted in both short-term and long-term time frames. For each option in this assessment, short-term and long-term implementation procedures have been identified. Table 5 shows the short-term and long-term implementation procedures for each option.

Implementation of Option 1 - Booth maintenance system can begin immediately because no new equipment is required. Vendors of booth maintenance chemicals can be contacted and arrangements made to have a representative come to the Fort to give a demonstration. More than one vendor should be contacted and several different systems evaluated in this manner to identify the appropriate booth maintenance system for this painting operation.

The remaining three options require new equipment or modifications to existing equipment. However, there are still procedures that can be instituted immediately to begin achieving waste reductions.

MEASUREMENT OF POLLUTION PREVENTION

The success of the pollution prevention options identified in this assessment can be measured by 1) monitoring of waste quantities generated; 2) monitoring raw material usage; 3) monitoring of operator time required; 4) monitoring the quality of the finished product; and 5) tracking costs. An option would be considered a success if it:

- reduced both waste generation and raw material usage;
- did not require significant time expenditures by the operator;
- did not adversely affect the quality of the finished product;
- had a reasonable payback period in terms of capital investment to annual operating cost savings.

RESEARCH DEVELOPMENT & DEMONSTRATION NEEDS

Two options identified in this assessment are very viable but may present potential problems at this facility. These are Option 1 - Booth Maintenance System and Option 3 - Recovery of Paint Thinner. The CARC paint is extremely hazardous and the implementation of Option 1 - Booth Maintenance System could possible bring incompatible chemicals in contact with one another. The implementation of Option 3 -

TABLE 4. ADVANTAGES/DISADVANTAGES OF POLLUTION PREVENTION OPTIONS

Option	Advantages	Disadvantages
Option 1 - Booth Maintenance System	• No new equipment is required • Suppliers will come on site to conduct demonstrations of chemical systems	• Cost of additional raw materials • Booth chemicals must be compatible with the CARC paint
Option 2 - Improve Painting Transfer Efficiency	• Decreases both waste generation and raw material usage	• Painting time may be increased
Option 3 - Recovery of Paint Thinner	• Decreases both waste generation and raw material usage	• Cost of the recovery still • A location will be needed for the still • An operator will be needed for the still • Still bottoms will have to be disposed
Option 4 - New Paint Booth	• New booth would eliminate the need for a water curtain	• Downtime for new booth installation and start-up

TABLE 5. IMPLEMENTATION OF POLLUTION PREVENTION OPTIONS

Pollution Prevention Options	Short-term Implementation Procedures	Long-term Implementation Procedures
Option 1 - Booth Maintenance System	• Contact vendors and arrange for demonstrations of booth maintenance chemicals • Have operators trained in the use of the chemicals while the vendor is on-site	• Carefully evaluate each maintenance system by testing for several weeks
Option 2 - Improve Transfer Efficiency	• Lower operating pressures used in the spray painting operation	• Modify existing painting equipment to a HVLP system
Option 3 - Recovery of Paint Thinner	• Instruct operators to minimize their use of paint thinner during equipment cleaning	• Evaluate technical specs of recovered solvent for reuse with CART
Option 4 - New Paint Booth	• Operator training	• Combustion with options 1 through 3 as appropriate

requires a location for the recovery still, an operator, and disposal of the still bottoms. These options would require further research before they could be implemented.

RECOMMENDATIONS/CONCLUSIONS

A pollution prevention opportunity assessment was conducted at Ft. Eustis Army base near Norfolk, Virginia in September 1991. The assessment focused on the painting operation conducted at the base, and resulted in the identification of four major options to reduce or eliminate waste generation.

Although the option requires some refinement and onsite testing, a painting booth maintenance system appears capable of reducing waste generation. New HVLP paint guns would immediately reduce paint loss, and would require limited operator training. Recovery of used paint thinner (Option 3) and a new paint booth (Option 4) are viable, but require larger capital cost; payback is a function of the scale of painting requirements.

APPENDIX A
WASTE MINIMIZATION ASSESSMENT WORKSHEETS

The worksheets that follow are designed to facilitate the WM assessment procedure. Table A-1 lists the worksheets, according to the particular phase of the program, and a brief description of the purpose of the worksheets.

TABLE A-1. LIST OF WASTE MINIMIZATION ASSESSMENT WORKSHEETS

Phase	Number and Title	Purpose/Remarks
	1. Assessment Overview	Summarizes the overall assessment procedure.
Planning and Organization (Section 2)		
	2. Program Organization	Records key members in the WMA program task force and the WM assessment teams. Also records the relevant organization.
	3. Assessment Team Make-up	Lists names of assessment team members as well as duties. Includes a list of potential departments to consider when selecting the teams.
Assessment Phase (Section 3)		
	4. Site Description	Lists background information about the facility, including location, products, and operations.
	5. Personnel	Records information about the personnel who work in the area to be assessed.
	6. Process Information	This is a checklist of useful process information to look for before starting the assessment.
	7. Input Materials Summary	Records input material information for a specific production or process area. This includes name, supplier, hazardous component or properties, cost, delivery and shelf-life information, and possible substitutes.
	8. Products Summary	Identifies hazardous components, production rate, revenues, and other information about products.
	9. Individual Waste Stream Characterization	Records source, hazard, generation rate, disposal cost, and method of treatment or disposal for each waste stream.

(continued)

TABLE 1. (continued)

Phase	Number and Title	Purpose/Remarks
Assessment Phase (continued) (Section 3)		
	10. Waste Stream Summary	Summarizes all of the information collected for each waste stream. This sheet is also used to prioritize waste streams to assess.
	11. Option Generation	Records options proposed during brainstorming or nominal group techniques sessions. Includes the rationale for proposing each options.
	12. Options Description	Describes and summarizes information about a proposed option. Also notes approval of promising options.
	13. Options Evaluation by Weighted Sum Method	Used for screening options using the weighted sum method.
Feasibility Analysis Phase (Section 4)		
	14. Technical Feasibility	Detailed checklist for performing a technical evaluation of a WM option. This worksheet is divided into sections for equipment-related options, personnel/procedural-related options, and materials-related options.
	15. Cost Information	Detailed list of capital and operating cost information for use in the economic evaluation of an option.
	16. Profitability Worksheet #1 Payback Period	Detailed list of capital and operating cost information developed form Worksheet 15, this worksheet is used to calculate the payback period.
	17. Profitability Worksheet #2 Cash Flow for NPV and IRR	This worksheet is used to develop cash flows for calculating NPV or IRR.
Implementation (Section 5)		
	18. Project Summary	Summarizes important tasks to be performed during the implementation of an option. This includes deliverable, responsible person, budget, and schedule.
	19. Option Performance	Records material balance information for evaluating the performance of an implemented option.

APPENDIX B

TIPPP POLLUTION PREVENTION FACT SHEETS

Nine fact sheets were produced under the TIPPP to develop and demonstrate innovative pollution prevention opportunities at Federal facilities. These fact sheets include:

01. Metal Working
02. Painting Operations
03. Laboratory Wastes
04. Solvents
05. Electroplating
06. Depainting Operations
07. Municipal Solid Waste
08. Land Management Practices
09. Chemical Material Management

The information contained in the following fact sheets, while accurate in 1992 may no longer be current. Many of the operations may have changed during the past three years.

Issue: Metal Working (Surface Preparation, Shaping)

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Metal shaping and surface preparation are two types of metal working operations that might be used to form a metal object, part, or piece. Shaping operations take raw materials and alter their form to make the intermediate and final product shapes and may include:

- casting
- drilling
- machining
- polishing
- shaping
- cladding
- extruding
- milling
- reaming
- stamping
- drawing
- grinding
- planing
- rolling
- threading

Surface preparation is an integral step in the metal manufacturing industry and is typically used in all metal manufacturing processes. Virtually all fabricated metal products require some form of physical and/or chemical surface preparation prior to finishing to remove unwanted surface materials or to alter the chemical or physical characteristics of the surface. Some surface preparation operations may also be desired prior to some final shaping operations. As a result of initial and intermediate shaping processes, metal surfaces usually become oxidized or coated with grease and machining oils, which may interfere with the finishing processes. Some products may require only the removal of rough surfaces and/or edges. Surface preparation operations may include:

- acid cleaning
- emulsion degreasing
- mechanical treatment
- pickling
- vapor degreasing
- alkaline cleaning
- etching
- paint stripping
- ultrasonic degreasing
- wiping

Installation	Estimated Volume of Waste Disposed		Key Locations
Langley AFB	N/A		N/A
Norfolk Naval Base	Coolant	163,900 lbs/yr	Bldg. 932, 941, 942, 972, 981, 993
Fort Eustis	N/A		N/A
NASA Langley Ctr	N/A		N/A

Note: N/A = Not currently available/applicable

Environmental Concerns: Metal shaping and surface preparation operations may result in liquid-, gas-, and solid-phase wastes that may present a threat to human health and the environment. Specifically, metal working operations usually result in two types of waste including scrap metal and spent metalworking fluids/oils. Surface preparation operations primarily generate wastes contaminated with solvents and/or metals, depending on the type of cleaning operation. Both waste types may contain heavy metals (lead, chromium, cadmium, nickel, etc.), various halogenated and non-halogenated organic constituents (1,1,1-trichloroethane, methylene chloride, benzene, toluene, poly nuclear aromatics, and others, depending on machining fluids and solvents used), and surfactants. Further, surface preparation may result in the release of volatile organic solvents that may pose a threat through direct exposure to workers and the surrounding environment.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Training and Supervision - Training to instruct operators in water conservation, materials segregation techniques and process monitoring.
References: 2,4,5,7,10,11,12

Planning and Sequencing - Pre-inspection of parts to identify reject workpieces prior to processing.
References: 6,10,12

Process Modification - Changing current processes to improve efficiency of operations and to decrease pollution potential. This includes reduction of atmospheric emissions using such techniques as increasing free board height, installing refrigeration coils to condense vapors, rotating workpieces before removal to drip solvents back to reservoir, implementing reduced drag-out techniques, increased drainage, proper racking, use of counter-current cleaning to maximize use of cleaning solvent prior to disposal or recycle.
References: 4,6,7,9,10,11,12

Raw Material Substitutions - Identifying and using less toxic materials. This includes using alternatives for chlorinated hydrocarbon cleaning solvents, such as aliphatic hydrocarbons, dibasic acid esters, N-methyl-2-pyrrolidone and terpenes.
References: 2,4,5,6,7,9,10,11,12,14

Waste Segregation - Segregating waste streams to recover and recycle metals, and to avoid contamination of other wastes with potentially toxic constituents.
References: 1,7,10,12,14

Recycling and Reuse - Devising methods to maximize use of rinse waters and other materials, such as solvents. Such methods include use of activated carbon, condensers, etc. to capture solvents for reuse, recovery of acids from wastewaters using evaporation, on-site recycling of solvents by distillation, filtration and gravity separation.
References: 2,3,4,6,7,10,11,12,14

Loss Prevention and Housekeeping Controls - Preventive maintenance on equipment to minimize leaks and spills. Establishment of solvent check-out procedures through shop foreman.
References: 10,12

Metal Recovery - Recovery of precious metals and metal salts from sludges and spent process baths through such procedures as evaporation, reverse osmosis, ion exchange, electrolytic recovery and electrolysis.
References: 1,3,4,6,5,7,9,10,12

Materials Handling and Storage - Pre-inspection of materials, proper storage of chemicals to prevent degradation, inventory control.
References: 6,7,9,10

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For further information on the TIPPP, please contact:

USEPA
Pollution Prevention Information Clearinghouse
Technical Information Service
c/o Science Applications International Corporation
7600-A Leesburg Pike
Falls Church, Virginia 22043
(703) 821-4800

Issue: Painting Operations

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Painting operations are conducted at all of the installations to some extent. These operations can range from small "spot" painting to full scale painting operations. Typically, equipment painted includes:

- trucks
- jeeps
- gun turrets
- tanks
- ships
- aircraft carriers
- helicopters
- airplanes

Installation	Estimated Volume of Waste Disposed		Key Locations
Langley AFB	Sludge	1 drum/wk	Bldg. 781
	Solvent	1 drum/mo	Bldg. 781
Norfolk Naval Base	Paint	2,400 lbs/yr	Shop 901
		3,150 lbs/yr	Shop 935
		293,700 lbs/yr	Shop 936
		350 lbs/yr	Shop 971
	Thinner	1,650 lbs/yr	Shop 901
		64,900 lbs/yr	Shop 935
		1,650 lbs/yr	Shop 971
Fort Eustis	Waste Paint	715 gal/yr	Bldg. 1411 and various locations
NASA Langley Ctr	Thinner	5 gal/yr	Bldg. 640

Environmental Concern: These painting operations can be conducted on an around-the-clock basis, thus generating large amounts of painting wastes including unused paints, paint sludges, and solvents. Paint, which may contain high levels of heavy metals including lead, cadmium, mercury, chromium, copper, and titanium, can cause significant damage to human health as well as contaminate potable water sources (ground and surface waters). Painting operations may also include the use of chlorinated solvents which create solvent- and paint-bearing sludges as well as release volatile organic compounds to the air creating health and safety hazards for the workers.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Air Assisted Airless Spray Equipment – A coating application technique in which paint is delivered to a spray gun under very high pressure. No air is required since the pressure at which the coating is delivered to the nozzle is sufficient to atomize it.
References: 28,30

High-Volume Low-Pressure Spray Painting (HVLP) – A compressed air paint spraying system utilized to reduce overspray.
References: 1,3,5

Electrostatic – A coating application technique in which an electrostatic charge is given to the workpiece and the gun nozzle is given the opposite charge. The spray is attracted to the work surface to the extent that some of the overspray curves back and coats the reverse side of the work.
References: 1,28,30

Dip Tanks – A technique in which a workpiece is inserted into a tank of coating, removed, and allowed to drain back in the tank. Excess paint may be removed electrostatically or by a doctor blade or squeegee.
Reference: 28

Cyclone Separator and Paint Detackifying Compound – This system is used to rteduce paint sludge generation. The cyclone separator and paint detackifying compound are used to dewater and concentrate solids in the paint sludge.
Reference: 6

UNICARB™ – A coating technique which applies coating by using supercritical carbon dioxide. Supercritical carbon dioxide produces vigorous atomization and allows for high quality coating without the use of volatile organic solvents.
Reference: 7

Product Substitution – The substitution of water-based paints for solvent-based paints. Water-based paints reduce worker exposure to solvent vapors and allows cleanup with only water.
References: 1,6,7,9,10,15,21,25,28,30

Recycling – This process channels hazardous wastes back into the production process. Organic solvents which become contaminated through industrial use without being consumed in the manufacturing process may be recovered, reused, and recycled.
References: 1,2,4,5,6,8,9,11,15,16,19,20,22,23,24,25,28

Incineration – The combustion of organic wastes used to dispose of still bottom wastes resulting from the use of organic solvents.
Reference: 7

Process Redesign/Equipment Modification – Includes the alteration of the existing process design to include new equipment or the implementation of new technologies or changes in operating practices affecting the process (i.e., housekeeping or maintenance).
References: 6,7,9,14,17,21,25

Segregation – Separation of a solvent waste stream from other solvent and non-solvent waste streams. Utilization of water can aid in future recovery efforts.
References: 7,9,13,25

Heat Recovery – Spent solvents may be used as supplementary fuels, particularly in high-temperature industrial processes.
References: 6,15,22,25

Housekeeping Changes/Training – Procedural changes and procurement modification to reduce waste of raw materials. For example, only purchase the amount needed to complete the task to avoid the accumulation of excess paints that may expire and require disposal.
References: 1,3,5,6,7,9,13,14,15,17,25,26,30

References

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[1] *This laboratory is a predecessor of the Risk Reduction Engineering Laboratory in Cincinnati, Ohio.*

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Issue: Laboratory Wastes

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Laboratory wastes may be generated by any operation that conducts chemical, engineering, toxicological, biological, health-related, and/or any other types of research. Any type of scientific research may require the use of hazardous chemicals and/or organisms. The chemical properties and quantities of laboratory waste generated will depend on many variables, including the raw materials used, the nature of any chemical reactions, the conditions of experiments, scale, physical changes in chemicals, etc. In most cases, laboratories will generate a large variety of different wastes, usually in small quantities. These wastes are often generated on a one-time basis. Although the number of source reduction and recycling options may be limited, such techniques may have broad application to various classes of laboratory wastes.

Installation	Estimated Volume of Waste Disposed	Key Locations
Langley AFB	N/A	N/A
Norfolk Naval Base	N/A	N/A
Fort Eustis	1,192 gal/yr	Bldg 576, 403, 409
NASA Langley Ctr	132 cyl. exotic gasses; appr. 1000 gal lab wastes	many facilities on-site

Note: N/A: Not currently available or applicable

Environmental Concerns: Laboratory wastes may pose a variety of hazards to both human health and the environment. In the laboratory, wastes pose a threat to personnel who work with and near these toxins on a daily basis. Lab wastes may also release toxic contaminants through various transport mechanisms (e.g. volatilization, leaching, etc.) when discharged or disposed in the environment. Such releases can contribute to the buildup of toxic materials in the environment as well as impact human, wildlife, and flora recipients.

Due to the potential for variability, laboratory wastes present unique challenges for protective and environmentally sound management. For example, laboratory wastes may pose different types of environmental risk because their composition (and thus the threat posed) will depend entirely upon the nature of the research. Specifically, laboratory wastes may contain mixtures of common organic solvents, exotic organic and organo-metallic compounds, and/or metal species (salts and complexes). In addition, laboratories may generate small quantities of numerous types of wastes, or they may generate wastes on a one-time basis for a specific experiment. Such generation patterns may complicate waste collection, disposal, and recycling possibilities.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Inventory Management - Optimizing the use of supplies on hand, including control of dispensed chemicals and checking for outdating of solvents and other chemicals.
References: 1,2,3,4,5,6

Norfolk Naval Base | Langley Air Force Base | Fort Eustis | Langley Research Center | ORD and OPPT

Product Substitution - Replacing hazardous materials with less toxic or hazardous substances.
References: 1,3,4,6

Experiment Design - Improving current research practices and to increase the efficiency of experiments to decrease waste generation. For example, laboratory experiments could be conducted on a smaller scale using smaller quantities of raw materials.
References: 1,3,4,5,6

Recycling/Reuse/Recovery - Using methods to promote reuse of materials, such as recovery of solvents using such techniques as distillation and/or metals extraction (in particular, silver and mercury).
References: 1,3,4,5,6

Volume Reduction - Reducing hazardous waste volumes by utilizing methods such as neutralization, precipitation and inactivation.
References: 1,3,4,5,6

Energy Recovery - Recovering energy, primarily from waste solvents in the form of fuel supplements.
References: 1,3,4,5

Waste Segregation - Separating waste streams to facilitate treatment/disposal.
References: 1,6,2

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Issue: Solvents (Halogenated and Non-halogenated)

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Both halogenated and non-halogenated organic solvents are used in a variety of operations at each of the participating installations. Specifically, solvents are used in the following operations:

- parts cleaning and stripping
- degreasing
- gluing
- painting and coating
- fiberglass repair
- printing
- dry cleaning
- equipment maintenance
- pesticide/fertilizer formulation

These operations can rely upon both halogenated and non-halogenated organic solvents and solvent mixtures that contain such toxic constituents as benzene, toluene, methyl ethyl ketone, isobutyl ketone, perchloroethylene, methylene chloride, 1,1,1-trichloroethane, and others.

Installation	Estimated Volume of Waste Disposed		Key Locations
Langley AFB	Safety Kleen	4,810 gal/yr	Vehicle Maintenance, Corrosion Control
	Others	4,735 gal/yr	Paint Shop, A/C Maintenance
Norfolk Naval Base		2,400 lbs/yr	Shops 961, 962, 993
Fort Eustis		63,114 lbs/yr	Bldg. 1411, 2413, 2750 and others
NASA Langley Ctr		1,210.5 lbs/yr	Various locations

Environmental Concern: Organic solvents may possess hazardous characteristics including flammability, toxicity, and carcinogenicity. They are often volatile, and thus create potential for release into the air and the surrounding area. Solvents create health hazards for workers in addition to a potential for industrial accidents due to the solvent's capability to ignite. When used in any of the applications listed above, solvents can also pose a threat to human health and the environment when discharged in water or land.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Substitution - Involves the substitution of a substance which is either less hazardous or produces a waste that is less hazardous, but which does not jeopardize equivalent product quality. For example, the replacement of benzene with aliphatic naphthas.
References: 2,3,5,6,10,15,20,21,22,24

Reformulation - Changing the product to reduce the volume or toxicity of the wastes produced. This may involve altering or lowering certain product specifications (i.e., concentration), changing the chemical composition, or changing the physical state.
References: 4,5,17

Process Redesign/Equipment Modification - Includes the alteration of the existing process designs to include new equipment ande implementation of new technologies or changes in operating practices to reduce waste generation (i.e., use of condensors to capture solvent emissions).
References: 2,3,5,9,12,15,20,24

Housekeeping Changes/Process Control - Careful monitoring of the use of solvents for product production and evaluation of current spill avoidance procedures can reduce solvent use.
References: 2,3,5,8,9,10,12,19,20

Segregation - Separation of solvent waste streams from other solvent and non-solvent waste streams. Utilization of water can aid in recycling efforts and reduce the amount of solvent-bearing wastes. Segregation is particularly important for halogenated solvent wastes.
References: 5,8,20

Minimization - Standardization and consolidation of solvent use. For example, many solvents can be used for more than one application. Further, solvents may be reused in the same application or in other applications. Such reuse may result in solvent usage reductions.
Reference: 5

Heat Recovery - Non-halogenated spent solvents may be used as supplementary fuels particularly in high-temperature industrial processes such as industrial boilers, rotary kilns and blast furnaces.
References: 2,10,16,20

Recycling/Reuse/Recovery - Regularly used solvents may be recovered from waste streams by use of techniques such as distillation, evaporation or steam stripping. Once recovered, solvents may be reused or recycled for industrial processes.
References: 1,2,4,5,7,10,11,13,14,16,18,20,24

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[1] *This laboratory is a predecessor of the Risk Reduction Engineering Laboratory in Cincinnati, Ohio.*

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Issue: Electroplating

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Electroplating is the formation of a thin surface coating of one metal upon another by electrodeposition. Ferrous or nonferrous materials may be coated by a variety of common (copper, nickel, lead, chromium, brass, bronze, zinc, tin, cadmium, iron, aluminum or combinations thereof) or precious (gold, silver, platinum, osmium, iridium, palladium, rhodium, indium, ruthenium, or combinations thereof) metals. In electroplating, metal ions supplied by the dissolution of metal from anodes or other pieces are reduced onto the workpieces (cathodes). Depending on the metals involved, electroplating cells may use acidic, alkaline, or neutral solutions. Plating processes may be used to produce a variety of surface effects. In general, electroplating is used to produce:

- protective coatings on metal or plastic objects,
- surfaces that perform or act in specific ways under the conditions of use, and
- decorative finishes.

Electroplating operations are common to various military maintenance and parts manufacturing operations.

Installation	Estimated Volume of Waste Disposed		Key Locations
Langley AFB	N/A		N/A
Norfolk Naval Base	Electroplating Solution	7,455 lbs/yr	Bldg. 932, 971, 972, 973
	Electroplating (Misc.)	1,175 lbs/yr	
	Hydrochloric Acid	1,635 lbs/yr	
	Phosphoric Acid	1,065 lbs/yr	
	Nitric Acid	1,630 lbs/yr	
	Potassium Hydroxide	4,780 lbs/yr	
	Sodium Hydroxide	2,480 lbs/yr	
Fort Eustis	N/A		N/A
NASA Langley Ctr	N/A		N/A

Note: N/A = Not currently available/applicable

Environmental Concerns: The majority of metals and cyanide discharged into the Nation's waterways comes from metal finishing facilities, primarily from electroplating processes. Electroplating operations can result in solid and liquid wastestreams that contain the chemicals of concern. Liquid wastes result from workpiece rinsing and process cleanup waters. In general, most surface finishing (and many surface preparation) operations contribute to liquid wastestreams. Centralized wastewater treatment systems are common to this industry and can result in solid-phase wastewater treatment sludges. In addition to these wastes, spent process solutions and quench baths are discarded periodically when the concentration of contaminants inhibits proper function of the solution or bath. When discarded, process baths usually consist of solid- and liquid-phase wastes that may contain high concentrations of the constituents of concern, especially cyanide (free and complexed).

Hexavalent chromium plating systems, frequently used for electroplating, are hazardous. Similarly, cyanide plating baths are a known environmental hazard. Hazardous sludges, spent process baths, backwash from plating tank filter systems, and stripping solutions produced from the electroplating process commonly contain heavy metals and cyanide and consequently pose potentially serious human health and environmental hazards through soil and groundwater contamination.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Training and Supervision - Educate plating shop personnel in the conservation of water during processing and material segregation.
References: 3, 7, 8, 10, 11, 12

Production Planning and Sequencing - Pre-inspect parts to prevent processing of obvious rejects.
References: 10, 11

Process or Equipment Modifications

Employ counter-current rinsing to greatly reduce rinse water usage.
References: 10, 11

Increase drain time to allow parts to drain 10 seconds or more after removal from bath.
References: 3, 6, 8, 9, 10, 11, 12

Add wetting agents to the plating baths to reduce solution adhesion to the parts.
Reference: 10

Increase bath temperature to reduce viscosity and improve drainage.
References: 10, 11

Use spray rinsing to increase rinsing efficiency for non-complex part configurations.
Reference: 10

Use air agitation in rinse tanks to improve rinsing efficiency.
Reference: 10

Change continuous treatment to a batch system to account for upsets in effluent levels.
References: 10, 11

Reduce bath evaporation by covering the surface with non-reactive gases or materials. For example, a blanket of polypropylene balls can be used to significantly reduce losses through evaporation.
References: 3, 8, 10, 12

Continuously filter process baths to extend their life.
References: 10, 11

If etching is done only to put a shine on the parts, some customers may agree to buy them unetched, thus, greatly reducing etch bath wastes.
Reference: 10

Use low concentration plating solutions rather than mid-point concentrations in order to reduce the total mass of chemicals being dragged out.
References: 3, 4, 10, 11, 12

Use the Kushner and Providence methods of double dragout, followed by treating or recycling the concentrated dragout solution to minimize rinsewater use.
References: 10, 11

Use electrolytic cells to recover metals from waste plating solutions. Applicable to recovery of gold, silver, cobalt, nickel, cadmium, copper, and zinc from solutions with 100 mg/l to 1,000 mg/l of metal.
References: 1, 3, 5, 9, 10, 11, 12

Substitutions - Use less toxic materials whenever possible. Examples include:

- Substitute zinc for cadmium in alkali/saline environments.
- Substitute nitric or hydrochloric acid for cyanide in certain plating baths in order to produce a less hazardous sludge.
- Substitute zinc chloride for zinc cyanide.
- Substitute a non-chlorinated stripper in place of methylene chloride.
- Replace hexavalent with trivalent chromium plating systems.
- Replace cyanide with non-cyanide plating baths.

References: 1, 2, 3, 4, 8, 9, 10, 11, 12

Waste Segregation and Separation - Wastewaters containing recoverable metals should be segregated from other wastewater streams.
References: 1, 4, 10, 11

Recycling

Use any combination of the following techniques to recycle materials:

- evaporation
- ion exchange
- chemical reaction
- reverse osmosis
- electrolysis
- reclamation

References: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Specific recycling opportunities include:

- Process chemicals 9
- Regeneration of caustic etch solutions 11
- Use of acid copper in the electroplating of plastics 10
- Recover spent chromatic acid from anodizing 1
- Filter and reconstitute plating baths instead of disposing of the bath when strength has decreased 10,11

References:

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Issue: Depainting Operations

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: All of the participating installations conduct depainting operations. These operations are conducted in a variety of ways, from small "spot" removal operations to large blast media operations. Specifically, depainting operations occur while preparing equipment for repainting. Depainting processes used by the installations include stripping baths, beaded blast media, and spot removal using solvents. Types of equipment needing paint removal include:

- trucks
- gun turrents
- aircraft carriers
- signs
- aircraft
- tanks
- jeeps
- trailors

Installation	Estimated Volume of Waste Disposed		Key Locations
Langley AFB	Blasting Grit	1 drum/yr	Bldg. 781
Naval Base Norfolk	Blasting Grit	133,600 lbs/yr	Shop 932
		3,325 lbs/yr	Shop 936
		2,850 lbs/yr	Shop 941
		4,000 lbs/yr	Shop 963
		32,300 lbs/yr	Shop 971
		950 lbs/yr	Shop 972
		91,400 lbs/yr	Shop 973
	Stripper	300 lbs/yr	
		300 lbs/yr	
		1,800 lbs/yr	
Ft. Eustis	Sand Blast Residue	562,600 lbs/yr	Bldg. 1411
	Stripper	6,195 lbs/yr*	
NASA - Langley Center	Thinner	23 gal/yr	N/A
	Solvent/Thinner	5 gal/yr	
	Paint Remover	10 gal/yr	
	1,2-dichloro-tetrafluoroethane	1 lecture bt/yr	
	Solvent/Paint Waste	220 gal/yr	
	1,1,1-trichloroethane	58 gal/yr	
	Thinner Dope	15 gal/yr	
	Thinner/Degreaser	495 gal/yr	
	Chlorobnezene	5 pints/yr	
	Dichloromethane	4 pints/yr	
	Spent Solvents	326 gal/yr	
	Paint Stripper	57 gal/yr	

* *These numbers, based on 1991 figures, are not typical due to Operation Desert Storm.*

Environmental Concerns: Depainting operations result in the generation of metal-based paint, blasting grit, and paint sludge wastes which pose a threat to human health and the environment. Paint, which may contain high levels of heavy metals including lead, cadmium, mercury, chromium, copper, and titanium can cause significant damage to human health as well as contaminate potable water sources (ground and surface waters). Depainting operations may also include the use of chlorinated solvents which create solvent- and paint-bearing sludges as well as release volatile organic compounds to the air creating health and safety hazards for the workers.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Fluidized Bed Unit: Uses heated bed of fluidized aluminum oxide to remove paint. The process reduces reliance on chemical stripping.
Reference: 1

Increasing Solution Life: Extends life span of paint stripping bath, thus minimizing use of chemical stripping.
References: 1, 2, 8, 9

Substitution: Replace less toxic cleaning media for solvents. For example, media substitution will often require a switch from vapor degreasing to cold tank cleaning.
Reference: 2, 3, 5, 7, 10

Aqueous Cleaners: The cleaning action of aqueous cleaners relies mainly on displacement of soils. Water can be used in conjunction with mechanical or ultrasonic agitation.
Reference: 8, 9

Emulsion Cleaners: Combine solvent cleaning with aqueous cleaning so the solvent is dispersed in the aqueous phase with the aid of emulsifiers, surfactants, and coupling agents.
References: 8, 9

Mechanical/Thermal Methods: Alternatives include air blast systems, abrasive blast cleaning, and dry stripping. These are effective in eliminating the need for solvents.
References: 1, 8, 9

Recycling and Reuse: Overall solvent consumption can be reduced by segregating solvent wastes for recycling or reuse.
References: 6, 8, 9

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Issue: Municipal Solid Waste

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Integrated solid waste management involves using a combination of techniques and programs to manage the municipal and industrial solid waste stream. This is based on the fact that the waste stream consists of distinct components that can be managed and disposed of separately. Source reduction, recycling, combustion and

Installation	Estimated Volume of Waste Disposed		Estimated Volume of Materials Recycled	
Langley AFB			Scrap Metal	400,000 lbs/yr
			Wood	148,000 lbs/yr
			Copper	126,000 lbs/yr
			Textile	80,000 lbs/yr
			Brass	60,000 lbs/yr
			Petroleum	20,000 lbs/yr
			Aluminum Cans	20,000 lbs/yr
			Stainless Steel	10,000 lbs/yr
Naval Base Norfolk	Scrap Metal	1,340,160 lbs/yr	Scrap Metal	2,878 tons/yr
	Tool Boxes	7,260 lbs/yr	Wood	4,038 tons/yr
	Tires	5,060 lbs/yr	Copper	95 tons/yr
	Non-regulated Waste	191,264 lbs/yr	Brass	32 tons/yr
	Trash	392,700,000 lbs/yr	Aluminum Cans	18 tons/yr
			Stainless Steel	2 tons/yr
			Paper	35 tons/yr
			Glass	6 tons/yr
			Steel	4,809 tons/yr
			Cardboard	1,750 tons/yr
			Plastic	15 tons/yr
			Aluminum	160 tons/yr
			Paint Solvents	23 tons/yr
			Tires	26 tons/yr
			High Temperature Alloys	2 tons/yr
Fort Eustis	Post	8,963,261 lbs/yr	Scrap Metal	1,814,000 lbs/yr
	Housing	3,585,860 lbs/yr	Aluminum Cans	27,000 lbs/yr
	NN/Rolo	663,190 lbs/yr	Paper	932,400 lbs/yr
	WTP/Rolo	2,086,000 lbs/yr	Glass	67,000 lbs/yr
	Metal	330,400 lbs/yr		
	Rubber	2,580 lbs/yr		
NASA - Langley Center			Used Oil	6,500 gal/yr
			Scrap Metal	303,010 lbs/yr
			Computer Paper	125,460 lbs/yr

landfilling can all have a potential impact on the solid waste management problem. Typical items in the solid waste stream which can be reduced either through source reduction or recycling include:

- paper
- aluminum
- glass
- plastic
- scrap metal
- construction debris
- batteries
- newspapers

Environmental Concern: Landfills and incineration facilities are currently closing at alarming rates because they have been filled to capacity, and/or are unable to meet current state regulations. A general failure to assume full responsibility for proper municipal and industrial solid waste management has resulted in adverse environmental impacts. Insufficient pollution controls on incinerators have led to air quality problems. Improperly operated landfills have been linked to soil, surface and ground water contamination. In addition, ground water contamination, odor, methane migration, dust, insects, and rodents have added to the environmental concerns associated with municipal solid waste. Future solid waste management will need to incorporate source reduction and recycling as an integral part of their program.

Known Solutions/References: Various options have been identified that may result in the reduction of waste associated with these types of operations. The following is a list of options describing prevention techniques that apply to one, some, or all of the operations discussed above. The references presented following each option describe, in detail, applicable pollution prevention techniques, associated costs of implementation, and potential source reduction gains.

Source Reduction – The design, manufacture, purchase, or use of materials to reduce the amount of waste and toxicity before they enter the municipal solid waste stream. Source reduction activities fall into the following basic categories: product reuse, reduced material volume, reduced toxicity of products, increased product lifetime, and decreased consumption. These source reduction activities can be accomplished by buying in bulk, avoiding disposable items (razors, cameras), reusing common products (plastic bags), repairing items, buying concentrates (drinks, laundry soap), using two-sided copies, using longer-life tires, and using longer-life light bulbs.
References: 6, 8, 9, 10

Recycling – The process by which materials otherwise destined for disposal are collected, reprocessed or remanufactured. Some commonly recycled materials in the solid waste stream include: paper, aluminum, glass, ferrous metals, plastics, batteries, used oil, and tires.
References: 1, 6, 8, 9, 10

Composting – The controlled biological decomposition of organic solid waste under aerobic conditions. Composting programs are designed to handle yard waste (leaves, grass clippings) or the compostable portion of the municipal solid waste stream (yard wastes, food wastes, or other degradable organics). High quality compost can then be used by or sold to greenhouses, golf courses, landscape contractors, public parks, military installations, and cemeteries.
References: 4, 8, 9, 10

Waste to Energy/Incineration – The process of burning solid waste, capturing the steam and using it to generate power, usually electricity. The primary end uses of steam from solid waste combustion facilities are industrial and institutional heating and cooling systems, many of which use forced steam in their processes.
References: 3, 4, 6, 8, 10

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Issue: Land Management Practices

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: Land management practices are an effective way to reduce the amount of nonpoint source nutrient, sediment, and toxic pollutants from entering the Chesapeake Bay ecosystem. Land management practices are applicable to different types of land use including:

- farming
- construction
- silviculture
- dredge material disposal
- road construction
- runways & flightlines
- golf courses
- pest and weed control areas
- housing areas

Environmental Concerns: The Chesapeake Bay system is plagued by poor water quality, declining fish and wildlife resources, and degraded ecologically sensitive areas such as wetlands. The exact causes of these problems are not completely understood, but it is clear that changes in the Chesapeake Bay ecosystem are directly linked to increased nutrient loadings. Land management practices significantly influence nonpoint source pollution and stormwater runoff— the major sources of nutrients and a significant source of sediment, and toxic pollutants to the Chesapeake Bay system. Nonpoint source pollution is pollution from diffuse sources, such as runoff from the land, that carrying natural and manmade pollutants. Nutrient over-enrichment contributes significantly to an array of interrelated problems in the Chesapeake Bay ecosystem, including:

- algal blooms and eutrophication,
- decreased dissolved oxygen levels throughout the Bay,
- decline in Baywide abundance of submerged aquatic vegetation, and
- decline in the abundance of fish and waterfowl.

Toxic pollutants in urban runoff (e.g., metals, pesticides, oil and grease) also negatively impact the Bay's fish and wildlife resources, and water quality. Stormwater enters the Bay either directly through stormdrains or indirectly through tributaries so it is important to prevent pollutants from contaminating stormwater. The four installations participating in the TIPPP all border on, or contribute runoff to, tributaries that ultimately drain into the Chesapeake Bay. While the exact impact of these installations on the Chesapeake Bay is unclear, the general effect of such communities can be detrimental and may include loss of vegetation and sensitive wetlands, the alteration of natural drainage patterns, and hydrologic changes to streams and waterways.

Nutrient	Land Use	Percentage
Phosphorus	Nonpoint source	68%
	Point Sources (sewage treatment plants)	32%
Nitrogen	Nonpoint Source	82%
	Point Sources (sewage treatment plants)	18%

Known Solutions/References: TIPPP includes various efforts to study and reduce the environmental impacts of land management pratices and daily operations on surrounding rivers and the Chesapeake Bay. Specifically, TIPPP is envisioned to investigate the following types of operations:

Flightlines and Runway Management: The largest potential source of contaminants to stormwater from flightlines and runways are fueling operations, vehicle maintenance/washing, and deicing practices. Best management practices for fuel operations strive to eliminate fuel coming into direct contact with stormwater runoff by managing fuel spills, covering chemical storage areas from the rain, and collecting and treating contaminated stormwater runoff. Vehicle maintenance/washing best management practices prevent washwater from flowing directly into stormdrains, streams or waterbodies; use low phosphorus content detergents or cleaning agents, and prevent and control spills of vehicle fluids (e.g., oil, radiator coolant). Best management practices for deicing agents have the goal of using the least environmentally disruptive deicing agent; applying deicing chemicals to only those areas requiring deicing; and evaluating storage, application, and excess deicing chemical management operations to minimize the contamination of stormwater and environmental damage. Deicing is less of an issue to TIPPP due to relatively mild winters in the Tidewater area.
Reference: 9

Erosion and Sediment Control: Best management practices involve structural and nonstructural practices to limit the amount of soil erosion and prevent sediment from entering the water. This includes preventing erosion by avoiding activities on steep slopes or areas with highly erodible soils, and limiting the amount of disturbed land and impervious surface area. Establishing and maintaining perennial vegetative cover to protect soil and water resources on vacant land, steep slopes, and around wetlands and waterbodies; planting critical erosion areas with stabilizing vegetation; leaving undisturbed vegetative buffer strips adjacent to streams, wetlands and waterbodies. Minimizing soil loss from the field, development site or roadway by planting a cover of grass or spreading straw to maintain soil cover. Constructing terraces and grassed waterways to limit erosion from channelize water flow. Constructing structures to detain sediment loss such as sedimentation fences, and wet or dry detention ponds.
References: 3, 7, 8, 9

Nutrient Management Planning: This is a collection of practices that limit the amount of nutrients applied to and lost from the turf. It involves collecting information to determine the soil's nutrient concentration and the vegetation's nutrient requirements prior to fertilization and only applying the minimum amount of fertilizer required. Practices include the proper rate of fertilizer application, and optimum timing and method of fertilization to limit loss of fertilizers to runoff. It also includes investigating organic alternatives to chemical fertilizers such as wastewater, sewage sludge, or compost.
References: 3, 7, 9

Pesticide Management: The most effective approach to reducing environmental impact of pesticides is to use less pesticides. Only use pesticides when there is a net economic gain, i.e., when a pest population is approaching the level at which control measures are necessary to prevent a decline in net returns. When pesticides are necessary select the pesticide with the least toxicity, leachability, persistence, and volatility that will still do the job. Apply pesticides in such a way as to minimize their movement into water or wetlands and exposure to workers and nontarget wildlife such as birds. Avoid spraying on windy days or right before a rain, do not spray directly onto waterbodies or wetlands. Many pesticides bind to soil and clay particles. Practices that reduce soil erosion are also effective at retaining pesticides on the treated area.
References: 3, 4, 6, 7, 9

Forestry Management Practices: The goal of forestry best management practices is to plan, design, and operate logging and silviculture practices to minimize erosion, pesticide use, hydrologic disruption to streams, wetlands and other waterbodies. This involves designating special management areas immediately adjacent to streams, wetlands or waterbodies where road building, logging, and related activities are prohibited. Building roads so as to minimize disturbances, controlling erosion near streams, and investigating alternatives to widespread pesticide use.
References: 3, 7, 9

Road Construction and Maintenance: The goal is to build and maintain roads in a manner that causes minimum erosion and disturbance to streams, wetlands, and environmentally sensitive areas. Locate roads away from wetlands, critical habitat areas and drainage channels. Minimize cut and fill. Size road culverts at waterbody crossings to minimize hydrologic disturbances such as restricting tidal flow to a wetland. Limit the amount of bare earth exposed to erosive forces, and the amount of natural vegetation that is disturbed. Prevent direct runoff of stormwater from roadways into wetlands, streams and waterbodies. Consider sweeping and vacuuming road surfaces to remove accumulated dust, debris and pollutants. Consider mowing more frequently and using spot application of herbicides versus large scale herbicide application. Evaluate cement sealers used on non-asphalt surfaces to find the least environmental harmful sealer.
References: 3, 7, 9, 13

Urban Runoff in Developing Areas: Institute practices that maintain natural hydrology at both the watershed and site levels by minimizing impervious surface areas, protecting natural vegetation, and retaining natural drainageways to the maximum extent possible. Minimize disturbances of unstable areas by locating development away from critical areas such as steep slopes, highly erodible soils, and wetlands. Protect natural resources which contribute to beneficial water quality impacts such as wetlands, forest areas, and riparian areas. Where possible retain buffer areas of natural vegetation contiguous to these resources.
References: 3, 7, 9, 10, 11

Housing Areas: Undertake practices that reduce lawn care nutrient and pesticide use, and manage pet wastes. Consider using alternatives to commercial fertilizers such as compost. If commercial fertilizers are used never exceed the recommended application rates. Over fertilizing results in a higher percentage of nutrients leaving the lawn as runoff. Consider alternatives to widespread pesticide use such as mechanical weeding. If pesticides are required use organic pesticides versus synthetic chemical pesticides, and use spot applications of pesticides versus broad application. Collect and compost grass clippings, leaves, branches and other yard waste. Manage pet waste to prevent it from directly entering storm drains or water bodies.
References: 3, 7, 9

Wetland and Riparian Area Protection: Preserving wetlands and riparian areas is vital to the Chesapeake Bay's survival. Wetlands function as a natural filter and regulator of nutrients and sediments entering the Bay, as nesting and nursery areas for fish and wildlife, as flood control structures, and home to a multitude of creatures. The best way to protect wetlands is to leave them undisturbed. Avoid any impacts to wetlands such as building, dredging, draining, or other activity, that changes the hydrologic conditions or directly disturbs a wetland. Riparian areas are uplands or floodplain areas immediately adjacent to wetlands, streams, rivers or other waterbodies. Riparian areas perform similar functions as wetlands. Minimize all disturbances in riparian zones. Loss of riparian zones allows nonpoint source runoff to directly enter the wetland or waterbody. When conditions are appropriate, restore wetlands and riparian areas instead of building structural nonpoint source management measures. Restore the natural hydrology (e.g., drainage patterns) and native plants in riparian areas when possible.
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Issue: Chemical Material Management

This Fact Sheet has been produced under the Tidewater Interagency Pollution Prevention Program (TIPPP), a cooperative effort between EPA, DoD, and NASA to develop and demonstrate innovative pollution prevention opportunities at Federal facilities.

Applications: One of the greatest environmental concerns associated with the operation of a military installation is the use, misuse, treatment, and disposal of materials that contain hazardous and toxic chemicals. Improper use and handling of chemicals (i.e., improper storage or use, stockpiling, etc.) can result in otherwise useful chemicals to be disposed of as hazardous waste. This not only wastes raw materials, but it needlessly adds to the liability, cost, and potential environmental damage from having to treat, store and dispose of hazardous wastes. In general, the misuse and mishandling of such materials is preventable through techniques including automated chemical materials management. Chemical materials management is a series of tools to control the procurement, distribution, and use of chemicals. Such tracking can assist the installation in:

- identifying less hazardous or non-hazardous material substitutes,
- reducing the amounts of materials that exceed expiration dates or shelf-lives. In addition, materials management may provide an opportunity to document inadequacies in current procurement practices,
- ensuring that the appropriate chemical is used for the right job,
- ensuring chemicals are used and disposed of or recycled in a safe and proper manner,
- maintaining chemicals in proper storage to protect the container and chemical integrity, to reduce leaks and segregate incompatible chemicals,
- ensuring that recertified products are not mistakenly disposed of as a waste,
- preventing unsafe storing and unauthorized stockpiling of chemicals that may lead to permit violations, unsafe working conditions, and out-dated chemicals, and
- borrowing and handling of chemicals among employees not authorized or trained to handle the chemicals.

Environmental Concerns: When materials are stockpiled and exceed recommended shelf-lives, the resulting expired material is usually disposed of as a hazardous waste. In some cases, the material may be recertified or sold. When disposed (or treated and disposed), toxic materials may be released to the environment. Hazardous waste disposal will also result in increased waste management costs and may also result in long-term liability for the installation. If sold, the installation loses control of the toxic-bearing material which may also result in environmental release through improper use or subsequent improper disposal.

Known Solutions/References: Inadequate tracking, improper use, and/or incomplete training in the use of materials can exacerbate the issues discussed above. With respect to military installations, the use of a chemical materials management practices could streamline materials requisition and transfer to the point where excess or stockpiled materials are minimized. By minimizing stockpiles and encouraging proper use of materials, the military could reduce the amounts of expired shelf-life and unusable materials that are disposed of as waste. Further, the command would reduce costs associated with wasting such raw materials.

Specifically, chemical materials management practices allow the installation to ensure that chemicals are purchased, issued, and used to meet process requirements, protect worker health and the environment, and limit the amount of unused materials requiring disposal. This provides more control over the entire life cycle of the chemical — from when it is first ordered for use to its safe and environmentally sound recycling or management. Various activities can be an integral part of chemical material management. Some of these elements are described below.

Procurement - For the military, procurement presents the greatest opportunity to reduce the amounts of chemicals and materials that are purchased and subsequently disposed of without full use. Several aspects of procurement result in waste including:

- requiring manufacturers to provide shelf-lives for materials without specifying criteria for developing such shelf-lives,
- allowing customers the opportunity to reject usable chemicals that have been recertified with extended shelf-lives,
- requiring supply operations to maintain stocks of materials that expire. In some instances, supply operations might use computerized ordering systems (available from most retailers) that can provide quick delivery of materials in usually 24 to 48 hours, and
- ordering chemicals without previous use rates and without verifying the appropriateness of the materials for the specified activity.

By studying various aspects of the procurement, the installation can evaluate the use of every chemical ordered, with the goal of determining if a less hazardous chemical substitute which meets process requirements could be used. By requiring the users of chemicals to justify use, the installations can ensure chemicals are purchased only for a specific task in required quantities. With automating ordering, the installation can reduce the amounts of expired materials and, at the same time, meet all of supply demands of the installation.

Employee Training - Train employees to correctly and safely use chemicals, what to do in case of spills, and how to properly recycle or dispose of chemicals. Properly trained employees help ensure that the right chemical is used for the right job and that useful chemicals are not needlessly disposed of as a hazardous waste through improper use, storage or disposal.

Inventory Control - Strict inventory control is an integral part of chemical material management. Routinely check the date of materials to prevent them from outlasting their shelf life. Practice first-in first-out inventory control, i.e., use older material before new raw materials. When possible, assign control over hazardous material supplies to a limited number of individuals trained to handle hazardous materials and who understand the first-in first-out inventory policy. Limiting access to supplies also prompts employees to conserve raw materials.

Chemical Storage - Routinely check the chemical storage area for leaking containers, or rusted or damaged containers that have the potential to leak. Storing chemical drums or containers off the ground makes identifying leaks easier. Store chemicals to preserve their chemical integrity. For example, store organic solvents so they do not undergo temperature extremes. Assign one person responsibility for checking for leaks and maintaining the storage area.

Use Proper Labels - Check to see that containers' contents are properly labeled and dated. Replace labels before they deteriorate. Unlabeled chemicals often are disposed of unnecessarily.

Return Empty Containers to the Supplier - Empty containers often contain hazardous residue. Investigate returning empty containers to the supplier for recycling. Rather than disposing of out-of-date material, return it to the supply center. Some chemicals can be recertified for use or recycled and reused. Some suppliers establish credit for returned material toward the next purchase.

Chemical use tracking - Comprehensive chemical use tracking involves using a computer system to track the procurement, storage, distribution, use, and disposal or recycling of each and every chemical used. Workers fill out a request form for each chemical. The requestor must justify the chemical by describing the process for which the chemical is intended, and the chemicals' proposed use. Before receiving the chemical, the requestor's hazardous chemical training level, the chemical's intended use, the quantity requested, and the material's hazard are checked against the computer database. Without authorization, the material can not be purchased and it will not be issued. If authorized, instructions on how to use and recycle or dispose of the chemical are issued along with the chemical.

Consider installing a bar code system on hazardous material containers. Each container is issued a unique code that records the chemical content, the recipient, the date it was issued, the chemical's intended use, and the chemical's expiration date. This allows the chemical to be tracked from the time it is issued to its disposal.
Reference 1.

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